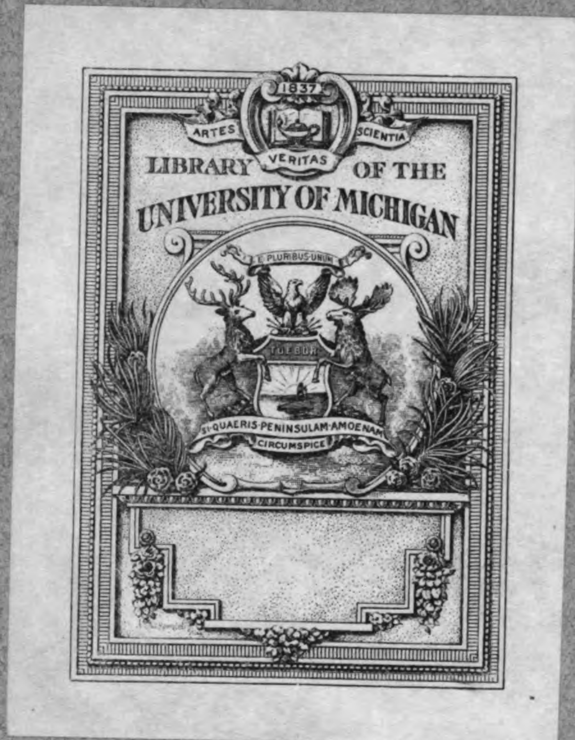

PENNSYLVANIA


1837
ARTES
SCIENTIA
VERITAS
LIBRARY OF THE
UNIVERSITY OF MICHIGAN
E PLURIBUS UNUM
TUEBOR
SI QUAERIS PENINSULAM AMOENAM
CIRCUMSPICE

THE

GEOLOGY

OF

PENNSYLVANIA

A GOVERNMENT SURVEY.

WITH A GENERAL VIEW OF THE

GEOLOGY OF THE UNITED STATES,

ESSAYS ON THE COAL-FORMATION AND ITS FOSSILS, AND A DESCRIPTION OF THE COAL-FIELDS OF NORTH AMERICA AND GREAT BRITAIN;

BY

HENRY DARWIN ROGERS

STATE GEOLOGIST

PROFESSOR OF NATURAL HISTORY IN THE UNIVERSITY OF GLASGOW; F.R.S., HON. F.R.S.E., F.G.S.; MEMBER OF THE AMERICAN PHILOSOPHICAL SOCIETY; MEMBER OF THE ACADEMY OF NAT. SCIENCE' PHILADELPHIA; FELLOW OF THE BOSTON ACADEMY OF ARTS AND SCIENCES; MEMBER OF THE BOSTON NAT. HIST. SOC., ETC, ETC.

IN TWO VOLUMES.

VOL. II.—PART II.

NEW YORK:
D. VAN NOSTRAND, 192 BROADWAY.
1868.

PART III.

MESOZOIC RED SANDSTONE SERIES.

INTRODUCTORY CHAPTER.

In the triple subdivision of the strata of Pennsylvania, the Mesozoic Red Sandstone, constituting the uppermost or latest system, presents itself for description after the Palæozoic formations: it will form the subject of the present subdivision of my work. Though a somewhat extensive stratum, it will not demand a very elaborate delineation, for the formation is characterised by no great variety of composition, possesses extreme simplicity of structure, has a very limited group of minerals, and is, moreover, almost wholly destitute of organic remains. I shall describe, first, the geographical limits, composition, local features, and mineral contents of the formation; in the next place, the igneous rocks of the district, and the changes they have caused in the stratified masses in contact with them; and shall close with an investigation of the geological age of the stratum, and of its origin, or the conditions under which it was deposited. The name *Mesozoic Red Sandstone*, by which I here propose to designate this deposit, is given to it in allusion to the geological age in which it was produced, both its organic remains and its position among the other systems of strata distinctly indicating it to have originated early in the so-called Mesozoic period, or the middle ages of extinct or fossil life. As a term, it is less theoretical and more descriptive than that of New Red Sandstone, the title often conferred upon it by geologists; it seems called for, likewise, as recognising the valuable nomenclature recently proposed for the fossiliferous rocks by Professor Phillips and other British geologists.

Geographical Limits of the Mesozoic Red Sandstone.—The entire area of this formation, one portion of which crosses Pennsylvania, is very great. It commences at the W. bank of the Hudson River, in a broad belt extending from the Bay of New York to the base of the first ridges of the Highlands, and is bounded on the N.W. by this chain and its continuation. South-westward it traverses New Jersey, Pennsylvania, Maryland, and, in a more interrupted manner, Virginia and a part of North Carolina, so that its total length is not less than 500 miles. Having a width in New Jersey of 20 miles between the Hudson and the Highlands, it crosses the Delaware into Pennsylvania with a breadth expanded to nearly 30 miles. It retains this until it approaches the Schuylkill, where it rapidly contracts, and maintains for the remainder of its course through Berks, Lancaster, Lebanon, Dauphin, York, and Adams counties, the diminished breadth of about 10 miles between the Schuylkill and Susquehanna, and of 15 between this latter river and the Maryland State line.

The S. margin of the formation crosses the Delaware River about 1½ miles above the town of Trenton, runs nearly W. to the Schuylkill, which it passes about 2 miles S. of Norristown. It advances by Valley Forge and Kimberton to French Creek, the course of which it follows nearly to the county line of Chester. It passes about half a mile to the N. of Morgantown, Churchtown, and Hinkleton; and goes through Millport to Buchanan's Run, when it suddenly folds back and runs towards the N.E., through Ephratah to Reamstown. From the last point it sweeps in a regular curve, first towards the N.W. and afterwards the S.W., crossing the turnpike at Middle Creek. Reaching Hammer Creek, it descends along the course of this stream to Erb's mill, where it turns again W., passing about a mile to the N. of Litiz, and reaches in the same course Manheim. Here it advances once more towards the E., which direction it pursues as far as Buchanan's Run, where, however, it again turns W., continuing in that course uninterruptedly to Springfield, at which place it makes another short flexure, but soon resumes its W. range, passing 1½ miles S. of Elizabethtown, and thence nearly in a straight line S.W. to Bainbridge on the Susquehanna.

Crossing the Susquehanna, the S. edge of the formation leaves the W. bank of the river about one mile above the little village of New Holland, nearly opposite to Bainbridge, and maintaining a direction very nearly S.W., the line extends to the N. base of the Pigeon Hills, passing about 2½ miles N.W. of the town of York, and crossing the York and Gettysburg Road, 9 miles W. of the first-named place. It now ranges along the N.W. foot of the Pigeon Hills, at the W. extremity of which it deflects somewhat more towards the S., and, passing one mile to the W. of Littlestown (Petersburg), it reaches the Maryland line near Arnold's mill on Piny Creek.

From the Delaware River at Trenton to the vicinity of Willow Grove the red sandstone overlaps the gneiss; between that point and the neighbourhood of Valley Forge it is in contact with the altered Primal and Auroral rocks, but chiefly with the limestone of the valley. From Valley Creek to the Warwick Iron-mine, near the head of French Creek, the S. margin again covers the gneiss; beyond this latter locality, for 3 miles to the edge of Chester County, it conceals the Primal sandstone and slate of the Welsh Mountain; and thence through the whole length of Lancaster County to the Susquehanna it is everywhere in junction with the Auroral limestone.

Crossing the Susquehanna, this S. or rather S.E. border overlaps first the Auroral limestone for a mile or more from the river, it then covers the Primal rocks of the Chiques anticlinal belt N.W. of the Codorus for 2 or 3 miles farther; thence to the foot of the Pigeon Hills it is again in contact with the limestone, and along the foot of these hills with the Primal slate. From their S.W. termination nearly to the Maryland line it overlaps once more the limestone, and at the State line rests again upon the Metamorphic Primal slate.

The N. border of this Red Sandstone formation, crossing the Delaware near Durham, will, if traced W., be found to pass about one mile S. of Springtown, and one mile N. of Cooperstown to the Hosacock Creek, where the road crosses it in Upper Milford Township. It then runs a little to the S. of the Mount Pleasant Iron-mines, passes Boyerstown, crosses the Perkiomen one mile S. of the Black Bear Tavern, and meets the Schuylkill about 2 miles S. of the town of Reading. From this latter point the N. edge of the sandstone stratum extends, with a slight undulation, in a nearly W. direction to the S.W. end of Millbaugh Hill, overlapping first the limestone of the

Kittatinny Valley, then gnessic rocks, and finally the Primal white sandstone of the hill. From Millbaugh Hill its range is a little S. of W., through Shaefferstown, past the Cornwall Iron-works, and thence along the turnpike to Campbelltown, from which spot it takes a nearly straight course to Highspiie on the Susquehanna. Between Millbaugh Hill and the Susquehanna, the red-sandstone formation lies everywhere in contact with the Auroral limestone of the Kittatinny Valley.

Passing the Susquehanna about 1½ miles below the mouth of Yellow Breeches Creek, the N. or N.W. edge of the formation is in contact with the Auroral limestone as far as the E. extremity of the South Mountain north of Dillsburg. From Dillsburg to the Maryland State line it is everywhere bounded by the base of the South Mountain, the line of contact of this group, and the Primal rocks of that chain, curving gently Southward, and passing by the little villages of Middletown, Cashtown, and Fairfield, and meeting the State line a little W. of Emmettsburg.

Composition of the Mesozoic Red Sandstone.—The predominant portion of this formation consists of reddish-brown shale and argillaceous sandstone in intimate alternations. In some parts of the mass, the argillaceous matter is in such excess that certain beds are little else than a homogeneous consolidated clay, with the laminæ of deposition extremely indistinct. Elsewhere there is such a superabundance of silicious sand in some of the strata as to constitute these true arenaceous sandstones; but this last-named variety of the rock usually includes a sufficient proportion of the red ferruginous clay to possess some shade of reddish brown, more or less pale or deep as the sandy particles more or less prevail. Occasionally, though rarely, there occurs a nearly white stratum, composed almost exclusively of rather weakly cohering sand. It is in the inferior and upper portions of the formation, or near its N. and S. margins, that we meet, for the most part, with the more distinctly arenaceous strata. In these portions of the belt, true sandstones, well adapted to architectural uses, are not uncommon; and in some localities, as on the Schuylkill and on the Delaware, but especially in New Jersey, extensive quarries are wrought, supplying a very beautiful building-material to the cities of Philadelphia and New York. On the New York side of the belt there are also red silicious coarse grits or conglomerates, well adapted to withstand heat, and therefore extensively employed as hearthstones for iron furnaces. In the central and upper parts of the deposit we not unfrequently meet with dark-grey and blue shales, containing much carbonaceous matter in a partially pulverulent state, and here and there a chunk of true compact *Lignite*, more or less bituminous, but retaining distinctly the fibrous structure of the wood from which it has been derived. This lignite is even occasionally in continuous layers of 2 or 3 inches thickness, extending for several yards. Approximating to the features of genuine coal, these little seams are a fertile source of delusive hope among those who are ignorant of the geological relations of our strata.

Besides the great body of red shale and sandstone thus characterised, the formation includes near its upper and lower, or N. and S. limits, two other subdivisions which claim a special description: these are coarse conglomerates, very heterogeneous in composition, and interrupted in their line of outcrop. In the E. part of the belt, and especially near the Delaware, the base of the whole formation is a mass of coarse pinkish and greyish sandstones, composed of rather angular fragments of quartz, felspar, and a little mica, the constituents of the neighbouring gneissic strata. These beds graduate upward into the soft red argillaceous sandstones; but in the vicinity of the Susquehanna, and at intervals along the S.E. edge of the belt in York and

Adams counties, a conglomerate of a very different quality holds the same position in the formation. It consists of pebbles of the adjacent older formations, especially the Auroral limestone and Primal sandstone, with some quartz, all cemented in an exceedingly irregular manner in a paste of the brownish red clay or shale. The composition of this conglomerate varies greatly, being influenced by the nature of the contiguous older rocks from which its coarse materials have been derived. These pebbles are of all dimensions up to a diameter of 5 or 6 inches.

Another very similar calcareous conglomerate to that which forms the base of the formation W. of the Susquehanna, constitutes in several neighbourhoods the upper or terminal stratum. This bed is so well characterised, and so little involved in the general red-sandstone deposit which it caps, that it is entitled to be regarded as a distinct sub-formation, the result of a special train of physical actions; it overlies the red shale along its N.W. margin, not in a continuous belt, but in several long narrow patches. It is an extremely heterogeneous rock, its pebbles, which are more or less water-worn and abraded by mutual rubbing, and which are of all sizes, from that of a grain of corn to that of a man's head, consisting promiscuously of all the materials of the neighbouring strata imbedded in a cement of the common red shale. In certain localities along the base of the gneissic hills between the Delaware and Schuylkill, a part of the pebbles are referable to the adjacent gneiss and Primal sandstone; and this is also the case at the foot of South Mountain in York and Adams counties; but the prevailing mixture is one containing a large proportion of pebbles of the Auroral limestone. Where the pebbles are for the most part from this rock, the cementing red clay is partially calcareous from infiltration; in these instances the rock is susceptible of being readily quarried and dressed, and when polished forms a rather pleasing and singularly variegated brecciated marble. Of this character is the Potomac marble, so called, of which the columns in the late Hall of Representatives at Washington city are interesting specimens.

Of the Dip of the Strata.—Throughout this extensive red-sandstone belt, the dip of the strata is uniformly towards the N., or towards some point intermediate between N. and N.W. This is shown in all the general sections, from No. II. to No. X. The average inclination is from 15° to 20°; perhaps it nowhere exceeds 25°, nor is it ever met with lower than 10° or 12°. This remarkable constancy in the direction and angle of the dip extends to both sides of the formation, and applies as well to the lower and upper conglomerates as to the main central body of red shale and sandstone. Throughout a breadth of nearly 30 miles, where the Delaware crosses the stratum, it preserves a uniform inclination of about 20°, although it is penetrated and overflowed in several places by masses of intrusive trap-rock. It is, indeed, a very interesting fact connected with the origin of this formation, that few, if any, of the very numerous intersecting trap-dykes, some of which are of enormous magnitude, appear to have exerted any influence upon the dip at the time of their eruption, unless, perhaps, they may have, in certain instances, added a little to its steepness, by compressing the horizontal area of the invaded mass. Scarcely in a single instance has the intrusion of the molten trap through the strata caused any sensible difference in the inclination of the opposite walls of the fissure; and it is obvious that, if the dip of the sandstone were the result merely of the internal force which injected the trap, such a difference should appear, giving a S. dip on the S. side of the dyke. This singular regularity of dip in the transverse direction cannot, on the other hand, be due to a wide wave or flexure in the crust, for in the broadest parts of the belt we can perceive no gradation in the angle to mark the existence of such a curve ; nor will it meet the case to assume the whole tract to be but the N.W. slope of one vast anticlinal, whose summit and S. side may have been swept away—as the enormous length and irregular form of the belt at once precludes this hypothesis. We shall have to seek, then, for the origin of the dip and its constancy of feature in actions or conditions of the surface anterior to the appearance of the trap, and unconnected with any of those majestic movements of the crust from which the inclinations of all our other still older strata unquestionably proceeded. I shall, in a future page, return to the consideration of these actions and conditions, and endeavour to make it appear that this oblique bedding of the sandstone is an original feature impressed at the period of the deposition of each layer, and the necessary consequence of the peculiar state of the adjacent ancient topography, and of the currents carrying and precipitating these sediments.

Igneous Rocks of the Mesozoic Red Sandstone.—Numerous dykes of Trap, in its several varieties, occur in this great tract of the Mesozoic red sandstone, and it is a curious fact, difficult of explanation, that the chief portion of all the injections of this class are restricted, if not precisely to the present limits of this belt, at least to the more extended area originally occupied by it. This geological relationship of the trap to the sandstone is not merely a feature of the important portion of the formation embraced within the limits of Pennsylvania, but belongs to the entire length of the stratum from the Hudson to Virginia ; and what is still more striking, it obtains equally in the independent belt which fills the valley of the Connecticut. Nor is this association of the two rocks restricted to these two long narrow lines of Mesozoic depositions S.E. of the first great range of the Appalachian Chain ; it extends remarkably enough to the basin of Mesozoic Sandstone, for such it must be regarded, which occupies the South shore ot the Bay of Fundy, in Nova Scotia. What the physical causes were, which, at the close of the Triassic period, confined the rupturing of the crust and the effusion of trappean matter to the comparatively narrow and local areas overspread by the Mesozoic red shale and their depositing waters, it is difficult, in the present state of geological dynamics, even to conjecture, and the present is not a fit opportunity for speculating upon a subject so purely theoretical.

The ordinary trap-rock of the Mesozoic belt of Pennsylvania—and the description is equally applicable to that of all the other districts above alluded to—is that variety which is known under the rather obscure name of Basalt, and which in its typical forms consists of an union of augite, felspar, and titaniferous iron, the first-named mineral predominating. In some dykes, however, the rock embraces much hornblende, replacing the augite. It is in such instances a true greenstone trap, but this is the less common variety of the two. It is of all degrees of relative fineness of crystallisation, from a coarse aggregate, such as we behold in some parts of the Conewago Hills, in Lancaster, in which the constituent minerals are very easily recognisable, to a very compact, almost homogeneous mass. It contains few extraneous minerals, and these are chiefly met with in the amygdaloidal varieties, near the borders of certain of the larger dykes, or more properly in immediate contact with the altered red shale, by the reaction of the trap upon which this amygdaloidal character has been acquired, and these minerals have been evolved, chiefly by segregation. They are principally *Epidote, Prehnite, Zeolite, Stilbite, Analcime, and Datholite.*

CHAPTER I.

DETAILED DESCRIPTION OF THE MEMBERS OF THE MESOZOIC SERIES.

RED SHALE AND SANDSTONE.

THE very great general uniformity of the composition and contents of this extensive stratum renders it unnecessary to offer here a minute description of it under all its local exhibitions. It will be more expedient to pursue the course adopted in relation to certain other of the more monotonous portions of our geology, describing one or more transverse sections of the formation, where it is most diversified and fully developed, and introducing only such local details as are of specially practical or scientific value. A correct conception of the nature of the formation will be best conveyed by a description of its several features, as they may be seen in the vicinity of the Delaware River, where the belt has its greatest breadth. A reference to the general section No. II. will aid the reader in following this brief analysis.

Observing, as usual, the ascending order, I shall commence with the S. edge of the belt near Trenton, and treat successively of the several natural divisions of the formation as we reach them, proceeding Northward. Along the S. margin of the formation, near the Delaware, there is a well-marked subdivision, having a breadth of nearly 2 miles, and consisting of coarse reddish-grey quartz, with occasional strata of conglomeritic sandstone. This rock is exposed below Yardleyville; it is composed of small angular grains and imperfectly rounded pebbles of the minerals of the neighbouring gneissic rocks, the upturned edges of which it rests upon unconformably. The pebbles are chiefly quartz and felspar, those of the former mineral being in certain layers nearly an inch in diameter. Some of this quartz is slightly opalescent. Much of the felspar is in a state of partial decomposition, passing towards the condition of Kaolin, as indicated by its want of lustre, and its dull yellowish-white colour. A certain proportion of hornblende, and also a small amount of mica, likewise occur. Among these materials there is dispersed in minute nests or specks much yellow hydrated peroxide of iron: this substance, and the partially disintegrated felspar, weaken the cohesion of the rock, and much impair its value as an architectural stone. The bedding of the more arenaceous layers is not very regular, and there is generally an oblique lamination, the result of inclined deposition, a structure which materially injures the utility of this rock for many purposes. Interstratified with the beds of pure sandstone are many strata of a more argillaceous and browner sandstone, and innumerable layers of soft red shale. The lower member of the formation, as here described, is traceable under more or less distinctiveness of character, for many miles E. and W., in both directions, from the Delaware; it is visible near the Schuylkill, below Norristown, but is there extremely narrow. Between the Schuylkill and the Susquehanna it seems to be generally absent, having, perhaps, been swept away in the extensive denudation to which the S. border of the belt has been exposed in that quarter.

A bove these rather heterogeneous rocks of the base of the formation there rests a series of beds of a somewhat different material, constituting a zone which, near the Delaware, is nearly 2 miles wide. In this division the predominant rock is a rather coarse-grained pinkish sandstone, composed of transparent quartzose sand, white specks of decomposing felspar, and occasional flat pebbles, or flakes of the compact red shale, or argillaceous red sandstone; but the silicious sand is the chief ingredient, and the cement uniting these materials is the red shale or clay. From the circumstance that no part of the formation has ever been deeply buried, either under a great mass of waters or beneath other strata, the cohesion of the particles in these rocks is somewhat feeble; nevertheless, the belt which I am now describing, furnishes altogether the best building-stone derived from the whole formation; it is quarried near Yardleyville, and in New Jersey, in a series of quarries near the canal; the stratification is for the most part regular, and the rock is easily quarried and wrought. Those varieties which possess a uniform reddish-grey colour should be preferred for architectural uses, since the quantity of disintegrating felspar present in much of the lighter and coarser pinkish sort, greatly impairs its cohesion and power of resisting the influence of the elements. This zone extends to the Schuylkill.

The next overlying division of the general stratum is much broader, extending from the Northern limit of that last described, to a point about 1 mile N. of the tract of Auroral limestone, near New Hope. This extensive mass includes all the more common varieties of the red shale, and red or brown argillaceous sandstone. All the forms of these rocks of every aspect, from the softest argillaceous shales, so homogeneous as scarcely to show the stratification, to hard silicious and micaceous sandstone, here abound in almost endless alternation. These strata, having a W.S.W. strike, range through the Southern half of Bucks and Montgomery counties, and appear in a broad belt N.E. of the Schuylkill. In the neighbourhood of the Delaware River this part of the formation is intersected by several enormous dykes of trap-rock, the heat imparted by which has caused an extensive alteration in the aspect and texture of the strata, and developed in certain localities some highly interesting phenomena of mineral segregation, the features of which will claim our attention in a future page.

Upon this group there lies a rather more diversified series of strata of alternating red sandstones and coarse yellowish conglomerates, subdivided by occasional thinner beds of the soft red shale. These coarser rocks much resemble those of the first-described division at the base of the formation. Some of the pebbles of quartz exceed half an inch in diameter; mingled among them are small flat fragments of red shale, evidently worn by attrition; many of the layers consist of a rather homogeneous coarse sandstone, and furnish a rock well adapted to some of the common purposes of architecture. This belt has a width of nearly one mile on the Pennsylvanian side of the Delaware: it crosses the river into New Jersey in the vicinity of Centre Bridge.

Passing the belt of conglomeritic sandstone, we again meet with the usual alternation of red shale and soft argillaceous red sandstone. These constitute a vast group occupying all the region between the belt just described and the calcareous conglomerate on the N. border of the formation. In the district of the Delaware these rocks are extensively altered by the temperature originally imparted to them by numerous dykes of trap-rock, and by much igneous rock which has not reached the surface, but of the proximity of which there exist the strongest indications. The partially-metamorphosed strata of the tract under consideration, which has its S. margin near the mouth of the Tohickon, are highly indurated and compact, have a prevailing dull-brown and purple colour, sometimes passing into dull-blue, and are moreover everywhere intersected by large joints cutting the beds into great rhombic blocks. Those portions which have experienced the greatest amount of igneous action have a semi-crystalline fracture, and when struck with a hammer give out a ringing sound. In the immediate vicinity of some of the large dykes where the alteration reaches its maximum, distinct mineral species have been developed in the shales by a well-known process of segregation, caused by extreme heat. The most common mineral thus elaborated from the union of the earthy particles of the sedimentary strata is Epidote, which here occurs in the form of spherical geodes or amygdals. The Nockamixon cliffs on the Delaware display these upper beds in all their features.

In the region of the Schuylkill, and through the whole tract between it and the Susquehanna, indeed as far as Maryland, the prevailing rocks are identical with these here referred to as forming the N. half of the formation of the Delaware. But the red shales and argillaceous red sandstones have not everywhere undergone the same amount of alteration from intrusive igneous matter. Except in the N. part of York County, there is no other neighbourhood in which the strata have suffered this general baking action to an extent at all approaching that discernible near the Delaware. A great number of small and insulated dykes of trap traverse the formation, and near the Susquehanna there are two or three of no inconsiderable dimensions ; but the changes induced by these injections rarely extend farther than a few hundred feet from the walls of the dykes, and in the greater number of instances are confined within narrower limits.

Throughout the district here described, the prevailing dip of the beds is about 18° or 20° to the N.N.W.

All along its N. border the formation contains, besides the ordinary red shales and red argillaceous sandstones, many strata of a coarse brown silicious sandstone, portions of which are often coarse enough to deserve the name of a conglomerate. These conglomeritic beds consist of little else than more or less angular grains of sand and small quartzose pebbles, cemented together by a very small amount of red shale or clay. It is difficult to trace these coarser beds very far, and it is certain that they are not to be regarded as great permanent members of the formation, but rather as local deposits of the extent of a few furlongs, or even a mile or two. Alternating with rocks derived from a finer class of sediments, they seem to indicate that the generally quiet movement of the waters was occasionally interrupted by sudden but not very widely extended currents, of sufficient velocity to sweep into this great estuary the heavier, coarser particles of its adjacent shores. Many of the silicious pebbles are fragments of the Primal white sandstone.

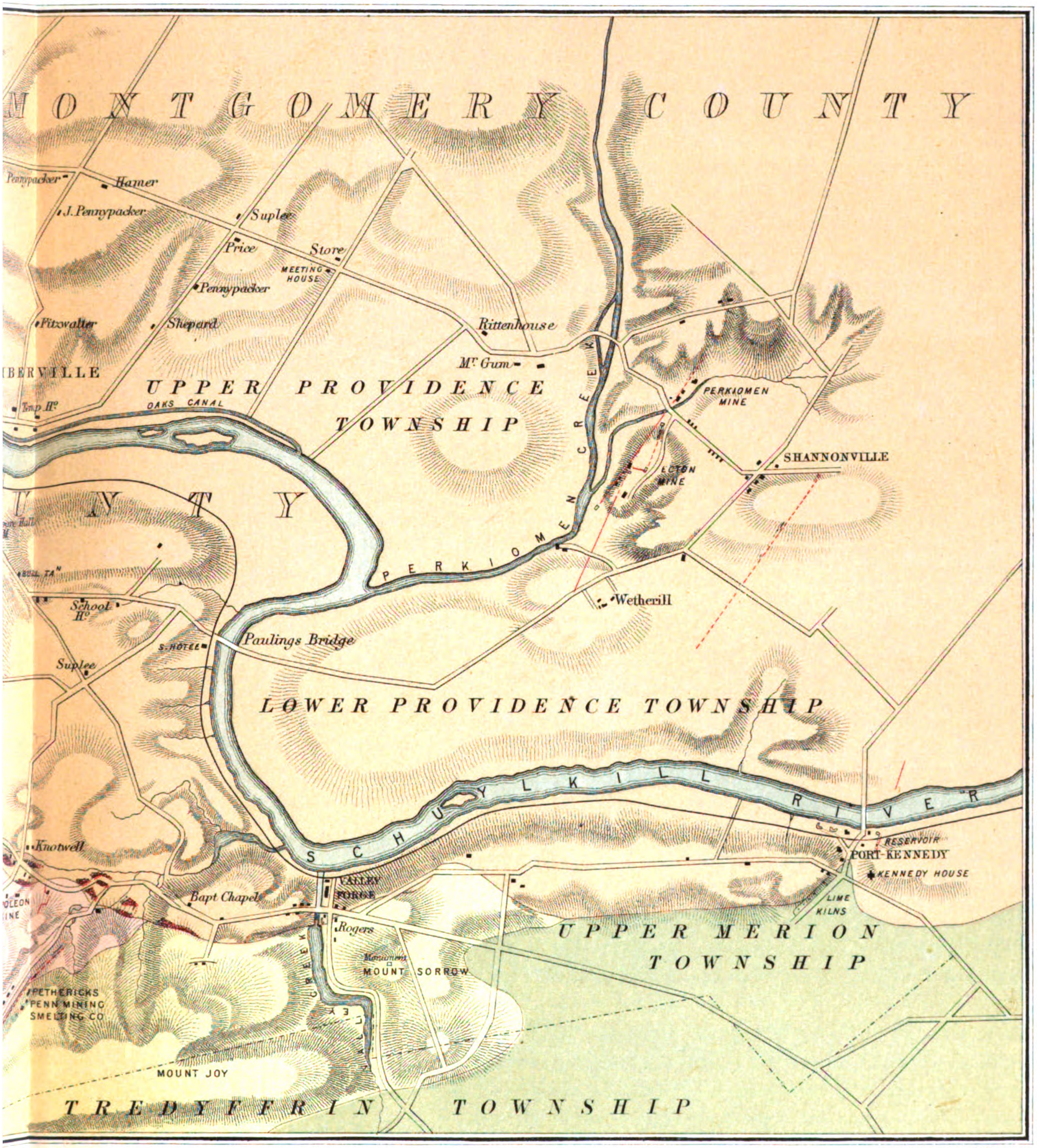
This coarse brown grit, or silicious conglomerate, has long been employed as a material for the hearths of iron furnaces, and in all cases where the fuel is charcoal, and the heat consequently not excessive, it bears the trial well. The hills W. of the Schuylkill have furnished hearthstones for many furnaces in the Eastern part of Pennsylvania for a long period. This rock, which is generally gathered from the surface, where it oftentimes is found in large detached blocks, is harder and coarser than the variety procured in Rockland County, New York, and which is known under the name of the Haverstraw Stone. In the application of anthracite coal to the smelting of iron, the more intense heat and greater force and volume of blast, compared with those used in the ordinary charcoal furnaces, cause a too rapid waste of the hearths constructed of this material. In this class of furnaces it is therefore not now employed.

It is a general fact well worthy of notice, as bearing upon the question of the nature of the

MAP OF THE MINING DISTRICT OF CH

Engraved & Printed in Colours by

CHESTER AND MONTGOMERY COUNTIES.



W. & A. K. Johnston, Edinburgh.

currents, and the condition of the surface at the origin of this Mesozoic formation, that not only these coarser grits, but indeed all the strata, viewed individually, are comparatively limited in their extent. We cannot, as in the case of many of the Palæozoic strata, trace any of the single layers over a wide area, but each bed appears to thin away at no great distance, and the whole mass, therefore, to be made up of narrow overlapping wedge-shaped strata. In this characteristic feature, the entire stratum bears a close resemblance to many estuary formations where we may witness, in the circumscribed extent and constant alternations of the smaller subdivisions of the deposit, the ever-shifting operation of river-currents, and of the still more inconstant tides.

On the Schuylkill, and in the belt of country between that river and the Susquehanna, the stratum presents very little departure from the type which it bears in all the middle and Northern portions of the section near the Delaware; the great mass of the formation being red shale and soft red sandstone, with occasional beds of more arenaceous grits and a few of silicious conglomerate. Perhaps there is, on the whole, a large proportion of grey felspathic sandstone in the series. This rock, some varieties of which seem well adapted to architectural uses, differs little in composition from the red and brown sandstones, except in the nature of the cement which holds together the granules of sand, this consisting, in the present case, of a whitish clay, apparently the product of decomposing felspar, and not of the common red shale. Some of these grey rocks imbed thin layers of bluish carbonaceous shale, with masses of lignite, and we not unfrequently find fragments of that substance, and of fibrous charcoal, imbedded in the sandstone itself. These facts indicate that such parts of the formation had probably an origin different from that of the red shales. Strata answering to the description here given are common in the vicinity of Litiz, Manheim, Mountjoy, and Elizabethtown, and they seem to constitute an almost continuous belt in this portion of the formation.

BOUNDARY OF THE MESOZOIC RED SANDSTONE IN THE CHESTER COUNTY LEAD-MINING DISTRICT.

Taking up the line of the red sandstone on the Schuylkill River at Port Kennedy, where a more than usually extensive denudation of its margin has cut it away, so that its edge touches the river, and tracing it W., we may follow it by the S.W. base of the ridge, running towards Valley Forge, the vale and meadow on the S. being in the Auroral limestone.—(See the Geological Map of the Mining District of Chester and Montgomery counties.)

Approaching the E. end of Mount Sorrow, or the N. hill near Valley Forge, the boundary extends a short distance to the W. of a cross road, and then suddenly swings back S. to recross that road, forming as it were a loop. It now sweeps round the low point of this hill, and takes its course once more steadily W., thus forming a sigmoid or double curve, as if the hill had jutted into the estuary of the red-sandstone waters, and deflected its shore line to make a little cove or bay behind it.

Tracing it over the N. flank of this hill, it passes to the N. of the Port Kennedy and Valley Forge Road, but on the W. descent recrosses this twice, the second time at the foot of the hill, near the Valley Forge Dam. From the W. abutment of the dam the line ascends a little slope, marking the junction of the Primal slates and red shale, parallel with the road leading Westward, and never more than 100 feet from it, until it gains the general level of the country, at the N. foot of the North Valley Ridge. It here passes about 250 feet S. of the Valley Forge Hotel, and is cut by the bed of the little brook W. of the Baptist Church, where the line is 700 feet S. of the main road. This point of intersection of the stream and the edge of the formation is an interesting spot, for it is just here that the Red Sandstone and the Primal slates diverge, and the gneiss rocks first appear at the surface, parting them as by the point of a wedge. The line, now taking a more undulating course, sweeps Westward and then N.W. over the hill dividing the little brook from the larger one of Vanderslice's machine-shop; it crosses this latter stream a little below the factory, and then swings in a smilar manner to the S. of the next knoll, till it strikes and crosses the Main Pickering and Valley Forge Road. This it recrosses a few hundred feet farther on, or just W. of the abortive mine-shaft of the so-called "Napoleon Mine;" thence it ranges once more nearly parallel with the road leading towards Pickering Creek, passing S. of Krause's Corner about 250 feet, and receding farther from the road, swings just S. of W. Miller's farmhouse by the margin of his meadow. Following the N. edge of the Meadow, it runs on Westward usually within 100 feet of the road, nearly touching the Friends' Meeting-house, and thus forward to the junction of the Pickering and Paoli Road, with Rapp's by-road. From this point we trace it through the fields to Wheatley's Gate, detecting it by the same chain of low summits which distinguish the outcrop of the conglomerate of the edge of the formation farther E. From Mr Wheatley's dwelling-house it may be pursued by the base of the knoll N.W. of his garden, and by the N. slope of the hill supporting the office of the Wheatley Lead Mine. Following the undulations of the ground, sweeping always Northward down the transverse ravines or little valleys, in obedience to the denudation on the outcrop, and swinging Southward round the higher-dividing summits and local water-sheds, the margin passes the Chester County Lead Mine, crosses the Brookdale Brook, and reascends Southward to nearly touch the stack of the smelting-works. Beyond this point it sweeps S. and N.E. through the fields next N. of the Montgomery Lead Mine, and touches the Pickering Creek Road just at Kinsey's mill. Here the outcrop takes another convex bend S. to touch the hill of the Charlestown Mine Shaft, and to range thence from near the office to the next ravine, along the W. bank of which it passes to the Buckwalter experimental mine-opening. Crossing the road, it next goes through the N.W. corner of J. Davis's field N.W. of his house. The edge of the formation is encountered on the road leading N.E. from Charlestown, at about half a mile S.W. of the Charlestown Mine Road.

In this vicinity, at the N. edge of a wood, there is a dyke of coarse felspathic granite just S. of the S. margin of the red sandstone.

Throughout the chief part of its distance from the first appearance of the gneiss near the Baptist Church to this Charlestown Road, the marginal beds of the red-sandstone formation are more or less conglomeritic, being composed of pebbles of quartz and sandstone of all degrees of size to the dimensions of hen's eggs, cemented by red shale or clay: this conglomeritic band is not, however, strictly continuous, being cut away by denudation for some stretches of a few hundred feet, and in others being too fine in its pebbles to attract attention as a conglomerate, or by its superior hardness to make any impression on the topography. It is between the E. commencement of the gneiss and the Black Horse Road at Wheatley's that the rock is developed most distinctly, but especially in the E. part of this space, and nowhere so conspicuously as between the Napoleon Mine and the Pennsylvania Mine Brook. In this E. part of the belt there are, in fact, two coarse massive beds of the conglomerate outcropping about 200 feet apart, almost identical in composition, and both capping a series of little summits or ridges. The lower of these forms, in fact, the little flat ridge along which the road leading by the Friends' Meeting-house passes. The two conglomerates evidently suggest two earthquake concussions, with a pause between them, early in the formation of the red-sandstone deposits. Their materials are manifestly derived from the adjoining older formations, especially from the Primal sandstones of the ridge just South. Much material of the adjacent gneiss, its granite veins inclusive, enters into the substance of all these lower beds of the red-shale series. It does not appear that the red-sandstone formation originally extended more than a very trivial distance S. of its present conglomeritic and sandstone margin, for no wide denudation in a region so irregular could have shaved off the whole Southern border so evenly as to stop over so long a line just at the base of this thin conglomerate. Undoubtedly this S. edge was greatly eroded and wasted in the district farther W., but not in this tract from Valley Forge Creek to the neighbourhood of Charlestown, where the S. barrier of hills was in fact too adjacent to give space for the waters of the formation to spread beyond the limits it there occupies.

Of the Red Shale and Sandstone in York and Adams Counties.—Having now exhibited in sufficient detail the composition of this formation in the tracts between the Delaware and Susquehanna, I proceed to sketch its features in the portion of the belt which is embraced between the latter river and the Maryland State line. The character of this portion will best appear by tracing a section along the W. bank of the Susquehanna.

Section along the West Side of the Susquehanna.—In the neighbourhood of the Susquehanna, the lowest member of the Mesozoic group is a calcareous conglomerate, consisting of large pebbles, chiefly of the Auroral limestone, cemented by a little calcareous red shale. This rock admits of an excellent polish, and has been wrought to a small extent as an ornamental marble. The belt crosses the river near the village of Bainbridge. On the W. side it is not well exposed. Overlying this rock is a coarse pebbly silicious conglomerate 80 or 100 feet thick, with some bands of red shale interposed. Above the conglomerate we find red shale alternating with red and grey sandstone, extending in very imperfect exposures, along the river-bank. It is chiefly of a grey colour, is micaceous, and in some places divides into very thin flat layers. Reposing on this rock we find a red shale.

At York Haven appears an altered rock S. of a trap ridge which lies immediately above the town. The trap-rocks of this ridge lie in large fallen masses for some distance along the river road; they are rather easily broken, and yield a good material for building: they are coarser and more crystalline in texture than those from the small dykes farther S.W. in the belt, and bear some resemblance to a sienite, having the hornblende and augite in distinct crystals.

Next above the trap is a hard altered slate or shale, which extends its ledges across the river, and forms the rock in the upper part of the "Conewago Falls." Above this occur fallen masses of trap from a spur of the ridge at York Haven, but no rock is seen in place for some distance. Near the mouth of Fishing Creek we have a red sandstone, which extends up the valley of the stream; it is highly valued as a building-stone. It was here that the red sandstone for the portico of the State Capitol at Harrisburg was obtained; it has also been much used in the construction of locks, bridges, &c. on the public works along the Susquehanna. Making good furnace-hearths where charcoal is used, it has been taken to a great distance for the purpose.

This rock is very abundant over a considerable part of the valley of Fishing Creek; but the purer sandstone is interstratified with much red shale in layers of varied thickness.

On the N. of Fishing Creek Valley there is another trap ridge, which abuts upon the river a little above Etter's Tavern. Near Etter's we perceive the influence of this trap on the shales and sandstone. Much of the altered sandstone has only its colour changed; but some of the altered shale, and an altered silicious conglomerate, contain *epidote* and micaceous oxide of iron. The epidote and micaceous oxide of iron are common in this neighbourhood; indeed, it seems to be a general condition both here and in other districts, that where the influence of the trap has been strongly exerted on the coarse sandstones and conglomerate, the result has been the production of epidote and micaceous oxide of iron, while the common red shale has been changed into a very tough compact bluish or purplish rock, varying in texture and colour in proportion to its contiguity to the trap, and sometimes containing rounded masses or small veins and strips of epidote.

About 300 yards above Etter's house we find the trap-rock in place on the river-bank, a little below which, and nearly in contact with it, appears the altered shale.

The trap-rock is exceedingly uniform in texture, not differing much from that of the ridge below, near York Haven.

The trap ridge above Etter's runs parallel with and near the river for about 4 miles, for which distance no rock is seen in place, the fallen masses covering the steep slope of the ridge to the very margin of the water. Near the mouth of March Creek the ridge leaves the river-shore, and stretches away N.W. towards Yellow Breeches Creek, below Lisburn. About the mouth of March Creek we have low alluvial ground for nearly a mile. The first visible rock on the river above the trap is a soft red sandstone; this is overlaid by red shale, which in its upper portion, near its contact with the South-east-dipping Matinal limestone, is somewhat calcareous, and evidently denotes the position of the upper calcareous conglomerate. The conglomerate in its true character is not found immediately at the river, but it is abundantly developed, as I shall presently show, along this line of outcrop farther Westward. Immediately N. of the last-mentioned calcareous red shale we meet the South-dipping limestone of the Cumberland Valley: this is about 1½ miles below the mouth of Yellow Breeches Creek, and nearly 5 miles below the Harrisburg Bridge. About 9 miles below Harrisburg there is an island in the river, called "Hill Island," from the circumstance of its having at its head a bold rocky hill, formed by a part of the trap ridge already noticed as reaching the W. shore of the river, a little above Etter's. S. of this trap we find the same range of altered rock, noticed near Etter's house as containing epidote and micaceous oxide of iron. Some specimens were found on the island, containing pisiform concretions of epidote, and others epidote and micaceous oxide of iron.

A very similar range of altered rock is found S. of the trap ridge which reaches the river at York Haven.

In the vicinity of the Susquehanna, and for 15 or 20 miles from it, much red sandstone is mixed with the red shale which overlies the lower conglomerate. This is particularly abundant in the neighbourhood of Strinestown, S. of the Conewago Creek, where large quantities of this rock are obtained for useful purposes, being taken to the river, and thence boated to different places for bridges, aqueduct locks, buildings, furnace-hearths, &c. Some of it is coarse, containing numerous pebbles, while the other strata are simple sandstone without pebbles. This rock forms the Conewago Hills marked on the State Map south of the Conewago Creek.

The N. branch of the Conewago Creek, opposite to and below Rosstown, flows chiefly in the hard blue altered shale, while on the S. side we generally find the red rocks not far from the stream.

About 3 miles South-westward from Rosstown, near the edge of the trap range, are some old diggings for iron ore, now long neglected. Some specimens were picked up among the rubbish which appeared to be chiefly a dark compact protoxide of iron, slightly magnetic.

The red-shale country about Berlin and Abbottstown is rather fertile and well cultivated ; but those portions of the red-shale belt S. of the trap, where the rocks are changed to a dark bluish or purplish colour, have usually a wet heavy soil, and are not so much esteemed for agricultural purposes. Two miles N. of Berlin we come to the altered bluish shale, and here, on a farm belonging to Mr Brown, traces of carbonate of copper are seen in the shale, and some excavations were made for the ore ten or twelve years ago, which are now filled up and neglected.

Westward from this, and about half a mile N.E. from Hampton, near the junction of the trap and the altered shale, there is what is called an old "*Silver Mine*," where some ignorant persons were deluded by the shining appearance of a micaceous oxide of iron into digging for silver. Some specimens found among the rubbish are considerably magnetic, and indicate that they might yield iron, if found in sufficient quantity.

Eastward and N.E. from Petersburg there is red shale ; and in this formation, at Gardner's, half a mile E. from the town, is a stratum of limestone in rather a novel position. It lies in the S. side of a little hill of red shale, dipping with that rock gently N.W., and is evidently an interposed stratum in the shale, which may be seen above it, while the slightly-altered shale of the little ridge S. of it must of course pass below it. The rock in the upper part of the stratum is rather loose, and the large interstices (which seem to be the effect of natural decomposition) are filled with red earth washed in from above ; the lower portion is more solid. A quarry has been partially opened here, and a kiln erected near it for burning this rock into lime ; but at the time of our survey it was not in operation. About 10 feet thickness of this stratum is apparent ; but its total depth is unknown.

The conglomerate seen at Robinett's is half a mile E. from Gardner's quarry ; but whether above or below it, or whether connected with it, we could not determine : the conglomerate is certainly in the lowest ground, and is also overlaid by red shale.

Another limestone is found from 1 to 1½ miles N. of Petersburg ; but this evidently belongs to the Auroral formation.

CHAPTER II.

LOWER CALCAREOUS CONGLOMERATE WEST OF THE SUSQUEHANNA.

We will now proceed to trace the range of the *Lower Calcareous Conglomerate*, forming the S. limit of the red-shale formation, from its position on the Susquehanna, a little above New Holland, S.W. to the Maryland line. It has been already said that it folds diagonally across the little limestone belt at New Holland, until, about a mile from the river, it conceals the whole of it, and reaches the range of silicious slate which runs W. from the mouth of the Codorus. This slate, like the limestone belt, is gradually covered by the invading red shale, until, about a mile W. of the York and Harrisburg Turnpike, it also disappears, and the lower portion of the shale series is found resting upon the limestone of York Valley. It may be proper to observe that the S. border of this red shale, or "Middle Secondary" region, is almost invariably marked by a line of gentle elevation above the country at its base, and this little elevation is called by the people in that region the "Red Hill," and in the country N. and N.W. of it the "Red Lands." The conglomerate, when present, usually lies at the base of Red Hill, and is seldom visible except when brought to the day by some ravine or artificial cutting. The main portion of Red Hill generally consists of the pebbly silicious conglomerate, or red sandstone, or, if neither of these is visible, of red shale.

Near Mr William Lerick's, about 2½ miles N.W. from York, the calcareous conglomerate appears in a cutting of the Carlisle Road, on the side of Red Hill. Some of the fragments abound in red micaceous oxide of iron. The same calcareous conglomerate is abundantly exposed in the bank near Lerick's distillery. Ascending a small stream W. of this spot, we meet above the conglomerate with a locality where many years ago excavations were made for coal, and it is said some carbonaceous matter was actually found. This digging, now almost obliterated, seems to have been made in a dark carbonaceous slate. Above and below this slate there occur two thin strata of limestone very similar in character, the upper one apparently 3 or 4 feet thick, and the lower one having only its upper surface exposed.

From this point at Lerick's, the South-eastern limit of the formation, ranging in a South-westwardly course, encroaches on the limestone range S. of it; crosses the York and Gettysburg Turnpike a little E. of King's Tavern, 9 miles from York; passes half a mile S. of King's, and meets the N. base of the Pigeon Hills, having entirely covered the branch of the limestone of York Valley, which passes on the N. side of these hills. Ranging Westward along the foot of the Pigeon Hills, it exposes the pebbly silicious conglomerate resting on the slate of the hills, and in some places extending a short distance up their N. slope. This pebbly conglomerate is finely exhibited near the road from Hanover to Abbottstown, about a mile from the latter place, but the *calcareous* conglomerate has not been observed along the N. side of the Pigeon Hills.

Passing by the W. termination of the Pigeon Hills, the lower margin of the formation rests again on limestone 100 or 150 feet N. of Adam Myer's lime quarries, near the Hanover and Carlisle Turnpike, 4 miles from Hanover. Thence passing near the Catholic Chapel, on Little Conewago, it bends rather more to the S., and ranges within a mile of Littlestown (Petersburg), reaching the Maryland line on the "Barren Slates," near Arnold's mill, having thus passed diagonally across the whole Southern belt of limestone. The calcareous conglomerate occurs in an altered condition near a small trap-dyke, 1 mile N. of Littlestown, at the base of the "Red Hill." It seems to consist of pebbles of white limestone, imbedded in a dark slaty paste. The most Southerly exposure of limestone is in a field 1 mile N. of the State line, and 1½ miles from Littlestown: it seems to be a variety of the conglomerate.

CHAPTER III.

UPPER CALCAREOUS CONGLOMERATE.

It has been already intimated that the Upper Calcareous Conglomerate does not form a continuous belt, but a succession of narrow insulated patches of no great length, at the S. base of the South Mountains; the longest of these is in York County.

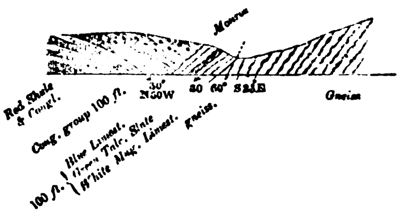


Fig. 567.—Contact of Mesozoic and older Palæozoic Rocks at Monroe.

The most Eastern mass of this formation is at Monroe, on the Delaware River, where it constitutes a bold hill, and abuts with a N.W. dip against highly-inclined and contorted beds of the Matinal limestone and gneiss. Fig. 567 illustrates the attitudes of the strata at their place of meeting.

This belt, which is likewise visible, though less conspicuous, on the New Jersey side of the river, extends W. not farther probably than 1 mile, for no trace of it can be detected on the Old Philadelphia Road, about 2 miles from the river.

Another small belt crosses Durham Creek a little S. of Springtown, and ranges W. as far as the W. branch of that stream. Between this locality and the S. Branch of Saucon Creek there extends another outcrop of the conglomerate, here concealed in many places by the superficial diluvial matter of the adjacent hills. We again meet with it on the Hosasock Creek, but at this spot the rock consists chiefly of silicious and gneissic pebbles. Entering Berks County, a small tract of it is seen near the main branch of Perkiomen Creek, crossing the road from Metztown to Sumanytown. Here it has been quarried for the purpose of conversion into lime; it is composed almost exclusively of angular or very slightly rounded fragments of limestone, and might, upon a careless inspection, be mistaken for a brecciated form of the Auroral Limestone. The calcareous conglomerate, cemented by the material of the red shale, next shows itself on the Manatawny Creek. Following the margin of the red-shale formation to its intersection with Limekiln Creek, a small tributary of the Monokesy, we encounter another local patch of the same rock. Another much larger and wider belt of it commences E. of the Perkiomen Turnpike, about 3 miles E. of Reading, and curving S. and then W. round the base of Neversink Mountain, crosses the double loop of the Schuylkill River about 2 miles S. of that town. The roadway of the Reading Railroad exposes in fresh excavations the strata of this interesting rock, and there is perhaps no locality in the State where it may be more easily studied than in the belt now referred to.

The accompanying cut pictures an exposure on the side of the Reading Railroad, near the S. base of Neversink Mountain, which shows the Mesozoic conglomerate lodged in a cleft of the steeply-upturned strata of the Old Auroral limestone, from the wreck of which, and the Primal sandstone of the mountain, the pebbly matter is chiefly derived. It illustrates well the action of the turbulent waters, which appears first to have scoured sharply the limestone floor of the formation, eroding it into deep gutters by removing the softer or most crushed layers, and then to have cast in without stratifying the promiscuous mass of loose materials which they were dragging with them at the foot of the hills.

Between the Schuylkill and the Susquehanna there are few or no tracts of this upper calcareous conglomerate, a fact readily explained by adverting to the marked difference between the topography of the N. border of this portion of the Mesozoic basin, where the chain of the South Mountains is interrupted, and the other parts of the belt where this barrier was everywhere present with its steep slopes to supply the coarse pebbly materials. This will be made more intelligible in a future part of this Chapter, where I shall offer some views respecting the physical circumstances which accompanied the formation of the Mesozoic deposits.

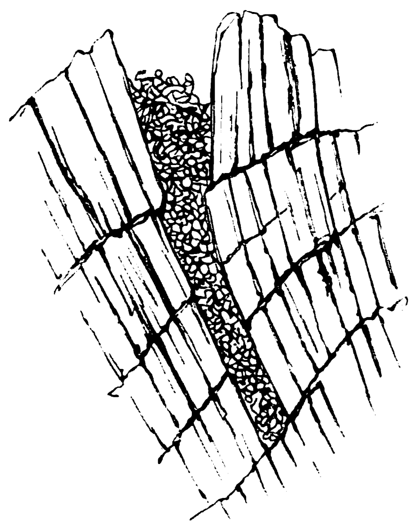


FIG. 568.—A Chasm in the Auroral Limestone, S. foot of Neversink Mountain, Reading, filled with Upper Mesozoic Conglomerate.

Passing the W. side of the Susquehanna, we meet with the upper calcareous conglomerate, constituting a much more continuous belt than exists between the Delaware and Schuylkill rivers. It ranges with but little interruption along the N.W. border of the red shale, crossing Cumberland, York, and Adams counties along the base of the South Mountains, the whole distance to Maryland, or, more correctly, into Virginia.

UPPER CALCAREOUS CONGLOMERATE SOUTH-WEST OF THE SUSQUEHANNA.

The upper conglomerate forms, as already stated, the N. boundary of the red-shale formation from the Susquehanna, along the S. base of the South Mountain to the Maryland line a little West of Emmettsburg.

It occurs on the Susquehanna, where it is very imperfectly exposed about $1\frac{1}{2}$ miles below the mouth of Yellow Breeches Creek. From this point it ranges nearly W. along the N. side of the Northern Trap Ridge, above Etter's, and crosses the Yellow Breeches Creek into Cumberland County, near Grove's fulling-mill, about 2 miles N. from Lisburn.

About a mile N. from Grove's fulling-mill the belt of conglomerate is intersected by a ridge of trap which crosses into Cumberland County. Here is a singularly-shaped elliptical mound, about 200 yards long, and 50 feet high, and remarkably narrow at the summit. This hill contains a rock which is evidently an altered calcareous conglomerate.

Near Grove's fulling-mill, and along the banks of the creek towards Lisburn, the conglomerate is seen exposed in very massive beds, but is considerably more impure, that is to say, less calcareous, and more silicious than farther down the creek. Opposite Lisburn, on the York County side, it is exposed in enormous beds, which are, however, much interstratified with red sandstone and shale. It is also seen below Lisburn on the Cumberland side, in the neighbourhood of the forge, where, with its alternating strata of red shale and sandstone, it cannot be less than several hundred feet thick. Some of the imbedded pebbles here are as large as a man's head, or even much larger, making a rock ofsuch coarse structure that cabinet specimens cannot well be selected. These imbedded masses are generally of various-coloured limestones, with some grey and reddish quartzose rock, or very compact sandstone, and some white igneous quartz.

The N. and N.W. limit of the red shale, on the Cumberland side of Yellow Breeches Creek, is about 2 miles from Lisburn, where it stretches S.W. to the creek S. of Bryson's, and a little below Grove's flour-mill. The conglomerate is seen E. of Bryson's, 2½ miles W. from Lisburn; it again appears on the bank of the creek near Cocklin's mill, above Grove's; and S.W. from this towards Dillsburg, we frequently see loose in the soil the large rounded limestone pebbles which have come from the decomposition of this rock.

This is also the case immediately above Dillsburg, and on the W. and N.W. of the town the rock appears in place. Near Prosser's mill it is altered to almost a white colour by the influence of a dyke of trap-rock, which is abundant about Dillsburg.

About a quarter of a mile N. of Dillsburg, in a meadow on the farm of Mr Weltz, there is a deposit of white clayey marl formed from the decomposition of this rock. It is covered with a foot or more of dark vegetable soil. This white calcareous mud would seem to be well worthy of trial as a manure.

The altered conglomerate is seen in many places in the immediate vicinity of Dillsburg, frequently on the sides of, and between, the little trap hills; it is generally of a whitish colour, with a more or less crystalline texture.

The E. termination of the South Mountain is near Dillsburg: there are here two ridges, the more S. one terminating a mile or more S.W. from the town, and the N. one, about 1¼ miles W. from the town. The calcareous conglomerate is distinctly exposed along a deep ravine worn by a little mountain-stream, which sinks into a fissure in this rock, and totally disappears. At this place the cliffs are 30 or 40 feet high, and the rock very coarse, consisting chiefly of round or flattish kidney-shaped lumps of several varieties of limestone (some weighing perhaps 50 pounds) imbedded in a coarse reddish cement.

On the farm of Mr Koontz, near the foot of the S. ridge of South Mountain (about 6 miles N.E. from Petersburg), loose pieces of limestone are abundant in the fields, and some excavations have been made in a bank disclosing many of these loose masses. No rock is visible in place in this vicinity.

At Buckholder's, nearly a mile farther S.W., and near the foot of the sandstone ridge of the mountain, there is an exposure in the steep bank of a small stream, where the rock is exceedingly coarse, consisting of loose rounded masses of limestone of different kinds and colours, with nearly an equal mixture of sandstone and quartzose pebbles cemented by a red-shale paste.

From this point S.W. to within a mile of Petersburg no rock is seen in place; but the innumerable pebbles of reddish and grey very compact sandstone and quartz in the soil of the little hills along the S. side of the mountain, seem to have come from the conglomerate, which is here losing its calcareous character. At Robinett's, about a mile E. from Petersburg, there is a small exposure in a meadow-bank of a conglomeritic limestone, which wants, however, the red colour so characteristic of the calcareous conglomerate. This is in the immediate vicinity of two other bands of limestone, of which we shall have occasion to speak hereafter.

At Feazier's, 1 mile N.W. from Petersburg, we find the rock only slightly calcareous, and of a grey colour. It is here quarried for a building-stone. A long belt ranges S.W. from this spot, in which, however, it does not appear in place; the hills abound in rounded pebbles similar to those of the rock.

We next meet with the conglomerate in place at John G. Minter's, 2 miles N.N.W. from

Mummasburg, where it has been quarried in the hope of burning it into lime (much in request in this neighbourhood), but it appears to be too silicious, and to contain too little lime.

At Shull's, on the North Branch of Marsh Creek, near the foot of the mountain, three-fourths of a mile N.E. from the Gettysburg and Chambersburg Turnpike, at Cashtown, the conglomerate is exposed on both sides of the stream. It is seen to be 15 or 20 feet thick, and is very similar to that at Minter's. Above this in an orchard, and in the fields nearer the mountain, are loose fragments of from 20 to 50 pounds weight of a limestone which has possibly come from large masses in the conglomerate, though it seems to have a different character, and may more probably have come from some hidden outcrop of the Auroral limestone, which, there is reason to suspect, occurs in several places along the S. side of the mountain, where it is not covered by the Mesozoic deposits.

Crossing the Gettysburg and Chambersburg Turnpike near Cashtown, and still keeping near the foot of the mountain, we find the conglomerate near Fairfield (commonly called *Millerstown*), consisting almost entirely of limestone pebbles. At Gilbaugh's, 1 mile E. from Fairfield, it is in immediate contiguity with a dyke of trap-rock, and is altered to a crystalline limestone. About a quarter of a mile farther N.E., a greenish shale apparently overlies it, and dips about 18° N. Three-fourths of a mile S.W. from this point, on the N. end of the hill S.E. from Fairfield, there is an altered white conglomerate containing large pebbles ; it lies at an elevation of 60 feet above the level of the valley at Fairfield, where the red conglomerate is found unaltered ; but it is nearer the trap. At both of these last localities the rock has been quarried for limestone.

The pretty village of Fairfield is situated in a very level tract of land between the trap ridges on the E. and S.E., and South Mountain on the N.W. and W. Throughout much of this valley the conglomerate prevails, and is generally of a superior kind, equalling perhaps the "Potomac Marble" of Maryland. It also appears on Tom's Creek, South from Fairfield, on the road to Emmettsburg. This rock finally passes between the trap hills to the E. of M'Devitt's mill, and the spurs of the South Mountain, across the Maryland line a little W. of Emmettsburg, though the valley is here so narrow that it is seldom exposed, and much of it has been removed by denudation.

CHAPTER IV.

TRAP DYKES OF THE MESOZOIC BELT, AND ALTERATIONS PRODUCED IN THE STRATA IN CONTACT WITH THEM.

As a detailed specification and description of all the trappean outbursts of the Mesozoic red-sandstone belt would involve much needless repetition, and serve only to fatigue the reader, I shall restrict myself to an enumeration of the more prominently interesting ones, and refer the student to the Geological Map for further information respecting the localities, courses, and relative magnitude of the various dykes.

Beginning at the Delaware and proceeding Westward, the first conspicuous masses of trap which we encounter are the three large dykes which approach the river below New Hope. These are nearly in a line with the outbursts of trap visible on the New Jersey side of the Delaware, and known as Smith's Hill, Belle Monte, and Goat Hill. The most Southern dyke is a long and narrow one, extending from near the little village of Pineville to within a mile of the river; the second is the bolder outburst of Bowman's Hill, and the third the still larger mass of Lackawissa Hill, these two last terminating near the river. The last-named ridge, the extension of Goat Hill of New Jersey, is connected with some extremely interesting phenomena of alteration and segregation in the adjacent strata on both sides of the river. Perhaps none of our trappean dykes disclose these effects so well. The following description of these metamorphic features is taken from my general account of the Geology of the State of New Jersey.* The rock constituting this great dyke is for the most part, especially in the central portions of the dyke, coarsely granular, being composed of large crystals of a yellowish-white felspar, traversed by elongated tabular crystals of green hornblende of considerable size. It bears no remote resemblance to some varieties of sienite.

"Along the N.W. base of this ridge, on both sides of the river, the strata dip as usual, but are affected in a striking manner in their structure and composition for at least a fourth of a mile from the trap. In the quarry N.E. of Lambertsville we discover the commencement of the change. There the red sandstone, varying but little from its ordinary colour, and being only rather more compact, contains a multitude of large spheroidal nodules of pure green *epidote*, many of which are at least an inch in diameter. They seem not to be distributed promiscuously through the rock, but to be arranged somewhat in layers parallel to the planes of the strata, though they are often several inches asunder. Two or three hundred feet nearer to the trap, we find the rock darker and harder, and the number of nodules greatly augmented, though they are generally of much smaller size. The common colour of the rock is here a very dull purplish blue, and that of the included nodules a dull black or a deep blue. They are of all sizes, from minute specks to the dimensions of a large hazel-nut, and possess every shade of distinctness contrasted with the material enclosing them. They seem to consist of some imperfectly-formed mineral, apparently tourmaline in a semi-crystalline state. These spherical nodules or specks are oftentimes surrounded by a crust or coating of another material, usually nearly white; and I have remarked that the more obviously formed this crust appears, the more crystalline or fully developed is the interior kernel, which at this spot seems to approximate in its features to black schorl or tourmaline. A few hundred feet nearer to the trap, or almost at its base, the rock presents a still different aspect, being of a dark-grey hue, and somewhat coarse-grained. It seems to have been a sandstone, containing little or no clay, as it has nothing at all of the baked jaspery texture of that previously described, which has plainly been either a shale or a very argillaceous sandstone. This grey rock is speckled with innumerable small crystals of very regularly formed *tourmalines*, some of which are more than half an inch in diameter. Upon the opposite side of the river, below New Hope, we meet with very nearly the same order of things, except that the rock containing the completely-formed tourmalines is absent.

"In one thin layer of the altered red argillaceous rock on the Pennsylvania side, the mass, which is of a pink hue, contains, blended with the crystallised *epidote*, some minute but perfectly-formed crystals of a mineral, apparently *idocrase*, of a beautiful wine-colour."

* See *Final Report on the Geological Survey of New Jersey*, by H. D. Rogers.

The altered belt here described ranges North-eastward from the river several miles, and has an average width in New Jersey of perhaps a quarter of a mile.

In Tinicum and Nockamixon townships there is an extensive tract towards the N.W. side of the Mesozoic red shale, where this formation is much altered in texture and colour by the presence of a great body of trappean injections. The baked and indurated condition of the rocks has destroyed the capacity usually possessed by the red shales and sandstones to disintegrate into a fertile soil, and the surface of this and all the similar tracts throughout the belt is characterised by cold, wet, and unproductive land. This district, which is several miles in breadth, is known on both sides of the Delaware under the name of the Swamp, from the undrained condition of the soil. It has a general elevation above the river of between 300 and 400 feet, is an undulating and irregular table-land several miles in width, and extends across nearly all the N.W. side of Bucks County. While the metamorphic aspect of the strata is a sufficient demonstration of the near proximity of much igneous rock, only a comparatively small portion of the surface consists of actual trap-rock; and where this material does show itself, it is only occasionally in long and elevated dykes, being oftener in insulated outbursts. One of these latter effusions of the trap is to be seen in the bold elliptical ridge called Haycock Hill, the crest of which is transverse to the more common direction of the dykes, ranging from S.E. to N.W.

A dyke of trap-rock is visible on both sides of the Delaware near Lawry's Island, but some of the injections here seen lose themselves in the cliffs, and do not appear upon the elevated surface of the swamp back from the river.

A careful examination of the natural section exposed at the river will satisfy the observer that the instances of this kind are not unfrequent. It is easy, therefore, to understand why the strata of this whole tract of the Nockamixon Swamp should display such marks of excessive heat, for we are authorised not only to assume the presence of much unseen subterranean igneous matter, but to conceive that, during the rending of the crust and intrusion of the molten trap, much intensely-heated volcanic vapour passed up through the innumerable fissures of the distended and dislocated shale.

Approaching the Schuylkill, we meet with a few short and narrow dykes of trap-rock, but, with the exception of the tracts above referred to, the wide area of Mesozoic rocks embraced between this river and the Delaware is penetrated by scarcely any of these injections. Two or three small dykes occur E. and S.E. of Pottsgrove and the Monokesy Hill, within sight of the turnpike road; and about 6 miles N.W. of that town is a rather copious outburst of this material. South of this section of the Schuylkill, between Pottsgrove and Reading, the red-shale region includes quite a number of short dykes, some of those nearer the river forming the summits of the bold conical hills seen from the river-valley. As all the more conspicuous localities are given in the Geological Map, more special references to the positions of these seem to be unnecessary.

At the mouth of Flying Hill Run, on the Schuylkill, one of these dykes, consisting of very coarsely-crystallised trap, has altered the red shale on the S.E. of it, and the Primal sandstone in contact with it on its N.W. side: these instances of alteration in the rock are very common.

One of the most interesting facts connected with certain of the trap dykes of the district between the Schuylkill and the Susquehanna, is their proximity to extensive beds of a semi-magnetic, semi-hæmatitic iron-ore.

Thus in the neighbourhood of Warwick Iron-mine, 6½ miles E. from Morgantown, there are two or three dykes, the rock being very close-grained.

Another instance is at Jones's Mine, 2 miles from Morgantown, where the deposit of iron-ore, on the margin of the red shale and Matinal limestone, is in close proximity to a regular dyke. But the most striking example of this association of the trap and iron ore is at the great Cornwall Mine, 5 miles S. of Lebanon: this is situated a little within the margin of the red shale, in the line of dykes extending E. from Colebrook. The ore, which occurs here in extraordinary abundance, and in a position uncommonly accessible, is embraced between two parallel walls of trap, where, protected from the action of denuding waters, it occupies the crest of two or three high hills. The presence of so much trap-rock in all the more conspicuous iron-mines of the Mesozoic formation, and the occurrence in each of them of more or less carbonate and sulphuret of copper, so usually associated with the trap, and so indicative of igneous sublimation, all seem to imply some mode of origin for these large deposits of oxide of iron in which igneous or volcanic agency has played a part.

Between Colebrook and the Susquehanna River there ranges the most extensive of all the belts of trap-rock of the red-shale region. The principal dyke forms a rugged undulating ridge known as the Conewago Hills. Its course from Colebrook to Falmouth, where it crosses the river, is nearly from N.E. to S.W., and is therefore not strictly coincident with the strike of the ancient Auroral strata, or floor of the red-shale basin. In this, as in many other instances, therefore, the fused materials were poured out through an actual *rent* obliquely transverse to the strata, and did not rise along the plane of their beds, or even along an anticlinal or synclinal line. The beds of red shale in contact with this dyke are greatly changed in colour, texture, and crystallisation, the total mass, as we approach the trap, being very hard, and graduating from purple to dark blue and greenish black, and acquiring more and more distinctly developed segregations of crystalline green *epidote*.

Northward a few miles from the Conewago trap appear two other conspicuous but shorter dykes: one of these forms the beautiful conical hill called Round Top, the other passes by Rocktown towards the river. The first of these has developed crystals of plumbago in the calcareous conglomerate in contact with it, while that of Rocktown is connected with alterations in the adjacent red shales, precisely analogous to those induced by the Conewago outburst.

Hill Island, in the Susquehanna near Middletown, consists almost wholly of trap-rock, and is nearly in the prolongation of the Rocktown dyke.

A long and slender dyke ranges from a point about one mile S. of Elizabethtown, in a S.S.W. direction to the river, parallel with the general course of Conay Creek. Its N. half is in the red shale, while its S. intersects the Auroral limestone E. of Bainbridge. This dyke crosses the channel of the Susquehanna, and is seen in a little island below the small village of New Holland. Whether the narrow dyke occupying the crest of the ridge penetrated by the tunnel of the Lancaster and Harrisburg Railroad is a portion of this outburst, or an independent injection, is a point we did not satisfactorily determine.

TRAP DYKES WEST OF THE SUSQUEHANNA.

Entering now the third division of the Mesozoic basin, the first trap-dyke W. of the Susquehanna appears upon the shore a little above York Haven. It forms a ridge which ranges nearly N.W., passing Newberry and to the E. of Lewisburg to its termination, in a point near Yellow Breeches Creek 2 miles N.E. of Lisburn. Here it seems to unite with another nearly parallel and conspicuous line of trap-rock, coming from Hill Island and the shore of the river opposite, and which, after following the W. side of the river for nearly 4 miles, sweeps gradually Westward, and joins this first or Southern dyke. These two bold ranges of trap-rock enclose the little red-shale valley of Fishing Creek.

The altered shales and sandstones along the trap ridges contain epidote and micaceous oxide of iron, and the sandstone about Newberry contains in its cross-joints, and of course on the surface of the loose fragments, abundance of micaceous oxide of iron in thin laminæ : some small lumps of iron ore, slightly magnetic, were also found near the town. From the junction of these ridges N.E. of Lisburn, a dyke of trap crosses Yellow Breeches Creek below Grove's fulling-mill into Cumberland County : the altered conglomerate accompanying it has been already described. The trap here is more fine-grained and compact than that of the main ridges on the York County side ; this, however, will be found almost uniformly the case with narrow trap dykes—the rock in the broad ridges being sienitic, having felspar for its base, frequently crystalline, and containing dark and greenish crystals of hornblende, while in the smaller ridges and dykes it is more homogeneous, with a bluish-grey or blackish colour, and is very compact and tough. The dyke here mentioned passes about 2 miles from Lisburn on the N., and appears to terminate at a point about a mile from the creek. On the N. and N.E. of it the Matinal limestone is in place, that portion of it nearest the trap being altered to nearly a pure white sparry rock.

Another dyke runs off S. from the main ridge near Newberry, crossing the Conewago about a mile above Demuth's mill, and passing W. of Strinestown, and probably connecting with the dyke observed in the limestone 1½ miles W. of York. The trap-hills on the W. of Lewisburg are not connected with those on the E. towards Newberry, neither are the shale and sandstone along Bennet's Creek, which runs from Lewisburg S.E., changed from their usual colour and appearance.

About 2 miles S. from Lewisburg, on the right of the road from that place to York, is the most Easterly point of a long trap-ridge, which ranges nearly S.W. from this place, passing near Rosstown, Hampton, New Chester, and so on, S. of Hunterstown ; 2 miles S.E. from Gettysburg it finally crosses the Maryland line, about 3 miles N.E. from Emmettsburg. This ridge is on an average about 1½ miles in breadth, and as the rocks in contiguity with the trap are generally altered in proportion to the mass or thickness of that rock, we find on both sides of this range the metamorphosed shale, extending to a distance about equalling the width of the trap, though this is not uniformly the case.

The trap-rock of the S. ridge is exceedingly uniform in character throughout its whole length ; it is of the coarse or sienitic variety, and is a beautiful and useful material, when artificially dressed, for architectural purposes. A mile S. of Gettysburg we have, on either side of the trap, a dark purplish shale ; but on the W. slope of a hill on the Hanover Road, three-quarters of a mile from Gettysburg, is a belt but a few feet thick, of a lighter colour, exceedingly tough and compact, which contains a little copper with incipient crystals of epidote. About 2½ miles S. of Gettysburg, a little below the turnpike bridge over Rock Creek, is an old quarry in the altered shale S. of the trap, where several varieties of crystallised zeolite are found ; but having been exposed for some time to the weather, the specimens obtained are not so fine as if freshly dug. In a bank on the other side of the stream, zeolite is also found mixed with epidote; the flat tabular masses showing the crystals of the two minerals curiously interlaced. Nearer Gettysburg, and rather on the N. side of the trap ridge, epidote is abundant in the loose fragments scattered about the fields, some of it mixed with crystals of quartz, some of it with bladed crystals of hornblende; other specimens are found, but in small quantity, containing along with the epidote a curiously radiated quartz. It seems to be a general, and doubtless a very natural consequence, attending the trap ridges in this region, that they have altered the shale in their vicinity in proportion to their width on the mass of the trap-rock. Thus we find the broad ridge S. of Gettysburg to have exercised its influence for half a mile at least on the contiguous shale, while the narrow dyke on the W. of the town has only 50 or 60 feet of altered rock accompanying it, as we shall hereafter have occasion to note when speaking of the cuttings on the Gettysburg Railroad.

It has been already observed that the most Easterly point of this S. trap range is about 2 miles S. of Lewisburg, and that it does not cross Bennett's Creek, and connect with the Newberry and York Haven range; on the contrary, it suddenly sweeps round N.W., passing up the course of Stony Run west of Lewisburg, and spreads out into a broad, rough, hilly region, about Stevenson's Mountain, Round Top, Rich Hill, &c. The latter-named hill, however, is only trap-rock on the E. side, the W. being sandstone and shale. From Stevenson's Mountain and the adjacent hills the trap passes in a broad range N. by Siddonstown to Yellow Breeches Creek, about 3½ miles above Lisburn. It does not, however, cross that stream, except in a narrow dyke already noticed, a little E. of Bryson's, on the road from Lisburn to Carlisle. In this trap, on the S. side of the creek, opposite Hursh's mill, we found a heavy, dark, peculiar iron-ore; but it is not to be procured in great quantity. It is immediately on the bank of the creek. From the trap on the S. of Yellow Breeches Creek, N.W. from Siddonstown, a dyke seems to extend S.W., passing a little North of Dillsburg to the S.E. base of South Mountain. Another branch passes from the neighbourhood of Stevenson's Mountain, ranging S. of Dillsburg, and probably connects with the last-mentioned branch near the base of South Mountain, W. of Dillsburg. In fact, the whole region in the vicinity of Dillsburg consists of trap dykes, altered calcareous conglomerate, and shale, with diluvium and low meadow-ground, so mixed as to make the tracing and describing of each accurately a work of more labour than real utility. Passing from Dillsburg, S.W. towards Petersburg (York Springs), we cross obliquely the trap range which runs from the hilly region E. of Dillsburg to the S. base of the South Mountain. About 2 miles from Dillsburg we leave the trap, and half-altered shale for a mile or more, and then pass on to the common red shale, which continues to Petersburg. About 3 miles S.E. from Petersburg, and not far from the junction of Bermudian and Latimore creeks, seems to be the E. termination of another trap range, which, passing S.W. near York Springs, Heidlersburg, &c., nearly touches Gettysburg on the N., and between that town and the Maryland line approaches very near to, if it does not actually connect with, the great range passing S. of Gettysburg. This second trap-ridge does not appear to be so uniform in its development and character as the S. one, being more irregular and interrupted in its course, and presenting coarser and finer varieties in the crystallisation of the rock. Near the Huntingdon Meeting-house, at the E. termination of the range, the rock is sienitic, showing crystals of hornblende imbedded in felspar. On the bank of Bermudian Creek, at York Springs, the trap-rock is seen on both sides of the stream. The spring issues from the low ground in the gap made in the trap-rock by the passage of the creek, and is so little above the level of the stream as to be overflowed by a moderate rise in its waters. A small trap-dyke crosses the turnpike about a mile S. of the springs. The strata to the S. and S.W. of the springs are altered bluish and purplish shales.

The trap formation, which ranges along near the S. base of South Mountain, passes about 2 miles N. of Petersburg, continuing, with some slight interruptions, S.W., passing near the Lutheran Church east of Bermudian Creek, thence along the N. side of Chestnut Hill, crossing Opossum Creek, near Keener's mill, and so continuing nearly the same course to the turnpike which runs from Gettysburg to Mummasburg. Crossing this nearly 3 miles from Gettysburg, it is seen in the cutting on the railroad about 2 miles from Gettysburg, and ranges thence W. of Willoughby Creek, appearing at Moritz's, on the Emmettsburg Road, W. of Marsh Creek, a little S.W. of which it crosses the State line into Maryland. This *third* trap-range, like the second, is much inferior in width, and effect on the neighbouring rocks, to the *first* or Southern ridge.

Associated with this trap, about 4 miles W. of Petersburg, is an iron ore, which was formerly worked by Messrs Duncan and Mahon at Chestnut Grove furnace, a little S. of Whitestown or "Middleton," as marked on the State Map. This ore bank, as well as the furnace, has been for several years abandoned, and all is going to ruin. The diggings have been deep and extensive, but the ore seems not to have been abundant. It is a compact dark ore, approaching the magnetic variety, and has some micaceous iron associated with it. In the ore-bank at the old furnace we found some specimens containing beautiful crystals of octahedral iron. Near Ludwig Group's, between the old furnace and the mines, lumps of micaceous oxide of iron are found in the fields. In the same range E. of Opossum Creek, and N. of Chestnut Hill, at Carson's, it is also found tolerably abundant on the surface. Some small pieces were found near Wilsonville, W. of Opossum Creek.

We come now to speak of a *fourth* range of trap, which seems to lie immediately along the base of the South Mountain, or rather to appear at intervals along the spurs which form the S. flank of that range.

This trap is apparently much more irregular, less continuous, and more frequently interrupted in its course than any of the others, and may more properly be regarded as a series of dykes. It is generally in close contact with the South Mountain rocks. We may suppose it to commence on the N.E., near Whitestown (Middleton), thence extending S.W., and crossing Opossum Creek near Minnich's mill. It appears between Wilson's and Bender's, on the road from Gettysburg to Pine Grove, and again near Griest's and Ellis's, 1½ miles farther S.W. at the foot of the mountain. It is seen on the Conewago below Bell's mill, near the mountain, and forms a considerable hill N. of Mark's mill, on Marsh Creek, 3 miles N.W. from the Gettysburg and Chambersburg Turnpike. In the shale S. of this hill, near Mark's mill, an iron ore is found, which was formerly partially worked by Messrs Paxton and Stevens at Maria Furnace. It is said to have made a good iron, but since the abandonment of the furnace the bank has been neglected, and the diggings have fallen in. Two veins appear to have been wrought about 50 yards apart, and are said to have varied in thickness from 9 inches to 2½ feet, dipping regularly N.W. with the altered shale: some of the ore found near the mill is highly magnetic, readily holding suspended a nail of considerable size. South-west of this spot, the trap of which we were last speaking diverges from the mountain, crossing the South Branch of Marsh Creek, near the turnpike and railroad, passing E. and S.E. of Fairfield (having the conglomerate between it and the mountain), where it forms considerable hills, and so ranging on the Maryland line, it crosses it about 3 miles N.W. from Emmettsburg. Near this trap, at Orr's, between Cashtown and Fairfield, there is a beautiful compact dark magnetic iron-ore, formerly explored to a small extent, but not found to be extensive. The old diggings are filled in.

This trap ridge E. of Fairfield swells out into large hills, and is a mile or more in width; consequently, we find it of the coarser or sienitic variety. It much resembles that of the first or Southern range, and was much used on the railroad for viaducts, being, when dressed, a very beautiful building-stone.

At Welty's, about a mile E. of Fairfield, and a little W. of this range of trap, is a place where some digging was done several years since in search of copper. The overlying rock is an altered shale dipping W. about 50°. Among the rubbish thrown from the old mine we found some green carbonate of copper, mixed with micaceous oxide of iron, and some micaceous iron.

On the E. side of the last-mentioned range of trap hills, near the road from Fairfield to Gettysburg, is a band of the altered shale of a black colour, which, as usual with black slates, has caused some trouble in the neighbourhood in a fruitless search for *coal*.

About 5 miles S.E. from Fairfield, and 1 mile N. from the State line, near Emmettsburg, in the altered shale a quarter of a mile S. from Abraham Eiker's, are large lumps of iron ore, compact and crystallised. Half a mile farther W. some digging has been performed for iron ore, but without success. About a mile S. of this spot are some very old diggings, made beyond the memory of the present inhabitants of the neighbourhood. Micaceous oxide of iron was found among the old rubbish.

The trap dykes and altered rocks of Adams County are well exposed in the cuttings of the Gettysburg Railroad. The first rock-cutting is through the ridge immediately N.W. of the town of Gettysburg—the *second* trap ridge of our previous account.

The following sketch (Fig. 569) will give an idea of the appearance of the rocks in this cutting.

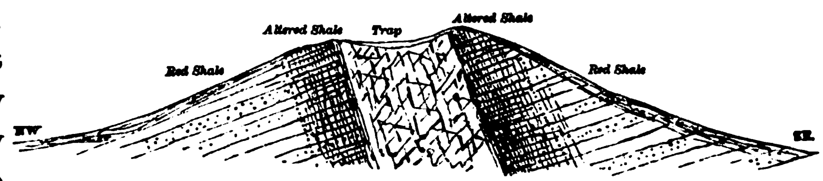


Fig. 569.

The altered shale on the S.E. side of the trap extends about 60 feet from the dyke, gradually changing its colour and quality until it imperceptibly shades into common red shale. The trap-rock is 150 feet wide, and dips 70° S.E.; its true course or strike is N. 12° E. It is much decomposed on both sides, where it is in contact with the shale. The altered rock near the contact with the trap on the N.W. side, like that on the other side, is about 60 feet wide before it resumes its red colour.

There is a thin band of copper-bearing slate in red shale N.W. from the trap-rock.

Between this and the next trap range occur a series of gentle ridges, through all of which the road is cut, showing altered shale in the middle of each ridge, and red shale on either slope towards the intervening embankments across the low grounds between the ridges. This may be caused by a succession of small trap-dykes, which have never reached the surface, but have altered the shale above them. This shale, being thus hardened, and rendered less subject to decomposition, has naturally formed ridges, while the softer red shale, crumbling more readily by atmospheric action, has, in the progress of decomposition and denudation, formed a series of little valleys between.

The third trap-ridge crosses the road about 2 miles from Gettysburg. A calcareous band, 10 inches thick, occurs in the altered rocks contiguous to this ridge. The trap of the third ridge is inferior in width, more jointed and decayed, and also in thinner blocks, than that of the second ridge near Gettysburg. Some asbestos is contained in the joints of this trap; a rough chalcedony was also found in the fissures of the trap-rock, containing the impressions of some cubic crystals, possibly sulphuret of iron.

We meet with a black altered shale 400 yards S.E. of the fourth trap-ridge, which crosses the railroad and turnpike near the gate 3 miles from Gettysburg. South-east from this trap there is a ridge of hard altered rock, in which the cutting is in a very unfinished state, much of the ridge having had none of its rock exposed. The trap-rock lies on the N.W. side of the ridge, and seems to occupy the whole of the low ground between this and the next small ridge near Marsh Creek, where the trap is found on the S.E. side.

Crystals of *zeolite*, &c. are found in the interstices of the trap-rocks. This trap seems to be about half a mile wide, but is only visible at the railroad on its two sides, the middle portion being on low ground where there is an embankment.

Near this place the railroad turns more to the W., and passes through low ground, crossing the turnpike near Marsh Creek, and continuing along the flats near that stream for some distance. A few small cuttings in red shale are seen; but the next cut of any importance is near Biesecker's, not far from the foot of the mountain, and between 3 and 4 miles N. from Fairfield: here a spur of the trap is cut through. This rock seems somewhat laminated or stratified, and dips gently W. The interstices contain several varieties of mineral matter, as zeolite, prehnite, crystals of yellow ferruginous sulphuret of copper, and carbonate of lime.

A single specimen of pale-blue chalcedony was likewise seen.

The next cutting is near Marshall's, one mile farther S.W., in a grey compact silicious rock, which belongs to the Primal sandstone of the South Mountain.

ORGANIC REMAINS AND GEOLOGICAL AGE.

The Red Shale and Sandstone formation of the Atlantic Slope in Pennsylvania has hitherto disclosed but few fossils, but these vestiges of extinct organic life are very significant and interesting. Besides a few rather indistinct impressions of plants, the deposit contains two or three species of crustacean animals, and the remains of two remarkable Saurian reptiles, the *Clepsisaurus Pennsylvaniensis* and *Centemodon Sulcatus*. The crustacean remains belong to two species of the genus *Cypris;* the fossils being minute, flattened, oval, seed-like bodies, not as large as a grain of mustard seed; also two species of the genus *Estherea*, flat, ovoid, shell-like fossils, resembling the *Posidonia minuta*, from which, however, they differ in the markings of the surface, and in the absence of the characteristics of the testaceæ of shell-fish.

The reptilian relics are the teeth and bones of large aquatic lizard-like creatures. The *Clepsisaurus* remains were first discovered in the uppermost layers of the formation near Upper Milford, on the S.E. border of Lehigh County. Their anatomical affinities were investigated and published by Isaac Lea, Esq. of Philadelphia. Subsequently a tooth, referable, if not to the same genus, at least to some allied Thecodont saurian, was found by us at the Phœnixville Tunnel, Montgomery County. Along with this tooth, a figure of which is here presented (see

Fig. 570), specimens of coprolite were found imbedded in the same rock, and subsequently there have been discovered a Saurian bone and a tooth, conjectured by Mr Lea* to be a portion of either the *Clepsisaurus Pennsylvanicus* or the *Centemodon Sulcatus.*

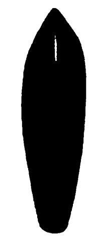


Fig. 570.

It is an interesting circumstance, that while a saurian existed during the deposition of nearly the uppermost or latest member of the formation, there were reptiles in the same waters early after the commencement of it. The vertebral bones of the Clepsisaurus of Lea are slightly concave, or dished, at both their articulating surfaces, and the name has been conferred on the genus in allusion to this hour-glass resemblance.

Much uncertainty has prevailed in the minds of American geologists respecting the precise geological age of this Red Sandstone formation of South-east Pennsylvania. Until twenty years ago, it was conjectured by the late William Maclure, Esq., R. C. Taylor, Esq., and others, on analogies of composition, to represent the Old Red Sandstone of Great Britain; but in 1836, in a report upon the geology of New Jersey, we proved that its date of deposition was certainly later than the upheaval of the Coal-measures in the Appalachian Mountains, and we called it the Mesozoic Red Sandstone, preferring to designate it by its general age rather than assign to it a European name and equivalency in the absence of any significant organic remains.

Professor Hitchcock, in his report on the geology of Massachusetts, regarded the formation as the equivalent of the then so-called New Red Sandstone of England.

In 1842, Professor W. B. Rogers adduced evidence, from a few fossils collected by him in Virginia, for referring it to the age of the European Trias, rather than to that of the older New Red Sandstone, to which it was then generally ascribed. Subsequently † he has presented evidence, from organic remains found in the formation of Virginia and elsewhere, for relating it in time rather with the beginning of the Jurassic period than with the Triassic.

Question of Age.—At the present time the views of geologists respecting the date of this red argillaceous sandstone are still divided, opinion preponderating in favour of a Triassic or Jurassic age rather than of a Permian. To understand the evidence appealed to in favour of the several doctrines entertained, it is necessary for us to go aside and note what has been done in developing the fossils of the other deposits kindred to the one under discussion: I shall as usual proceed from the N.E. to the S.W.

In Prince Edward Island there is a group of red sandstone and red-shale strata, separable apparently into two formations, one on the S. side of the island, imbedding what appear to be true carboniferous plants; the other on the N. side, containing remains of a fossil reptile, *Bathygnathus borealis,* the affinities of which, point to a middle secondary epoch. The basin of Mesozoic strata in Nova Scotia is proved to be of post-Carboniferous age, from its resting unconformably in a trough of carboniferous rocks uptilted at the close of the Coal period. No fossils have yet been discovered in it to indicate its epoch more precisely, but we may conjecture it to be coeval with the red sandstone of the Connecticut Valley, and with that of the Middle States, from the near resemblance of its materials to those of these more Southern belts.

* See Proceedings of Academy of Natural Sciences of Philadelphia, June 2, 1857.

† See Communications to Boston Society of Natural History, by Professor W. B. Rogers, 1854, *et seq.*

RED SANDSTONE OF THE CONNECTICUT VALLEY.

The organic remains of the Connecticut Valley belt are some of them highly curious, and though not decisive as respects the age of the formation, are very suggestive even upon this point. The vegetable fossils are chiefly Cycadites, Lycopodites, Equisetaceæ, and a somewhat characteristic fern, Clathopteris rectiosculus, a large reticulated fern found at Easthampton, Massachusetts.* This Clathopteris is represented in Europe by the *C. Miniscoides*, a characteristic fossil of the Trias, and the Lias or lower Jurassic formations.

Of animal remains, the best defined are several species of fishes, and the foot-prints of reptiles and of many birds. The fossil fishes belong to the family of the Lepidoides. They were at one time referred to the genus Palæoniscus, but one group of them has been placed by J. H. Redfield, Esq., in a new genus, Catopterus; and another group by Sir Philip Egerton in a newly-established genus, Ischypterus, both of them possessing the homocercal or equally-lobed form of tail not seen in any formations older than the Trias.† But the most interesting of all the organic remains in the Connecticut Red Sandstone are the quadruped and biped footprints above referred to. The former, it is believed, were left by different species of lizards, turtles, and frog-like or batrachian reptiles; the latter by various species of wading birds, some of them of very colossal size. Coprolites, or specimens of the dung of these creatures, have also been occasionally met with. The tracks occur at intervals throughout a distance of more than 80 miles, from Turner's Falls, in Massachusetts southward, and are repeated on successive surfaces through a thickness of more than 1000 feet of strata, measuring this by the usual rule of the dip.

This, as will presently appear, does not, however, necessarily prove a subsidence of the bed of the red-sandstone estuary through so great a space. No actual remains of birds recognised as such have hitherto been brought to light; though a few obscure bones, believed to be reptilian, have, it is said, been discovered. As the bird-tracks here spoken of are the earliest vestiges yet met with in any country of this high class of creatures, an especial interest attaches to the determination of the true antiquity of the rocks which contain them. In a recent communication to the American Association for the Advancement of Science (1858), Professor Hitchcock, in presenting a general description, with drawings, of all the foot-marks, tracks, and trails noticed by him imprinted in the Connecticut red sandstone, displayed impressions which he conjectured might have been produced by mammalian animals of the Marsupial family (the tribe including the kangaroos, opossums, and other pouched creatures), but no mammalian bones have been discovered to confirm this interesting suggestion. Among the tracks are some attributable to crustations—viz., to crabs, crawfish, and the like; while there are others so minute and delicate as to imply that they were formed by insects. The non-discovery of the bones of birds amid strata so abundantly marked with bird-like footprints, has been attributed to the floating away of the carcasses of the birds after death by the waters of the estuary upon whose slimy shores the impressions were left, or to their dying and decaying on the dry land. These ingenious suggestions will not apply, however, to the non-appearance of any remains of the reptilians, inferred, from the footprints, to have coexisted with the birds; and we must acknowledge that this

* See description by E. Hitchcock, Junr., in *American Journal of Sciences*, vol. xx. p. 22.

† See paper on the "Relation of the Fossil Fishes of the Sandstone of Connecticut and other Atlantic States to the Liassic and Oolite Periods," by W. C. Redfield, in the *American Journal of Sciences and Arts*, vol. xxii. p. 357.

absence of solid relics where analogy drawn from other formations elsewhere teaches us that we should find them, casts some doubt upon the conjecture that certain of the foot-marks were impressed by either reptiles or mammals.

ORGANIC REMAINS OF THE MAIN RED-SANDSTONE BELT OF THE ATLANTIC SLOPE.

Notwithstanding the great extent of this, the chief Mesozoic deposit of the Atlantic States, stretching almost continuously from the Hudson to South Carolina, the number of fossils hitherto found in it is very scanty.

Of *Plants* it has disclosed fragments referable to *Equisetites*, and probably *Zamites*, besides specimens of coniferous wood, either petrified or in the coaly condition called *Lignite*. These vegetable forms seem to relate the deposit to the Triassic or older Mesozoic epoch.

Among the *Animal* remains are two species of Cypris and two species of Estherea, both genera of crustaceans. These have been met with in different parts of the formation in Pennsylvania, Virginia, and North Carolina, but I am not aware that they have hitherto been detected in the equivalent deposit of the Connecticut valley.

Of *Fishes*, several species of the genus *Catopterus* have been discovered in New Jersey, Virginia, and North Carolina, and three of these have likewise been encountered in the Connecticut Valley belt, associated with one or two others of the same type not yet met with farther S.

Another genus, the *Ischypterus* of Egerton, has also been met with both in the New Jersey extension of the Pennsylvania belt and in the deposit of the Connecticut Valley, adding to the palæontological links which tend to identify in age these two disconnected formations.

Of *Reptiles*, the main formation, or that which alone passes across Pennsylvania, has thus far disclosed the remains of several interesting species; two of these, the *Clepsysaurus Pennsylvanicus* and *C. Leai*, were first discovered, as already intimated, in Pennsylvania; and a species, probably the first named, has been since recognised in the deep river coal-field at North Carolina, nearly a prolongation of the same, by Dr Emmons, who has added several other species of reptiles as belonging to the deposit in North Carolina,—namely, *Rutiodon Carolinensis*, *Palæosaurus Carolinensis*, and *Palæosaurus Sulcatus*. In New Jersey the formation has disclosed the remains of another reptile of the same general structure as the *Clepsisaurus*: it has been named by Mr Lea, who discovered it, the *Centemodon Sulcatus*.

Some of these saurians or lizard-like reptiles of this red-sandstone formation—the *Clepsisaurus*, for example—have been referred to Professor Owen's group of *Thecodont Saurians*, or extinct gigantic lizards, having the inner parapet of the lower jaw almost as high as the outer one, and teeth of a slender compressed conical form, finely saw-toothed on their edges, and closely set in a row between the parapets. A distinctive feature of the teeth is their having the saw-teeth of their margins directed towards the point of the tooth. Much stress has been laid upon these characters, because hitherto they have been restricted to reptilians coming from as low a position in the geological column as the Permian formations. As this is a point bearing directly upon the question of the geological age of the Mesozoic red sandstone, it is important to concentrate upon it as much learned opinion as we can. Now, it is stated by Professor Leidy of Philadelphia, who devotes to the Fossil Osteology of the United States an uncommon share of acuteness, patience, and learning, that the *Clepsisaurus* of Lea found in the rocks of Pennsylvania and

North Carolina "is not properly a Thecodont reptile, but may form the type of a new family, as its teeth are inserted in the jaw by solid conical fangs."* Such mode of insertion is clearly indicated in the teeth procured from the Phœnixville Tunnel. So far, then, as the reptilian remains have a bearing, the question of the geological age of the formation rests very much where it was before their discovery. The removal of the *Clepsisauri* from the *Thecodonts*, like the previous setting aside of the fishes of the formation from the Permian genus *Palæoniscus*, withdraws every Palæozoic link, and leaves us nothing to countervail the evidence of a Triassic or still later date, deducible from the affinities of the other organic remains.

Along with the fossils hitherto discovered at the Phœnixville Tunnel are some scales of ganoid fishes, and remains of bones and teeth conjectured by Dr Leidy to be batrachian.

FOSSILS OF THE MESOZOIC BELTS OF VIRGINIA AND NORTH CAROLINA.

Confining our attention, in the first place, to the most Western of the three Mesozoic deposits of the Atlantic Slope of Virginia and North Carolina, as being the belt which is most evidently the representative of the red-sandstone tract of Pennsylvania, and looking at its distinctive fossils, we find the plants to resemble very nearly those of the carbonaceous deposits of Whitby and Scarborough, in Yorkshire, near the base of the English Oolitic or Jurassic series. Among the forms of fossil vegetation are a species of Zamite and the *Equisetum Columnari*. Besides these plants, the formation contains two species of *Estherea*, formerly regarded as *Posidonomya*, and two of Cypris, one smooth, the other beautifully granulated. One of the *Esthereas* resembles closely the *Posidonomya Brownii* of the European *Lias*. According to Professor W. B. Rogers,† who has devoted much attention to the Mesozoic Fauna of the United States, these fossils are all to be met with in the middle and Eastern or coal-bearing belts of the same district in Virginia and North Carolina; and as the more complete series of fossils of these last-named deposits implies an old Jurassic date, he is disposed to regard the main or W. belt as of that age likewise.

Dr Emmons, the able State Geologist of North Carolina, in his recent Geological Report on the Midland Counties (1856), gives a full account of the organic remains discovered by him in the Mesozoic rocks of the Deep and Dan rivers. He conceives that these deposits embrace strata of two distinct periods: a lower series, consisting of conglomerate, red sandstone, coal, and fire-clay, calcareous and bituminous shales and drab-coloured sandstones, equivalent to the *Permian* of Europe; and a conglomerate, a blue slate with coal and fossil plants, and red sandstones and marls equivalent to the European Triassic. In the lower he finds various forms of vegetation—namely, several species of *Fucoids*, or sea-weeds, chiefly of the genus *Chondrites*, and *Equisetum*, the *E. columnaroides*, some *Lycopodiaceæ* or *Club-mosses*, and two or three species of *Ferns*. Among the *Animal* remains are one species of *Cypris* in great abundance, and an *Estherea* or *Posidonomya*. He states that the remains of fishes, chiefly small shining rhombic scales of the ganoid type, are numerous in the black bituminous slates. They seem to belong to the genus Catopterus; but the most remarkable of his discoveries are the relics of several reptiles, a *Clepsisaurus Pennsylvanicus*, *Rutiodon Carolinensis*, *Palæosaurus Carolinensis*, and *Palæosaurus Sulcatus*.

* See Proceedings of the Society of Natural Sciences of Philadelphia, June 9, 1857.

† See Communication to the Boston Natural History Society, 1854.

In the upper group, or the argillaceous blue slates of imputed Triassic age, Professor Emmons has found an equally interesting series of organic remains. Of ferns he describes several species, as *Tæniopteris, Strangeritis obliquus, Pecopteris Whitbyensis,* and others. He shows two new species of Cycadites and two *Zamites,* one of them, the *Z. obtusifolius,* a characteristic plant of the Richmond Coal-field, and two new species of *Podo-Zamites:* besides these are several Lycopodiaceæ and Equisetaceæ, and two species of Sphenoglossum. Among the *Animal* remains are two species of Posidonia or Estherea, and a tibea of a Saurian reptile.

Since the publication of the *Geological Report of North Carolina* in 1856, Professor Emmons has discovered the remains of an insectivorous mammalian animal in the older or supposed *Permian* group of the Deep River Coal-field. According to Dr Leidy,* this mammal, the *Dromotherium sylvestre,* is closely allied to the *Spalacotherium* of Owen, a fossil of the English Purbeck limestone of the oolitic series. This analogy, and the decision previously reached, that the reptiles are not of the Thecodont type, seem to argue against the opinion that some of the Mesozoic rocks of North Carolina are of the *Permian* age. All the evidence from organic remains appears to tend to the conclusion that they were formed late in the Triassic or late in the Jurassic periods. Confirmatory of the testimony derived from the entire absence of any well-authenticated Permian fossils is the evidence from stratification. This exhibits not merely a total absence of a physical division of the series by a break of sequence in the deposits, but the existence of one remarkably homogeneous group, as the description of the several members already cited will clearly show.

For the purpose of correlating more clearly the several Mesozoic deposits of New England and the Middle and Southern States, let us here briefly link them together by the organic remains which they are found to possess in common :—

The main belt of New Jersey, Pennsylvania, and Virginia, and that of the Connecticut Valley belt,	Are identified in time by their both containing the same footprints of birds, &c. ; and the same species of fish,—viz. of Catopterus.
The main belt of Virginia and that of the coal-bearing rocks of Henrico and Chesterfield counties of the same State,	Are linked together by apparently the same species of Cypridæ and Estherea, and by the same plants.
The main belt in North Carolina, that of the Dan River, and the coal-bearing strata of the Deep River of the same State,	Are related by several identical species of plants and animals.

Thus the whole of this long chain of deposits reposing unconformably upon the upturned edges of the Metamorphic and Palæozoic formations of the Atlantic Slope, are to be regarded as very closely approximated, if not identified in time, by the possession in common of important distinctive fossil remains, to be met with nowhere else among the American rocks, but represented in European strata, in part by the self-same species, in part by nearly-related analogies.

These strata are placed in parallelism with the middle Mesozoic formations of Europe—the upper Triassic and lower Jurassic rocks—not merely through the few European species which they possess, but quite as obviously by the general aspect or *facies* of nearly all the organic remains which they have hitherto disclosed. Every year is adding to this list, and, as they multiply, the impression produced leans more and more towards the conviction that they were created in the period which unites the Triassic and Jurassic ages.

* See Proceedings of Academy of Natural Science of Philadelphia, June 9, 1857.

PART IV.

IGNEOUS ROCKS AND MINERALS, VEINS AND ORES.

No portion of the Atlantic States, of equal area with Pennsylvania, contains so small an amount of igneous or unstratified crystalline rocks. Even the Atlantic Slope, the metamorphic and crystalline zone of the country, is within this State unusually free from these once molten and intrusive materials, being occupied, to a far larger extent than in the districts to the N.E. and S.W., by sedimentary strata, which have escaped metamorphism. Excepting one solitary narrow dyke of trap-rock crossing Cumberland County, there is a total absence of injected rock anywhere to the N.W. of South Mountain, or the first range of the Appalachian Chain; and even within this range, which in New Jersey and New York on the one side, and Maryland and Virginia on the other, abounds in mineral veins and dykes, the amount of genuine Plutonic matter is comparatively small. Between the South Mountain and tide-water, or within what I have termed the Atlantic Slope, the chief outbursts of igneous matter are the numerous dykes and outpours of basaltic trap-rock of the Mesozoic Red Sandstone zone, which have been already described in the chapters upon that formation. The other mineral injections of the district, or those which have invaded the strata—metamorphic and unaltered—which are not covered by the red sandstone, are the dykes and veins of granite and greenstone, confined principally to the gneissic belts, and certain veins or lodes of complex composition, interesting for the metalliferous ores and crystalline minerals which distinguish them. I propose to offer in this place some account of these several classes of injections.

Granitic Dykes.—As already mentioned in the earlier chapters of Book I., the S. zones of gneiss include numerous small dykes and veins of granite. This rock is nowhere seen in sufficient mass to constitute a feature in the scenery, or indeed to make itself recognised in other than minute fragments. In the lower part of the State, especially in Philadelphia and Delaware counties, the prevailing character of the rock is that of a triple mixture of very coarsely crystallised felspar, quartz, and mica; the felspar greatly preponderating, and being very generally in a state of more or less advanced decomposition, passing in some cases into kaolin. Those parts of the gneissic districts which exhibit that formation disintegrated to a greater or less depth below the soil, present the granitic veins rotted and softened to fully as great an extent: this circumstance makes the detection of the granite usually an easy affair, as it is betrayed by the coarse flakes of indestructible mica, and the white decomposing felspar usually contained in the otherwise grey soil of the surrounding gneiss.

The granitic veins observe no very constant direction, though their prevailing strike conforms to that of the metamorphic strata which enclose them. On the banks of the Schuylkill the granite may be seen in many instances to ramify and expire within the gneiss rock, partly intersecting it, and partly conforming to its contortions: it occurs, though much more seldom, in the form of regular dykes or veins of considerable length and thickness, having parallel walls. The few conspicuous injections of this class, such as that which crosses the Wissahicon below Middleton's, have been already specified. A different class of granitic dykes from those bordering the Schuylkill occurs in the S. part of Delaware County. The rock is not so truly a granite as a sienite, for it contains little or no mica, and consists of a vitreous felspar (its chief component), a little quartz, and a little hornblende. This rock appears in wide dykes, which increase in magnitude and frequency as we trace them into the State of Delaware, where the material has long been quarried as a rough building-stone.

Greenstone.—Greenstone trap-rock occurs occasionally in narrow dykes in the metamorphic districts both S. and N. of the Chester County Valley, but these igneous outbursts are invariably slender and obscure. Some of the chief ones have been described in the previous text, and a second detailed reference to them would be superfluous. It is worthy of note, however, that these injections not only intersect the older metamorphic strata of the belts S. and N. of the Montgomery and Chester Valley, but they cut the Palæozoic strata—Primal slates and Auroral limestone—of that tract likewise; whereas the dykes or veins of the granite are never seen within the limestone, or indeed anywhere outside of the belts of typical gneiss rock. We might hence infer, if this observation is correct, that the granite was intruded at a decidedly more ancient date than the greenstone. There is some reason, nevertheless, to doubt the accuracy of this generalisation; for, as already shown in Book I. Chapter II., dykes of rotten granite occur in the middle zone of gneiss, near the Yellow Springs, in immediate contact with red sandstone and iron ore, under circumstances which imply their intrusion to have been later than the deposition of the Mesozoic formation, since they seem to occupy dislocations which involve insulated patches of that formation.

The other classes of intrusive matter to be met with in the metamorphic zone of the State—as the dykes of serpentine of Chester County, and the metalliferous lodes of the same county and of Berks and other districts—have been either already treated of in detail, or are presently to receive a special description; they consequently do not demand any more particular mention here. We will therefore proceed to a detailed account of such of the more interesting veins and localities of crystalline minerals as remain undescribed.

MINERAL VEINS OF THE PICKERING CREEK VALLEY, NEAR PHŒNIXVILLE.

We will first direct our attention to the interesting group of metalliferous injections which occupies a narrow district N. of the great Limestone Valley, and extends E. and W. of the Schuylkill for a few miles, from the neighbourhood of Charlestown Village, in the valley of Pickering Creek, to the Perkiomen Mines in Montgomery County.

GEOLOGICAL RELATIONS OF THE MINERAL VEINS.

It will be seen, upon consulting the map of the mining district of Montgomery and Chester counties, that the metalliferous lodes or veins extending from the Perkiomen Mines in Montgomery County to the Charlestown Mines in Chester County, occur not far from the boundary which separates the gneissic rocks of this region from the Middle Secondary formation of red shale and sandstone. Some of them would seem to lie entirely in the one set of strata, and some of them in the other; while others again, especially the interesting group of the Pickering Creek Veins—on the economical prospects of which I propose to venture some opinions—are partly within the gneiss and partly within the red shale, penetrating the latter, however, to apparently a trivial extent. It would seem to be a pretty general fact, that such of these veins as are confined entirely or chiefly to the gneiss bear *lead* as their principal metal, whereas those which are included solely within the red shale are characterised by containing the ores of *copper*. But the *zinc* ores, viz. zinc-blende and calamine, prevail in greater or less proportions in both sets of veins, existing, perhaps, in a rather larger relative amount in the copper-bearing lodes of the red shale. Thus the Perkiomen and Ecton Lode, the United Mine Lode, the Shannonville South Lode, a small lode on French Creek, a lode at Port Kennedy, and the Morris Lode near Phœnixville, are genuine *copper* veins, and they are all, without exception, in the Red-shale formation.

On the other hand, the Wheatley and Brookdale Lode, the Chester County Lode, the Montgomery Lode, and the Charlestown Lode, with other adjoining ones of the same group at present more imperfectly developed, all lying within the gneissic rocks, or if extending into the Red shale not explored beyond its mere margin, are equally genuine *lead* veins. This interesting general fact is not presented, however, as an invariable law, unattended by exceptions, for it must be observed that several of the lead veins of the gneiss actually enter the red shale; two of them, the Wheatley and the Chester County Lodes, carrying their ores of lead and the usually accompanying vein-stones into this rock, while some of the others enumerated are traceable still farther within its boundary by their characteristic surface-fragments. Nevertheless, in all these cases the red-shale formation which they penetrate is a very thin and superficial capping, or unconformable covering to the gneissic strata, within which, even here, the chief body of the veins must be contained below this shallow depth. Thus, even in these instances, the exceptions to the rule are more apparent than real. But partial deviations from the law, of another sort, are met with; some of the lead veins of the gneissic strata contain traces more or less abundant of the ores of copper, and, more strikingly, very considerable proportions of lead ore are occasionally associated with the copper ores, in the copper veins of the red shale, especially in the lodes of the Ecton and United mines. Yet even in these last-mentioned instances, which are the most conspicuous exceptions to the general rule hitherto brought to light in the district, the proportions of lead ore to copper ore are quite subordinate, when estimated for each entire lode.

The *gneissic strata* of the tract embracing this group of lead-bearing veins seem to differ in no essential features from the rest of the formation ranging E. and W. through this belt of country. Here, as elsewhere, they consist chiefly of soft, thinly-bedded micaceous gneiss, a more dense and ferruginous hornblendic gneiss, and a thicker-bedded granitic gneiss, composed not unfrequently of little else than the two minerals, quartz and felspar.

A soft, white, and partially-decomposed granite is a very frequent associate of the stronger lead-bearing veins, particularly in their more productive portions; but this material belongs, in all probability, not to the ancient granitic injections of the gneiss, but to those much later metalliferous intrusions which filled long parallel rents in that formation with the lead ores and their associated minerals. It appears to be, in fact, of the same date of origin with these metalliferous lodes, and may be viewed as derived in part or altogether from the fusion of the intersected gneiss, by the intensely hot mineral matter of the vein brought into close contact with the walls of the fissure. The melted constituents of the gneiss have thus floated up along the sides of the true vein, and re-crystallised, upon cooling, in chief abundance upon the exterior of the lode. Soft granitic matter of this sort very frequently adjoins the hanging walls of the less steeply pitching lodes of magnetic iron-ore in New Jersey and New York; and it would naturally tend to place itself in this position, from its superior lightness compared with the metallic matters.

The gneissic strata and their granitic injections throughout this district, display a softened, partially decomposed condition, extending in many places to a depth of several fathoms. This rotted state does not, however, pervade these materials to as great a depth as it does in the belt of gneiss lying S. of the Chester County Valley and nearer the level of the tide. To its influence we must impute the fertility of the soils resting on the formation, and the soft lines of the landscape. Its origin is due, in part, at least, I think, to the action of the sea-water, which once evidently rested over all this S. edge of the low Atlantic slope of the country, dissolving by chemical forces the more soluble ingredients of the felspar, hornblende, and mica.

Immediately adjoining some of the mineral veins at the Wheatley and Chester County lodes, the gneiss is softened and decomposed to a very considerable depth, and, in some places, in a very thorough manner; the more micaceous beds being converted into a crumbling, purplish-red, unctuous, and clayey material, easily crushed in the hand, though taken from a depth of many fathoms. This condition, which has much facilitated the cutting of the upper adits of these lodes, is the result, in all probability, of a chemical influence exerted on the materials of the strata by some of the elements which belong to the veins, or which passed up through the fissures they fill at the time of their injection. Highly-heated steam and other volcanic vapours have manifestly been the agents of many of the changes we witness in the walls of our igneous veins. At the same time, it must be borne in mind that, near the surface, the penetration of external water and its carbonic acid, and free oxygen along the sides of the lodes, may have assisted this decomposition; and there can be no doubt that these elements, thus introduced, by leading to chemical changes and replacements in the constituents of the lodes, have caused the formation of several of the minerals we find—the carbonates and sulphates, for example, which are usually met with in the cavities and nests of the veins.

The dip of the gneiss throughout this district is generally about S. 20° E., and seldom at any high angle, the most common being 30°—40°; but this direction and inclination are, in some cases, much affected by contact with the veins. These *cut* or intersect the beds of the gneiss, both in strike and dip, even where they seem, by the violence of the disruption at the formation of the vein, to have twisted the strata from their ordinary bearings. This intersection or cutting shows these to be true lodes.

Of the *general relations of the mineral veins* of the district to each other, enough is already known to convince us that these lodes are physically associated as members of one natural group of igneous injections, indicating that this is a genuine mineral region, and that the distribution of its metallic wealth is controlled by definite and ascertainable laws.

Of the one dozen or more lead and copper lodes of greater or less size brought to light in this quite limited region of five or six miles length, and two or three miles breadth, the greater number are remarkably similar in their course, ranging N. 32°—35° E., and S. 32°—35° W.; and what is equally worthy of note, they dip, with scarcely an exception, towards the same quarter, or S.E., though in some instances so steeply as to approach the perpendicular. Those which do not observe this direction, seem, as far as traced, to range N. 52°—54° E. and S. 52°—54° W., and by their mutual parallelism to each other, to constitute, as it were, a second subordinate group or system of veins. There are one or two other lodes, such as the *counter-lode* of the United Mine, which range at even a less angle to the meridian than the first or principal set, namely, about N. 26° E.

The point of chief interest is the wonderfully close parallelism of the more numerous group embracing the larger and more promising veins of the district.

There is no marked difference in the general character of the vein-stones of the several mineral lodes, nor any features to distinguish as a class those of the red shale from those of the gneiss, nor, again, those observing the normal direction of N. 34° E. from those of the more exceptional direction of N. 53° E. Yet each vein possesses certain special subordinate characteristics in both its non-metallic minerals and its ores, and even in its surface vein-stones and gossans, by which the initiated observer may recognise its individuality.

The predominant material in all these lodes is quartz, then sulphuret of iron; next to this, perhaps, the sulphate of baryta, though this is a much more variable ingredient, being scarcely seen in the Wheatley and Chester County veins, while in others, as in the Charlestown, Morris, and the United mines, it is in great abundance: besides, these, there occur frequently the materials of the walls of the veins, but in a more or less altered condition; such are the soft, white, felspathic granites in some of the lead-veins, conspicuous, for example, in parts of the Wheatley Mine, and the altered shale and sandstone fragments involved with the ore in the Morris Lode. These veins are recognised and traced on their "backs" or outcrops by fragments of indestructible vein-stones, chiefly cellular quartz and sulphate of baryta, and by their gossans, or masses of pulverulent oxide of iron and ochreous earth, interlaced with quartz, or filling cavities in the lumps of this mineral, and still more definitely by the presence of the metallic ores, sometimes well preserved in the cavities, or in the body of these fragments, or oftener only in stains and surface-coatings of the phosphate of lead or the carbonate of copper.

The different lodes differ more, perhaps, in the amount and distinctness of the gossan which they show on their backs and in their higher levels, than in almost any other particulars. In this excellent indication of a good and remunerative metalliferous vein—an abundance of soft brown gossan—perhaps none of the lodes of the region will compare with that of the Wheatley Mine. This material, the product evidently of the decomposition of the sulphuret of iron of the vein, often contains, in this Wheatley Lode, especially at some depth below the surface, a very appreciable trace of silver, derived, most probably, from the decomposition of argentiferous galena, which is one of the characteristic ores of the vein. Sundry assays of its gossans show an average proportion of about ten ounces of silver to a ton of the material.

The metalliferous and other minerals found in these veins form quite a numerous list.

Selecting the Wheatley Lode, as presenting perhaps the greatest diversity of species, and as that which has received altogether the closest study, we find the mineralogy of these veins represented by the following large and interesting catalogue: Sulphate of Lead, Carbonate of Lead, Phosphate of Lead, Arseniate of Lead, Molybdate of Lead, Chromate of Lead, Chromo-molybdate of Lead, Arsenio-phosphate of Lead, Sulphuret of Lead, Antimonial Sulphuret of Lead and Silver, Sulphuret of Zinc, Carbonate of Zinc, Silicate of Zinc, Sulphuret of Copper, Green Malachite, Blue Malachite, Black Oxide of Copper, Native Copper, Oxide of Manganese, Native Sulphur, Native Silver, Quartz, Cellular Quartz, Oxide of Iron containing Silver, Hæmatite Iron, Brown Spar, Sulphate of Barytes, Iron Pyrites, and two or three other species.

THE WHEATLEY LODE AND ITS MINES.

A prolongation of the Wheatley Vein, entitled the "Brookdale Lode," is really but the extension of the first-named vein, as is apparent from its lying precisely in its course, the line connecting them not deviating, in fact, the amount of half a degree in a distance from the N.E. end of the Wheatley levels, of more than 3000 feet to the engine-shaft on the back of the Brookdale portion. It is furthermore confirmed by the correspondence in the direction of the dip of the two veins, but especially by the close agreement, amounting to identity, between the vein-stones and ores of the respective lodes.

This remarkably regular silver-lead vein, already one of the most extensive, as respects its developed length, in the country, has been opened and mined at intervals along a range of about 3072 feet. It is first approached from near the water-level, from the S.W. side of Pickering Creek by an adit cross-cut of 410 feet through the Red shale; the distance from this point, where the adit turns into the lode to the cross-cut leading from the vein to the main or engine shaft, is 540 feet; thence along the vein to the most Western point now reached in the Wheatley Mine, which is, in the 10-fathom level, 571 feet,—making a total length here wrought, to the date of the 1st of May 1853, of 1111 feet. The main adit-level, including the part in the red shale, is 1279 feet long.

Between the Wheatley and Brookdale engine-shafts, the distance on the lode is 2076 feet, and at the Brookdale Mine the lode has been opened by an adit-level a farther length of 456 feet,—making in all, the developed length already specified of 3072 feet. That the lode is prolonged several hundred feet beyond the present termination of the adit of the Brookdale Mine, is evident to any careful observer; for the surface is marked, in the vicinity of the course of the vein for this space, by lumps of cellular quartz, containing the well-known gossan of the vein, and its distinctive ores and minerals. It is certainly an encouraging feature in the vein that it thus so well preserves all its characters over so considerable a length. Although there intervenes a space of about 1501 feet between the S.W. workings of the Wheatley Mine and the N.E. openings of the Brookdale, within which the lode has not yet been sought for nor proved, there cannot be much doubt that it maintains itself continuously through this interval, and is a regular persistent vein.

In width this vein varies from 1 foot to 2 or 2½ feet, its average size in the Wheatley Mine being about 18 inches, and in the Brookdale adit nearly 2 feet. Thus far it gives all the indications of being about as productive in ore in the latter mine, at an equal depth, as it is in the former. While the Brookdale end is somewhat thicker than the other, it is rather more full of quartz; yet the adit there, which is only some 30 feet below the surface, and is at present rather more than 456 feet long, presents, for 400 feet, what miners would call a "kindly lode for ore," with quartz, gossan, phosphate of lead, carbonate of lead, and galena, growing somewhat poorer, however, farther towards the S.W. end. The Brookdale shaft, descending on the lode, is only 75 feet deep as yet, but the lode seems gradually to improve as the sinking advances.*

The dip of the lode in the Wheatley Mine is about 2½ feet to the fathom, or 68°; while it is steeper in the Brookdale end, being there about 18 inches per fathom, or 76°. Its mineralogical characters have been sufficiently described already, when alluding to it as the type of the more promising lead-bearing lodes of this district. It may be well enough, however, in this place, to call attention to what has been said under the head of "General Remarks" upon these veins, respecting the prevalence of a soft felspathic granite on its walls, a soft rich gossan in its upper levels containing silver, and the gradual reduction in the proportion of the phosphate and carbonate of lead, with a corresponding increase of that of the galena in descending from level to level in the Wheatley Mine. This last fact, showing a progressive replacement of the more easily vapourised ores—condensable only in the upper cooler parts of the vein—by other ores requiring a higher heat to sublime them, gives us, as already intimated in a former statement, a right to anticipate a somewhat further augmentation in the quantity of galena as the mine descends. By indicating the energy of the igneous action which attended the injection of the metalliferous materials in the fissure, these more readily sublimated compounds are in themselves an assurance of the probable permanency and constancy in size of the lode. That this vein is the product of true igneous or volcanic agency from a deep source within the earth, is not only clearly implied by all that has been here stated of its geological and mineralogical features, but is plainly demonstrated by the occurrence of pure volcanic or crystalline sulphur in the cavities of the less compact masses of the galena or sulphuret of lead. Were a conclusive proof of an igneous origin really needed, it would be furnished, I conceive, by this interesting fact. Other and equally striking evidences of the force with which the vein was injected will present themselves in the cross courses of trap-rock, intersected and displaced by the lode. To the description of these I now proceed.

TRAP DYKES OF THE WHEATLEY LODE.

Throughout this mineral district, and indeed extensively over all this part of Pennsylvania, the strata are intersected by dykes or injections of all dimensions, chiefly narrow ones, of a fine-grained bluish trap-rock. These seem to observe one prevailing course, at least a general E. and W. direction of the principal ones has been detected by me. They traverse equally the oldest strata of the region, the gneiss, and the ancient palæozoic limestone of the Chester County Valley, and the newest formation in the district, the Middle Secondary or Red shale and sandstone. It is thus manifest that some at least of these igneous injections are of a date subsequent to the deposition of the red sandstone, and it is highly probable that even many of those included within this tract of the oldest rocks are of the same relatively recent age; yet we have in the Wheatley and Brookdale Lode, which cuts no less than three of these small dykes of trap-rock, the interesting proofs that this lead-bearing vein, and, by analogy, the other metalliferous lodes, are of a date even somewhat more modern. These would appear to be, in fact, the newest of the igneous injections of any sort encountered in all this Atlantic portion of the continent. Their precise geological age is not susceptible of any closer limitation than a date subsequent to that of the formation of the red sandstone, and prior to that of the cretaceous deposits which, in New Jersey, overlap this red sandstone and its trap dykes unconformably, and which, from their embracing no mineral veins whatever, have very evidently been laid down after these I have now described were injected. They may possibly belong either to the epoch of disturbance which attended the elevation and close of the oolitic coal deposit of Virginia and North Carolina, or that other period, of a far greater and wider movement, which shifted the shores and interior basin of the continent, immediately before the vast cretaceous formation commenced its long term of sedimentary accumulation.

* At date of August 1, 1853, the shaft was down 110 feet; and a level, at 90 feet depth and 20 fathoms long, exhibited a much richer condition than the adit-level above.

THE TRAP DYKES IN THE WHEATLEY LODE.

Dyke No. 1.—From the engine-shaft cross-cut, S.W. in the 10-fathom level 399 feet, there is a trap dyke (No. 1) ending against the lode on its N.W. side or foot wall; it is about 3½ feet thick, its course is E. and W., and it dips N. about 18 inches per fathom. Between this N. part of the dyke and its S. half, which abuts in like manner against the S.E. side or hanging wall, there is a space of 56 feet. This has the same course, but its dip N. is not more than 12 or 15 inches per fathom.

Dyke No. 2.—There is another smaller dyke composed of close-grained trap; it also abuts against the lode on its N.W. side about 93 feet from the S.W. half of dyke No. 1, or 555 feet from the engine-shaft cross-cut. This dyke is about one foot thick; its course is about N. 70° W., and it dips almost perpendicularly. The other part of this dyke meets the lode on its S.E. or opposite side, at a distance of 18 feet, presenting the same nearly vertical dip, and holding about the same thickness as its counterpart.

Dyke No. 3.—Another dyke, 3 feet or more in thickness, occurs at a distance of 30 feet from the S.E. half of dyke No. 2. As this lode has not yet been driven on this level beyond the dyke, or even entirely through it, it is not possible to state definitely its dimensions, or even its course and dip, though the latter appears to be N., like the other two dykes above described. It would seem to be heaved, but to what extent remains to be seen hereafter.

Adverting to the very different distances to which the two dykes, Nos. 1 and 2, are heaved in this level—viz., 56 feet and 18 feet respectively—it is obvious that the displacement of these divided portions cannot be the result of an exclusively horizontal movement of the walls or cheeks of the fissure filled by the lode, but must be due, in part at least, to a vertical dislocation or shifting. The conditions of the case seem plainly to indicate that the throw of the N.W. side of the fissure has been upward and forward towards the N.E., or that of the S.E. side downward and backward towards the S.W. The exact direction and amount of this oblique displacement of the walls of the lode cannot be computed from the limited data at present furnished by the mine. It seems, however, to have amounted to at least some 3 fathoms in a horizontal direction, and to not less than 12 or 15 fathoms in a vertical one. So heavy a dislocation or throw, when viewed in connection with the great length of the vein, is certainly a very encouraging feature; for it is plain that a crack, whose sides have been so much displaced, cannot pinch itself to very small dimensions, but must remain the same open well-defined fissure which we see it in the mine for a great depth beneath the present workings. Thus the trap dykes, or cross courses, by disclosing to us an extensive displacement of the cheeks of the vein, confirm in an interesting manner the inferences already derivable from the lode itself, that, compared with the others of its district, it is an injection of mineral matter of more than ordinary regularity, extent, and richness.

EXTENT AND CONDITION OF THE WHEATLEY MINE IN 1853.

The Adit-Level.—The adit or water-level lies at an average depth beneath the surface of about 8 fathoms. Its total length is 1279 feet. Of this space, 410 feet are through red shale from the adit mouth to the lode. From this oblique cross-cut it is 540 feet along the lode to the short cross-cut at the engine-shaft. Thence to the W. whim-shaft it is 194 feet, and beyond this the adit extends 135 feet farther.

The 10-*Fathom Level.*—This level has a total length at the present date, May 1, 1853, of 935 feet from the end of the engine-shaft cross-cut to its present S.W. terminus. It has now been driven 604 feet; and from the same point to its N.E. end it is 331 feet long. It extends, therefore, about 275 feet past the S.W. end of the adit-level.

The 20-*Fathom Level.*—Up to the same date, the 1st of May, this level had been driven S.W. from the engine-shaft cross-cut 465 feet, and N.E. from the same point about 95 feet, being a total length of 560 feet.

Of the Shafts and Winzes.—There are five external shafts and six shorter interior ones—called Winzes by miners—connecting the different levels.

The Engine-Shaft.—The main shaft of the mine, by which all the water is lifted, and a portion of the ore also, has a present depth of 234 feet. It is perpendicular, and enters the gneiss rocks at a point 122 feet S.E. from the lode at the surface. At the adit-level, its distance from the lode, in consequence of this being nearly perpendicular in its upper portion, is still 120 feet; opposite the 10-fathom level its distance is 103 feet, and at the 20-fathom level the space is 76 feet. On the assumption that the present very regular rate of dip of the lode will continue, the shaft will be off from the 30-fathom level—not yet quite reached—about 51 feet, and 26 feet from the 40-fathom, and only 1 foot from the 50-fathom level, a little beneath which it will enter the lode. This shaft is, in regular-dipping gneissic strata, penetrated here and there with injections of granite and sienite.

The S.W. Whim-Shaft, 194 feet S.W. from the engine-shaft, descends in the lode, and has a depth of 174 feet.

The N.E. Whim-Shaft, 311 feet from the engine-shaft, is not in the lode, but in the gneiss rocks, and is so placed that it will cut the lode at the 20-fathom level. Its present depth is about 100 feet.

The Two Adit-Shafts meet the lode at the adit-level, and are only for ventilation. They both are to the N.E. of the engine-shaft: the *first* at 201 feet from it, with a depth of 57 feet; the *second* at 530 feet from it, having a depth of 40 feet.

Of the Winzes within the mine, there are two which descend from the adit-level to the 10-fathom level; one of them situated to the N.E. of the engine-shaft cross-cut, and the other to the S.W. of it.

The other four descend from the 10-fathom level to the 20-fathom level; and of these, one is N.E. of the engine-shaft cross-cut; one lies between this cross-cut and the W. whim-shaft, while the remaining two are to the S.W. of this whim-shaft.

Note.—Subsequently the 10-fathom level has been extended 72 feet, and the 20-fathom level 168 feet.

PRODUCT OF THE MINE IN ORE.

I will now present some notes of the past productiveness of the mine, with my views of its prospective yield.

Good ore has been extracted in stoppings even between the surface and the adit-level: for example, near the engine-shaft cross-cut, for a length of about 40 feet. In the next lift, or between the adit-level and the 10-fathom level, the mine has yielded good ore in three several stoppings: one, N.E. of the engine cross-cut, 40 feet long and 30 feet high; another, just S.W. of the cross-cut, 80 feet long and nearly up to the adit-level, or about 55 feet high; while the third or largest was both N.E. and S.W. of the W. whim-shaft, and had a length of 214 feet, and an average height of some 36 feet.

In addition to this portion already taken out, I would observe that there was in 1853 a mass of ore still above the 10-fathom level, at its extreme W. end, some 35 feet in length.

Between the 10-fathom and the 20-fathom levels there has been very little ore removed as yet, the chief piece of stopping being a little S.W. of the engine-shaft cross-cut. Another mass, about 50 feet long and only 9 feet high, has been taken chiefly from the S.W. of the whim-shaft; and there is yet a third stopping, on the main lode at the S.W. end of the 20-fathom level, 45 feet in length, but carried up at present no more than some 12 feet on an average.

In the portions of the main lode which seem to promise a profitable future yield, there remains some ore above a long stopping near the W. whim-shaft above the 10-fathom level. The ground S.W. of this old stopping is dead, and beyond it we find 36 feet of good stopping-ground to the present end of the level.

From the 20-fathom level on the N.E. end, N.E. of the engine-shaft, occurs a piece of good ground, almost 40 feet long, near the winze S.W. of the engine-shaft cross-cut. This first piece is 66 feet long between the cross-cut and winze. A second piece, beginning 50 feet N.E. of the whim-shaft, and extending for some 250 feet to the present end of this level, though in places quite lean, will pay well for stopping. At the S.W. end of the workings, the lode appears of average richness. On the 10-fathom level there is a cross trap-dyke 3 or 4 feet thick, and beyond this the vein is resumed, but is at present thin, being only just at the dyke. The 20-fathom level is not as far forward within 150 feet. It ends in a very fair lode, and has very recently increased both in size and richness, the ore part being estimated to be 2 feet thick, and to yield 3 tons of ore per fathom.

BRANCHES FROM THE MAIN LODE IN THE WHEATLEY MINE.

An interesting and encouraging feature in this vein, betraying the energy and extent of the rupturing and injecting force, is the presence of several branch lodes which fork off at an acute angle from the main mass, and, for the most part, re-enter it again at a similar obliquity, insulating at the same level, at least, a thicker or thinner mass of the adjoining rock. These enclosed "horses," as the miners call them, are sometimes entirely insulated in certain mines, sometimes only partially so. In the Wheatley Lode, the principal one points off to nothing upwards, and feathers off in both directions horizontally, by the branch veins running into the main lode upwards as well as horizontally; but whether it is thus surrounded in the downward direction cannot be known, since it is growing progressively thicker from level to level descending. That this branch lode will eventually enclose the "horse" in the downward direction, seems altogether probable, from its appearing to be so essentially a true branch shot upward and laterally from the main injection of ore.

The branch veins, as now developed, are—

First, A branch vein or offset from the main lode, which turns out and re-enters it, insulating a horse. This branch at the 10-fathom level is 80 feet between its two junctions with the main lode, and at this level it recedes 9 feet at the thickest part of the horse. The horse contains strings of phosphate and carbonate of lead. This branch joins the main lode about 20 feet above, back of the 10-fathom level. It dips steeper than the main lode, underlying not more than 6 inches in a fathom; for, at 16 feet below the 10-fathom level, the cross-cut to it is 12 feet long, and it will be 20 feet at the 20-fathom level.

This branch yields good ore throughout, chiefly galena. Its average thickness is about 9 inches, and it is richest where the horse is widest, and thins at its junction with the main lode.

Opposite this branch the main lode contains galena and phosphate of lead as on the 10-fathom level—good ore, say about 18 inches in thickness.

There is another branch also on the N.W. or underlying side of the lode, visible in the 10-fathom level, but opened and mined from the 20-fathom level. It has been mined 60 feet from the S.W. point of the horse N.E. to where the workings now are; but it has not been worked round into the lode.

This branch, like the other, is nearly perpendicular, underlying not more than 9 inches per fathom. The horse, at the thickest, is about 12 feet, and at the present end of the workings, 5 feet thick, the branch now approaching the main lode.

The horse is streaked with thin veins, and has chunks and strings of galena, carbonate of lead, &c. There are symptoms of other branches or turn-outs of the vein, some of them on its S.E. side; but these two, here mentioned, are the only ones now working.

These branches, it will be seen, promise to contribute quite a considerable auxiliary amount of ore to that derived from the main lode, and they deserve to be very carefully sought and pursued.

Of the other or productive half, a careful study of the Wheatley Mine induces me to believe that the average yield in good ore, calculated to the square fathom, is from 1¼ to 1½ tons.

It is in the power of any person, from these data, and from the other elements of length and depth already presented, to estimate for himself, on the reasonable assumption of a permanency in the averages I have ventured to give, the total future yield of the whole lode, embraced between the limits within which it has been opened, and is now being wrought, in the Wheatley and Brookdale mines.

In support of the general accuracy of my estimate of February 1852, of the quantity and aggregate value of the ore then accessible in the mine, I beg leave to mention, that I learn from the books of the Company, that the quantity of marketable ore actually extracted from those workings and sold, proved to be almost exactly what I at that time computed it, as it lay unbroken in the mine.

I cannot conclude this description on the Wheatley and Brookdale Lode, and the two mines recently wrought in it, without expressing, in distinct terms, my conviction, that the whole vein, as far as opened, holds out a good promise of permanency and richness, or, in other words, of fair remunerative profit, if efficiently and frugally wrought. But to work it to the best efficiency, which in mining is the only true economy, it will be indispensable, I conceive, to drain the lode of the chief part of its water by a powerful pumping-engine and central shaft, stationed at some point between the present Wheatley and Brookdale engine-shafts, competent to relieve both of these mines of their main influx of water, and to make the vein accessible through a greater length and depth than can possibly be commanded by the existing comparatively feeble engines.

THE PRESENT EXTENT OF THE BROOKDALE MINE.

The Brookdale Lode, or, more strictly, the Brookdale end of the Wheatley Lode—for every indication implies that the two mines are situated on one and the same metalliferous vein—has been already sufficiently described in referring to the features of the whole under the name of the Wheatley Lode. There would seem to be very little room to doubt that this assumed continuity of the vein really exists; for though both the Wheatley and the Brookdale portions, in certain sections of their length, deviate considerably from the direction of the line joining the most distant shafts, yet the vein appears to return again to this general average course, the departures being neither very wide nor long. The same undulation in its course is noticeable at the Brookdale end which we witness in the Wheatley portion. Though the actual distance on the lode between the S.W. end of the present workings in the Wheatley Mine, and the nearest positively proved point in the Brookdale Mine, is about 1308 feet, yet the coincidence in direction in the surface vein-stones, and in the ores, and all their accompaniments, is so striking as to convince every attentive observer that the two mines are seated upon one and the same lode. Referring to the general statements given in the preceding sketch of the geological and mineral features of this vein, and its relations to the other veins of the district, I proceed to offer a few notes and observations respecting the Brookdale Mine.

The length of lode opened by the adit-level is about 456 feet, but there are decided indications on the surface along the course of it, even a few hundred feet beyond the point at which the adit at present terminates, that the vein still continues. The lode through much of the Brookdale ground or sett, outcrops near the bed of the little transverse valley which descends N. from a range of higher land; as a consequence, the adit-level is not deep beneath the surface, being nowhere lower than 6 fathoms, and, on an average, only 4 fathoms.

In this adit-level, the lode is stained with spots of carbonate and phosphate of lead, and with galena, for a length of about 400 feet, or within some 60 feet of the end of the level. The gossans, vein-stones, and ores of the Brookdale Mine are identical with those of the Wheatley, and it exhibits in its hanging wall precisely the same variety of soft white felspar and quartzose granite which distinguished the same wall of the latter, and which I have so very often noticed to be the accompaniment of our richest metalliferous veins.

Above this adit, several tons of marketable ore were procured at no greater depth than some 20 feet; and below this level the vein steadily improves in richness in the shaft.

On the whole, the indications of a productive vein in the lower levels of this mine seem encouraging; but to open the lode satisfactorily, a powerful pumping-engine is indispensable. The position of the vein so near the bed of a ravine will render this mine a wet one; and although the present excellent engine of 60-horse power will be competent to the drainage of the first upper levels, it can never grapple with the burden of water to be lifted when the workings grow deep and extensive.

MINERAL VEINS AND METALLIFEROUS DEPOSITS OF THE GNEISSIC REGION N. OF THE CHESTER COUNTY VALLEY.

GRANITIC AND TRAPPEAN DYKES.

Penetrating the gneiss in different parts of the district are many injections of various kinds of granite, greenstone, and augitic trap, and other true igneous rocks. Throughout the region the injections of granite consist, for the most part, of a coarse binary mixture of white opaque felspar and quartz, showing a tendency to decomposition. This rock occurs in narrow dykes with nearly parallel walls, and in ramifying veins. Sometimes these cut the beds of gneiss nearly perpendicularly, while, in other instances, they partially conform to its bedding, or die out in more or less tortuous branches among its contorted layers. A somewhat common variety of the granite consists of quartz, greenish semi-translucent felspar, and a small proportion of dark hornblende. These white felspathic granites seem most to abound in the S. half of the district, where, as we have already seen, the prevailing constitution of the gneiss approximates to that of the dykes. In the N. half of the region we meet with a relatively greater proportion of intrusive rocks containing a predominance of hornblende, augite, and the minerals which usually go with these; and it is worthy of note that in this quarter the stratified crystalline rocks themselves include a commensurately greater amount of the same minerals.

PREVAILING DIRECTION OF THE GRANITE DYKES.

Though these intrusive rocks observe various directions, their prevailing course is N.E. and S.W., or still more generally, perhaps, N. 55° or 60° E., and their dip, where not perpendicular, is, for the most part, steeply towards the S.E.

TRAP DYKES.

The trappean dykes of this district are generally narrow, and consist for the most part of a closely crystalline, fine-grained, bluish, hornblendic trap-rock. They run in nearly all directions, but their usual course is E.N.E. and W.S.W. They are part, in fact, of that extensive system of trappean injections which embraces the whole belt of country S. of the chain of the South Mountains or Highlands; or, more comprehensive still, includes, we may say, the entire Atlantic slope from New England to the Southern States, defining this as bounded on the N.W. by the chain of the Green Mountains and Hudson Highlands, the South Mountains and the Blue Ridge.

Small trap-dykes are common in the townships of Vincent and East and West Nantmeal. The two high hills near Warwick's furnace consist of trap—the largest mass of this rock in the township.

METALLIFEROUS VEINS.

Besides the above classes of intrusive rocks, and some others, too few and local to be referred to in this place, there occur, in the region before us, several interesting injected veins, or groups of veins, of metalliferous and other minerals. Some of these have been objects of mining enterprise, and have already well repaid the investments upon them, while the commercial value of the chief number yet remains to be tested.

These metallic veins are distributed in two principal neighbourhoods or local mining districts, distinguished from each other by important general differences in the nature of the metallic ores and their associated minerals. One of these districts is that narrow belt of the gneissic rocks which lies nearly in the prolongation of the Welsh Mountains on the N. branch of French Creek. The predominant metalliferous injections are veins or lodes of magnetic oxide of iron; but other mineral lodes, especially one or two, bearing ores of copper and zinc, likewise occur here. I will here introduce the following brief description of such of these as have hitherto been explored or mined.

KNAUERTOWN IRON AND COPPER VEINS.

The most Eastern or first vein of this belt which meets our attention is that of Crossley's iron-ore pits, about one mile N. of Knauertown. These pits are no longer wrought, and the true geological character of the vein or veins in which they were sunk it is now difficult to ascertain, inasmuch as they are abandoned, and, indeed, were never very extensively pursued. Sufficient indications prevail, however, and enough information is accessible in the neighbourhood, and through persons at one time commercially interested in the success of the mines, to satisfy me that these several pits all pertain to an irregular lode, or a chain of closely-connected lodes, of igneously-derived magnetic oxide of iron. This vein occurs between walls of gneiss rock, in a low ridge just E. of the N. branch of French Creek. Near the extreme Western end of this little ridge, the ore, when uncovered to the day, presented a mass in the form of a large expansion of a vein of several feet thickness; but upon sinking the mine in it, this promising body of ore rapidly thinned down, and was even almost cut out by a contraction of its walls. Well-formed octahedral crystals of the magnetic iron-ore are very abundant in this vein; and indeed this variety is rather characteristic of the iron lodes of this N. belt of gneiss. The absence of regularity in the vein, and the necessity of providing steam-power for the deeper prosecution of the mine, caused its suspension some years ago; but it is not improbable that it will be resumed at a future day, since the work done was not without encouragement.

ELIZABETH COPPER MINE.

Immediately adjoining the before-mentioned vein of magnetic ore of iron, there exists a very interesting mineral vein, known sometimes as the Knauertown Copper Lode, or that upon which is seated the Elizabeth Copper-mine. This injection, likewise, occurs in the gneiss; but a granitic vein, composed chiefly of felspar and augite, forms its actual wall on the S.; the vein itself, observing a course nearly parallel with the strike of the strata into which it has been injected, consists largely of crystallised calcareous spar, dispersed through which occurs well-crystallised oxide of iron, and many brilliant octahedral crystals of the sulphuret of iron, and likewise some copper pyrites. The copper ore, diffused feebly throughout the calcareous spar, is most abundant next the N. wall of the vein. Measured transversely on a horizontal line, the dip being steeply N., the width of this whole vein or bed of spar is not less than 45 feet; an engine-shaft descends upon the lode a depth of 140 feet; and there is an interior underlay-shaft, descending from the bottom of the main shaft, 45 feet deeper. From the bottom of this latter pit, a cross-cut runs S. 28 feet, and another to the N. 22 feet; while a drift has been carried along the lode E. a distance of 55 feet; and this is the present extent of this small experimental copper-mine, the active prosecution of which was suspended in May 1854, whether to be resumed or not I cannot say.

It deserves to be here noted that these mineral veins are situated a short distance N. of a very thick dyke, or wide belt of trap-rock, which extends along the N. side of the narrow tongue of middle secondary red sandstone which insulates the metalliferous belt of gneiss from the main gneissic region S.

STEEL'S IRON-ORE PITS.

The next metalliferous vein of the tract, of any note or present promise, is one situated about half a mile N. of the village of St Mary's. This has not been wrought for many years; and very little precise information is derivable respecting it, beyond that furnished by observation of the old surface-diggings, and by vague tradition. There is obviously here a true lode or vein of magnetic iron-ore, containing much of the octahedral variety. A wide surface-pit and an adit suggest that the ore was in some abundance here, and such is the tradition of the neighbourhood; but what the precise geological characters of the vein may be, or what promise it may have held out of some day proving profitable, there are no sufficient data for determining. It occurs in gneiss, a little N. of a heavy dyke of trap-rock, and seems to have an E. and W. direction.

HOPEWELL FURNACE ORE-PITS.

Proceeding Westward along this strip of gneiss, the next and last important mineral injection which we meet with is that of the iron mines of Hopewell Furnace. These are situated about one and a half miles N.W. of St Mary's, or the Warwick Iron Mine, and near the N. edge of the belt of gneiss, where it is margined by a range of white Primal sandstone, forming a spar in prolongation of the Welsh Mountains, called Thomas's Hill. This mine has been wrought for very many years. There are in all four ore-pits here, only two of which, however, are now wrought: both of the new pits, or those at present worked, are drained by one engine-shaft. This ore is a highly crystalline variety of the magnetic oxide of iron, presenting many specimens of beautiful octahedral crystals. The ore is in two veins, both dipping at a moderate angle of about 30° towards the N.W. One of these, the undermost, varies in thickness from 15 to 25 feet; the other overlying vein has an average thickness of some 7 feet. A thick dyke of close-grained grey trap-rock cuts and partially shifts the ore. Its course is about S.E. and N.W., while that of the veins of iron ore is N. about 65° E., or, as usual, nearer E. and W. than the trappean dyke. Unfortunately, the engine-shaft has been sunk thus far almost entirely within the trap-rock, a mistake entailing great delay and much unnecessary expense. It is designed to intercept the veins or beds of ore, at a good depth below the surface, in their dip to the N.W.

WARWICK IRON MINES.

To avoid dispersing unnecessarily our descriptions of the mineral veins and ore localities connected with the gneissic district, we will pass in the next place to those which lie contiguous to the insulated belt of gneiss on the N. border of the region, without adhering too rigorously to principles of classification. This brings us to treat of two or three localities along the N. margin of the main district of gneiss, but compels us to introduce a description of some ores and minerals, which, though in some respects of igneous origin, are not wholly so. There are, however, in this tract, some genuine intrusive lodes, and to the best developed and chief of these we will proceed first.

LEIGHTON IRON-ORE MINE.

A little south of the village of St Mary's, just outside of the margin of the shallow deposit of the red sandstone, and its fringing lower layers of conglomerate, is situated the Leighton Iron Mine. A large surface-excavation, embracing two veins of igneous magnetic iron-ore: these range N.E. and S.W., and to the N.W., at an angle of about 33°. The overlying vein, when first opened at the surface, measured 15 feet transversely, but, pursued for 25 feet below the water-level towards the S.W., it has dwindled to a thickness of only 15 inches.

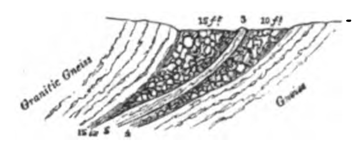


FIG. 571.—Leighton's Iron Mine, Warwick, Chester County.

The other, or lower vein, distant from the first from 3 to 5 feet, was 10 feet thick at the surface, and declined in size to 4 feet. The mining and exploratory shafts together extend along the vein about 500 yards, but the actual excavations in the ore do not cover a length of more than 200 feet. The dip of the open cut in the ore is about 40 feet.

From this mine the whole quantity of ore removed before its abandonment was about 20,000 tons.

The accompanying little section (Fig. 571) illustrates the form and position of these veins.

WARWICK IRON-MINE PROPER.

This extensive and interesting body of iron ore, situated just S.E. of St Mary's Episcopal Church, is in reality not a genuine lode or igneous intrusive vein, though the ore derives some of its characters from intrusive igneous action, but it is a bed or deposit at the base, or very near the base, of the middle secondary red sandstone, which here laps upon the gneiss. The explored extent of this bed, hitherto penetrated only near its outcrop, or where the overlying strata are shallow, is already very great, amounting to many acres. The ore-deposit observes everywhere a very gentle dip, and seems to undulate in two or three waves across the tract which includes it. A somewhat conspicuous anticlinal change in the dip occurs to the S. and S.W. of the present main engine-shaft by which the mines are dried, and there is every indication that the ore basins both S. and N. of this saddle. Though the basin to the S. of it is intersected, and the ore in one place cut off or thrown out to the surface, by the intrusion of a wide dyke of trap-rock, there is strong reason to infer that the ore occupies a comparatively wide, though perhaps shallow basin, N. and N.E. of the engine-shaft.

Besides this intrusion of trap, there seem to exist here injections of serpentine and other mineral matters, and at one point, just by the S.W. margin of the ore bed, there exists a very singular intrusion of mineral matter penetrating the ore, and altering, in a remarkable manner, the conglomeritic layers which here constitute the S.E. border of the red-sandstone formation. This rock is greatly baked and changed in aspect, includes numerous spheroidal bunches of segregated crystalline mineral matters—some of them in the form of hollow geodes—and is intersected besides with numerous strings, or little veins. In these spheroidal nests occur beautiful linings of crystallised epidote and other minerals, and bunches of large crystals of the fine variety of garnet called Melenite. The list of the minerals occurring here is not extensive. The conditions under which they present themselves are such as strongly to impress the geological observer with the notion of their having been introduced chiefly in a vaporous state, or by sublimation, for in many of these hollow spheroids we can detect no connection whatever between the interior or even the exterior walls of the geodes, and any external veins or filaments of injected matter, such as any other theory would demand, for the introduction of the materials of the crystalline minerals here so curiously insulated.

The bed of iron ore for which this locality is chiefly noted is of very variable thickness, fluctuating from 1 or 2 to 9 or even 17 feet. As illustrating the general levelness of this undulating deposit, it may be stated that in no place has it been required to sink deeper than about 60 feet to reach the ore, while generally the covering is so thin that the ore is conveniently procured by merely stripping off a thickness of a few feet or yards of loose disintegrated rock. The average richness of this ore may be stated at about forty-five per cent of metallic iron, though much of it exceeds fifty per cent. It is somewhat sulphurous, and when care is not employed in selecting it for smelting, and in the after-processes, it tends to produce a hot-short or red-short iron, but when carefully manufactured it yields an excellent metal. The annual product of the Warwick Iron Mines for fifteen years was not less than 4000 tons, and the average yield for the past twenty years has been 6000 tons. In the year 1853 the amount mined reached 12,000 tons. These ore-pits have been wrought for the last 120 years, and there would seem to be at present really more ore within sight than there has ever been before, at any one time. The present average cost of mining this ore is about one dollar and fifty cents per ton.

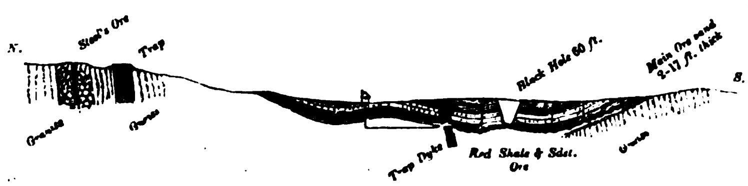


FIG. 572.—Ore Ground at St Mary's, Old Warwick Pits, Chester County.

Annexed is a little section—not the result of any critical measurements, however—of this valuable and interesting mass of iron ore.

This ore is intermediate in its physical characters and aspect between the true brown hæmatite and the magnetic oxide of iron. As, on the view of its having been originally a hæmatite, but subsequently altered by igneous action, we might naturally anticipate, those portions of it which have undergone the highest degree of metamorphic influence are of a grey colour, quite crystalline, and partially endowed with magnetic force, whereas the less altered parts are nearly in the condition of a compact closely-cemented hæmatite. Minutely interstratified with this ore, there occurs more or less earthy matter, apparently lamina of indurated slate or shale; and when the layers of this rock are thick, and they disperse the ore, they interfere materially with the economical prosecution of the mine. This slaty or earthy matter tends furthermore, by intimately mixing itself in with the finer granular ore, seriously to reduce the richness of the mingled mass in iron.

KNAUERTOWN IRON MINE.

A little N. of Knauertown, just on the S. margin of the tongue of red sandstone which there divides the N. belt of gneiss from the principal district of that rock, there occurs a small deposit of iron ore precisely identical in geological position with that of the Warwick Mines, and very similar to it in aspect. A few shafts have been sunk in quest of this ore, under the hope that it might prove abundant enough to be a source of profit, but no sufficiently large deposit has been reached to justify anticipations or encourage any further mining. The indications of igneous action, though not entirely wanting here, betray much less of the subterranean energy than was manifested in connection with the ore at the old Warwick Mines.

OTHER MINERAL VEINS IN THE NORTHERN GNEISSIC DISTRICT.

Near the junction of Beaver Creek with French Creek, or a short distance to the S.W. of Pughtown, there is a vein of impure plumbago on the farm of Jesse Hawley. It occurs between beds of gneiss, is about 3 feet in thickness, and dips with the strata to the S.E. about 45°. The plumbago is pulverulent, and mixed somewhat with foreign matters, especially oxide of iron, oxide of manganese, and some of the minerals of the gneiss, in a state of disintegration. The excavation exposing it is a very superficial one, being merely a drift, of the length of a few fathoms, penetrating the vein at the water-level. After being mined, the material is broken, screened, and washed, when it is packed and sent to West Chester, there to be converted into a fireproof mineral paint for railroad cars, houses, barns, and other structures. This paint is prepared dry, and also ground in oil. It has been found very useful in resisting atmospheric exposure, though it has been employed as yet to a very limited extent

OLD COPPER MINE, ON COPPER MINE RUN, IN BATH TOWNSHIP, IN LANCASTER COUNTY.

A mineral locality of some note, but of small mining interest at present, is that of the Old Copper Mine in Lancaster County, on the N. margin of the long narrow belt of gneiss, at the S. foot of the Mine Ridge. The vein here, of the ancient workings of which very little is at present known, contains iron pyrites, copper pyrites, and a sulphurate of iron, and nickel.

This copper mine was originally opened for copper, but very little ore of this metal has ever been extracted. The lode ranges nearly E. and W., and its ascertained length is about 60 yards, though probably it is actually greater. The vein is nearly perpendicular, dipping very steeply to the S. On its N. side the wall is a fine-grained trap-rock; on its S. side a crystalline hornblende. The lode itself is from 10 to 12 feet thick. There are two levels, one about 10 fathoms, and the other 17 fathoms, below the surface, but the ore is not reached until about 7 fathoms are gained. This ore is very poor in copper, not yielding more than from three and a half to four and a half per cent, but the mine seems to promise somewhat better as it advances. The ore is conveyed to Canton, New Jersey, to be smelted there, though very little has yet been taken.

LOCALITIES OF WELL-CHARACTERISED CRYSTALLINE MINERALS WITHIN THE GNEISSIC DISTRICTS OF PENNSYLVANIA.

The following lists of well-defined mineral species, suitable for cabinet specimens, ranged under the localities where they can be found, have been derived chiefly from the latest edition of Professor James D. Dana's excellent *System of Mineralogy*, to the descriptive text of which work I must refer the reader for more copious information respecting the minuter characters of the minerals, and their precise positions. The memoranda were mostly furnished, as Professor Dana states, by Messrs Williams and Seal, of Chester County, two well-informed local mineralogists, who have explored the mineral neighbourhoods of Southern Pennsylvania with much zeal and care. We desire here to return them our own thanks for useful notes guiding us to the places, and the mineral species mentioned.

The catalogue of Easton minerals is due chiefly to Dr Swift of that town, while other memoranda, relating to other places outside of Chester and Delaware counties, are the results of our own personal observations.

MINERALS IN THE SOUTHERN GNEISSIC DISTRICT.

PHILADELPHIA.—In the Southern range of true gneiss, *laumonite*, *garnet*, *tourmaline*, and *mica*, occur on the Schuylkill, near the foot of the old inclined plane; and yellow *uranite*, a fourth of a mile from the Suspension Bridge. In the same belt, at Frankford, occur *garnet*, *staurotide*, and *iron pyrites*.

DELAWARE COUNTY.—Within the S. range of the gneiss are to be found, in

Aston Township, near Village Green, *amethyst, corundum, emerylite, staurotide, sillimanite, black tourmaline, pearl mica, asbestos, anthophyllite;* and near Tyson's mill, *garnet* and *staurotide;* and at head of Peter's mill-dam in a brook, *garnet*, resembling *pyrope*.

Birmingham Township.—At Bullock's quarry, *zircon, bucholzite, fibrolite, nacrite.*

Chester Township.—Amethyst, black tourmaline; in Burk's quarry, *beryl, black tourmaline, felspar, manganesian garnet*, and *cryst. pyrites;* on Chester Creek, at Carter's, *molybdenite, molybdic ochre, copper pyrites, tourmaline, kaolin;* at Little's quarry, *brown garnets, tourmaline;* and near Henvi's quarries, *amethyst* in *geodes.*

Chichester Township.—Near Trainer's mill-dam, *beryl, tourmaline, cryst felspar, kaolin;* and on W. Eyre's farm, *tourmaline.*

Concord Township.—On Queen's Creek, *garnets*, resembling *pyrope, bucholzite, mica*, in hexagonal prisms, *beryl, actinolite, agthophyllite, fibrolite, rutile*, in capillary crystals in the cavities of cellular rose quartz.

Darby Township.—In a boulder, *kyanite, zoisite*; and near Gibbon's, *garnets, staurotide.*

Leiperville.— Beryl, in granite; in Leiper's quarries, *beryl, tourmaline, apatite, garnet, cryst. felspar, mica;* at Morris's Ferry, *kyanite, sillimanite, apatite, red garnet*, and *mica;* at Hill's quarries, *chabazite, stilbite, zeolite, epidote, sphene, albite, calcite, cryst. pyrites;* near Leiper's church, on the edge of a wood, *andaluzite, apatite, tourmaline, mica, and grey kyanite.*

Springfield Township.—Andalusite; on Worrell's farm, *tourmaline, beryl, ilmenite (?) garnets;* on Fell's Laurel Hill, *beryl, garnet;* near Beatty's mill, *staurotide apatite;* near Lewis's paper-mill, *tourmaline, mica.*

CHESTER COUNTY.—The only localities in this county, belonging seemingly to the true gneiss formation, are as follows :—

Pennsburg Township.—Brown garnets; on Cloud's farm, near Pennsville, *mica*, in hexagonal prisms, from one quarter to seven inches in diameter

Kennet Township.—On Gregg's farm, *actinolite, brown tourmaline, brown mica, epidote, tremolite, scapolite, arragonite;* at Peirce's paper-mill, *zoisite, epidote, sunstone, chabazite, stilbite, labradorite;* on R. Lamborne's farm, *chabazite* in small brownish-yellow crystals (rare), and *zeolite;* and at Gauss's corner, *epidote.*

Goshen Township.—At water-works, *zoisite;* at Jeffrey's Ford, *zircon.*

MINERALS IN THE MIDDLE GNEISSIC DISTRICT OCCURRING IN THE GENUINE OR OLDER GNEISS.

Wheatley Lead Mine, near Phœnixville.—The Wheatley Lode is the best developed, richest, and most abundant in crystalline minerals of the group of veins to which it belongs. A list of its ores and minerals has been already given.

Chester County Lead Mine, adjoining the Wheatley Mines.—*Allophane.*

Gap Mine, near Mine Ridge.—*Magnetic pyrites*, containing *nickel, copper pyrites, actinolite.*

Knauertown, N. of Pughtown.—*Graphite, sphene, cryst. magnetic iron;* in Chrismard's iron-mine, *zircon.*

Keim's Iron Mine, near Knauertown.—*Flos-ferri, pyroxene, micaceous iron-ore, aplome, actinolite, yellow octahedral pyrites, copper pyrites* in tetrahedrons, *red garnet, malachite, hornblende* (var. byssollite).

Steel's Iron Mine, half a mile N. of village of St Mary's.—*Magnetic iron-ore* in octahedral crystals, *micaceous iron ore, coccolite.*

Hopewell Furnace Iron Mine.—Beautiful specimens of octahedral crystals of *magnetic oxide of iron.*

South Coventry Township.—On farm of Jesse Hawley, near junction of Beaver and French Creek, *plumbago.*

MINERALS OF THE NORTHERN GNEISSIC DISTRICT, OR OF THE SOUTH MOUNTAINS AND THEIR SPURS BETWEEN THE DELAWARE AND SCHUYLKILL.

The genuine gneissic rocks of this range include but few mineral localities; the interesting points near Easton from whence so many beautiful cabinet specimens have been derived, belong to the Primal slate and Auroral limestone formations, and their contents will be mentioned under these heads, in their proper places, later in this chapter.

Chestnut Hill, N. of Easton, consisting of gneiss, but flanked by higher formations, contains several crystalline minerals already mentioned in the text, some of which belong to its gneissic rocks.

Near *Bethlehem*, but in the South Mountain, there occur, in a sienitic gneiss, *allanite, magnetite, epidote, brown garnet, black spinel, and tourmaline.* In the same range, near *Allentown*, occurs *magnetic iron-ore.*

MINERALS OF THE METAMORPHIC PRIMAL STRATA, AND OF THE MIDDLE RANGE OF THE SOUTHERN GNEISSIC DISTRICT, POSSIBLY THE SAME FORMATION UNDER MORE EXTREME METAMORPHISM.

PHILADELPHIA, Mica-slate range :—

Chestnut Hill.—Mica, serpentine, dolomite, asbestos, nephrite, talc, tourmaline, sphene, apatite, tremolite.

Germantown.—Mica, apatite, felspar, beryl, garnet.

Banks of Wissahickon.—Actinolite, garnet, staurotide.

Manayunk Tunnel.—*Stilbite, chabazite.*

DELAWARE COUNTY :—*Marple Township.*—*Tourmaline;* on A. Worrell's farm, *andalusite, tourmaline;* near Palmer's mills, *beryl, tourmaline, actinolite, amethyst.*

Edgemont Township.—*Rutile* in quartz, *amethyst, oxide, manganese, cryst. felspar.*

Mineral Hill.—*Corundum, aventurine, felspar* (sunstone), *chatoyant felspar* (moonstone), *actinolite, green coccolite, green felspar, chromic iron, cryst. green quartz, ferruginous quartz, hydrous asbestos, anthophyllite, brown garnet, magnesite, marmolite, bronzite, chalcedony, limonite, labradorite, floatstone, red garnet, beryl, serpentine.*

Providence Township.—At Blue Hill, *serpentine, cryst. green quartz* in *green talc, asbestos, talc, anthophyllite, actinolite, hydrous anthophyllite;* on Hunter's farm, *amethyst* (one fine crystal weighed more than 7 pounds), *andalusite.*

CHESTER COUNTY :—*Birmingham Township.*—*Kerolite, amethyst, quartz, serpentine.*

East Marlborough Township.—*Epidote,* and nearly *white tourmaline.*

West Chester, 3 miles S. of town.—*Clinochlore, phlogopite.*

ALTERED PRIMAL SLATES.

MONTGOMERY COUNTY :—at *Gulf Mills.*—*Limonite, garnets, chromic iron.*

DELAWARE COUNTY :—*Radnor.*—*Garnets, marmolite, deweylite, serpentine, chromic iron, asbestos, magnesite.*

CHESTER COUNTY :—*Willistown Township.*—*Magnetic iron, chromic iron, actinolite.*

West Goshen Township.—*Amianthus, asbestos, precious serpentine, cellular quartz, jasper, chalcedony, drusy quartz, chlorite, marmolite, dolomite, cryst. carb. magnesia, chromic iron, magnetic iron.*

West Chester, 1½ miles N. of town.—*Hydro-magnesite, clinochlore, brucite in serpentine;* 2 miles W., *zircon;* 1½ miles N.W., *pitch-black allanite.*

Unionville vicinity, 1½ miles N.E. on Serpentine Barrens.—*Corundum* massive and cryst. in *albite,* also loose on surface, sometimes coated with *gibbsite* and *steatite; talc, green tourmaline, asbestos, hydrate of magnesia, yellow beryl* (rare), *serpentine, brucite, magnetic iron, octahedral iron, chromic iron, hydrated oxide of nickel* on *chrome, quartz crystals, green quartz, actinolite, chlorite, picrolite, clinochlore* in cryst. *diallage, granular albite, adularia, oligoclase, halloysite, margarite, euphyllite, allanite, hematite, chalcedony, cornelian, jasper, pechkohlite;* half a mile S.W. on Webb's farm, *serpentine, chromic iron;* 2 miles S.W., at Pusey's sawmill, *zircon, rutile;* 1 mile S., bright yellow and nearly white *tourmaline, orthoclase* (*chesterlite*), *albite;* near Marlborough Meeting-house, *epidote, serpentine, acicular black tourmaline,* in white quartz; 1 mile W., near Logan's quarry, *staurotide, kyanite, yellow tourmaline.*

East Bradford Township.—On Minorcus Hill, green, blue, and grey *kyanite, apatite, allanite;* on Taylor's farm, *sphene, cryst. smoky quartz;* on farms of Jones, Price, Sharpless, and Entriken, *amethyst;* near Strode's mill, fine *talc, asbestos, magnesite, marmolite, garnets, lithomarge;* near Hooper's sawmill, *epidote, asbestos;* on Osborne's Hill, *sphene, manganesian garnet, wad, tourmaline, actinolite, anthophyllite, felspar, fetid calcite;* near Black Horse Inn, *rutile.*

Chester and Lancaster Serpentine Barrens, near the State line.—The Serpentine belt and its borders contain, at Scott's Chrome Mine :—*Chromic iron, foliated talc, marmolite, serpentine, and chalcedony.*

Near *Texas,* at Wood's Chrome Mine :—*Emerald-nickel, pennite, kœmmererite, millerite, baltimorite, chromic iron, marmolite, picrolite, hydro-magnesite, brucite dolomite, cryst. magnesite, calcite, serpentine;* at Low's Mine, *hydro-magnesite, brucite, picrolite, magnesite, chromic iron, talc, emerald-nickel, serpentine, baltimorite:* on Boice's Farm, N. of village, in soil, *cryst. pyrites, anthophyllite, marmolite, magnesite;* near Rock Spring, *chalcedony, cornelian, moss agate, green tourmaline* in talc, *titanic iron, cryst. magnetic iron* in chlorite; at Reynolds' Mine, *calcite, talc, picrolite.*

Parkesburg.—In Primal white sandstone of N. and S. valley hills, much *black tourmaline,* often in dislocated crystals; in soil for 7 miles along S. edge of valley, *rutile.*

Little Brittain Township.—*Anthophyllite.*

The metamorphic Primal strata embrace several important very extensive deposits of brown iron-ore, in some of which there occur magnetic oxide of iron, and even perfect crystals of the octahedral form. The chief part of these accumulations of half hæmatitic, half magnetic ore, belong either to the very upper portion of the upper Primal slate formation adjoining the base of the Auroral limestone—that is, to the first alternating limestone and slate beds constituting the transition from the one series to the other; or to the very base of the upper Primal slate, where it rests on the Primal white sandstone. The Cornwall ore occurs high in the Primal slate; that of Jones's mine in Berks County, in this slate, just below its contact with the limestone; some of the deposits of Safe Harbour on the same horizon; others rather lower down, more nearly on the horizon of the Cornwall ore; while the great Chestnut Hill deposit is at the very base of this upper Primal slate, where it reposes on the Primal white sandstone.

BERKS COUNTY.—At Jones's Mine, near Morgantown, *green malachite! cerusite, chrysocolla! octahedral* and *dodicahedral magnetic iron, iron pyrites, copper pyrites.*

YORK COUNTY.—*Calc spar; cryst. smoky quartz; cryst. pyrites;* in Peachbottom slate-quarries, *wavellite.*

NORTHAMPTON COUNTY :—*Easton.*—*Quartz* (large crystals); *augite* (at the Bushkill, Chestnut Hill); *zircon* (in talcose slate at Larrich's, Chestnut Hill); also *plumose mica.*

LOCALITIES OF MINERALS ASSOCIATED WITH THE AURORAL LIMESTONE.

SOUTHERN METAMORPHIC DISTRICT.

BUCKS COUNTY.—Near *Attleboro'*, at Vanartsdalen's limestone quarry, *sahlite, scapolite, sphene, green coccolite, graphite, green mica, tabular spar, rutile, actinolite, augite.*

CHESTER COUNTY :—*Pennsbury Township.*—At Harvey's limestone quarry on the Brandywine, *chondrodite;* at Burnett's lime quarries, *sphene, diopside, augite, coccolite;* at Mendenhall's quarry, *carb. strontia;* at Brinton's mill on Brandywine Creek, *chondrodite.*

New Garden Township.—At Nevin's limestone quarry, *brown tourmaline, scapolite, brown and green mica, rutile, arragonite, kaolin.*

London Grove Township.—In Jackson's limestone quarry, *yellow tourmaline* (rare), *fibrous tremolite;* at Pusey's quarry, *rutile, tremolite.*

West Bradford Township.—Near A. Jackson's limestone quarry, *green kyanite, rutile, scapolite, iron pyrites;* near Marshall's mill, *chromic iron, serpentine;* at Poorhouse limestone quarry, *rutile*, in brilliant crystals, *cryst. calc. spar, cryst. dolomite, zoisite:* on quartz, *talc* (cryst. or dolomite), *chesterlite* (in fine crystals on dolomite).

Unionville Vicinity.—Two and a half miles S.W. of Unionville, in Bailey's limestone quarry, *fibrous tremolite, mussite, kyanite, margarodite;* on farm of Bailey and Brothers, *yellow, green, and white tourmaline, chesterlite;* at Edward's limestone quarry, *purple fluorspar, rutile;* in limestone quarries near Doe River village, *scapolite, rutile, tremolite.* In this range of limestone quarries, extending from near the Red Lion Tavern South-westward, parallel with and S. of the street road, occur *rutile, yellow tourmaline, tremolite, chesterlite, &c.*

Montgomery and Chester Valley, in Auroral limestone.—At Henderson's marble quarry, *calc spar;* one mile N., on railroad, *cryst. quartz in geodes;* at Spring Mills, *cacoxene, lepidokrokite*, and *spathic iron;* 5 miles W. of Penningtonville, near Bear Tavern, in crystallised limestone, *rutile* and *bitter spar.*

MIDDLE METAMORPHIC DISTRICT.

LANCASTER COUNTY :—*Pecqua Valley.*—Eight miles S. of Lancaster, *argentiferous galena* (250 to 300 ounces of silver to the ton); 4 miles N.W. of Lancaster, on railroad, *calamine, galena, blende.*

CHESTER COUNTY :—*East Nantmeal Township.*—S.W. of Chrissman's Ford, *graphite, augite, sphene.*

NORTHERN METAMORPHIC DISTRICT, OR SOUTH MOUNTAINS.

LEHIGH COUNTY.—In Saucon Valley, near Friedensville, occur *calamine* (promises to be a valuable mine), *lanthanite, crystallised quartz, malachite, pyrolusite* (*wad*).

NORTHAMPTON COUNTY.—Hill N. of Easton, *cellular quartz* (pseudomorphous), *pyroxene, coccolite, green augite, sahlite* (opposite the Spring, Jersey side), *white fibrous tremolite, lead-coloured tremolite, glassy tremolite, actinolite, radiated actinolite, glassy actinolite, asbestos, nephrite, jade, reddish jade, chondrodite* (opposite Wolf's quarry, on Jersey side of river), *mica, silvery mica, saussurite, green talc, tourmaline, serpentine* (cryst.), *serpentine with carb. lime* (a kind of verde-antique); at Spring, *chlorite, calamite, limonite, magnetic iron, flesh-coloured carb. lime, fibrous and rhombic carb. lime, magnesian carb. lime.*

ON THE IRON ORES OF THE GNEISSIC AND PALÆOZOIC FORMATIONS OF PENNSYLVANIA.

INTRODUCTORY REMARKS.

Few tracts of the earth's surface contain, in proportion to their area, so abundant a supply of the ores of iron as the State of Pennsylvania. There are particular localities in other regions where, perhaps, the quantity of iron ore is even larger than in any of the yet discovered deposits of this State, extensive as many of these are; but it is doubtful if any territory of its size possesses as enormous an aggregate amount of this form of mineral wealth in a position so accessible to the different kinds of fuel essential to its conversion to human use. The variety in the composition of these ores is not less remarkable than their amazing quantity; nearly every species employed for making iron being met with, and in some districts many kinds in a single neighbourhood. Their great diversity in chemical constitution and properties is of itself an advantage to the iron manufacture of the State not easily to be estimated. Taken in connection with a no less extraordinary variety in the fuel, embracing almost every known description of fossil coal and charcoal, it enables the iron-smelters of Pennsylvania, by the use of judicious mixtures, and the application of suitable fuel, to produce nearly every description of iron acceptable in commerce.

This very encouraging feature in the picture of the vast mineral wealth of the State is intimately connected with the enormous variety and wide distribution of the Palæozoic strata, and with the remarkable structure already elaborately explained, by which many different formations are brought together in the same districts in numerous narrow outcrops. It is primarily dependent on these two circumstances—first, that much ferruginous matter entered originally into the composition of several of our great Appalachian rocks; and secondly, that the subsequent changes of upheaval to the surface, and the chemical action upon these rocks, have brought the iron of each formation within reach in many successive parallel belts. If we regard the positions which the different iron ores occupy in the thick and diversified strata of this region, we perceive that, from the ancient metamorphic groups to the coal-rocks inclusive, almost every great series of deposits contains one or more special kinds of ore. In the gneissic or metamorphic series we meet with both the crystalline magnetic iron-ore and the brown peroxide. The Primal newer slate, and Auroral magnesian limestone, have each their own special varieties of the hæmatitic ores. The Levant series embraces a stratified fossiliferous ore of great extent and importance. There is a hæmatitic ore peculiar to the horizon of the Pre-meridian strata, and low in the Cadent series there occurs a form of ore unlike any belonging to the other formations. Near the base of the Ponent rocks we find a stratified and fossiliferous iron-ore essentially different in qualities and appearance from that of the Levant group; and in the Vespertine red shale a peculiar nodular ore occurs, occupying its own definite level in the formation, and visible along a very extended line of outcrop. Lastly, the various subdivisions of our vast coal-formation yield their own special sub-varieties, sharing certain common properties, yet differing both externally and in their chemical nature.

I propose to offer, in this division of my work, some general remarks upon the geological and chemical relations of the ores of each iron-bearing formation, with a few practical suggestions and calculations; and to accompany each such general sketch with a series of analyses sufficiently numerous to display the characteristic properties and relative richness in iron of particular varieties, and to append some condensed comparative statistics tending to show the present and future growth of the already vast and important iron-manufacture of Pennsylvania and other regions.

CHAPTER I.

OF THE IRON ORES OF THE METAMORPHIC OR GNEISSIC ROCKS.

Two principal varieties of iron ore occur in association with the gneiss rocks of the South-eastern district of the State. These are the crystalline-magnetic ores, and the brown or hæmatitic-peroxide ores. The chief localities of the first are in the N. belt, or that of the South Mountains between the Delaware and Schuylkill, while the greater number of those of the latter species are in the S. tract.

MAGNETIC IRON-ORE, OR OXIDULATED IRON.

This ore of iron, in its purest form, consists of two atomic proportions of the peroxide of iron and one of the protoxide, and therefore contains nearly 73 per cent of metallic iron. It is, however, seldom absolutely free from admixture of other crystalline minerals, the presence of some of which materially influence its value as a source of iron. It is strongly magnetic, attracting soft iron and the magnet, and many masses of it are endowed with true magnetic polarity, or are themselves native magnets. The minerals most generally interspersed among the crystalline oxides of iron are hornblende, felspar, quartz, sahlite, and apatite. Another ore of iron is not unfrequently associated with it—this is the *chromiferous iron-ore*, a combination of oxide of chromine with peroxide of iron and alumina. In the Serpentine belts of Chester and the Southern part of Lancaster counties, the chromiferous iron-ore is somewhat abundant, and, as I have stated, is mined in several localities, being chiefly transported to Baltimore, where it is applied to the manufacture of chrome-paints. The magnetic iron-ore occurs only in the form of true veins of injection or genuine mineral lodes. Its veins very generally coincide approximately in direction and inclination with the crystalline strata, between the layers of which they lie; yet this conformity is only partial, for when they are traced with close attention, they are occasionally found to intersect the strata for a short distance, and then resume their parallelism. These iron ores evidently reached the positions in which we thus find them while in a melted state, their intrusion being the result of an enormous subterraneous force, rupturing the earth's crust in the direction of the strata, or in the planes of weakest cohesion, and pressing the liquid ore and other fused mineral matters into the open fissures. Where the rent has been at all irregular or splintery, the vein which filled it is interrupted or uneven, being in some places pinched to very narrow dimensions by the approximation of its walls, in others dilating by their recession, and in many cases being split into two or more parallel branches by the insertion of a wedge-shaped portion of one or other wall. The veins incline at all angles between 45° and the perpendicular.

As a general rule, the lodes of magnetic iron-ore of the chain of the Highlands, tracing them from the Schuylkill to the Delaware, and then across New Jersey and New York, give evidence, in the nature and mode of distribution of the included crystalline minerals, of their having in many cases derived at least a portion of these from the fusion of the materials of the walls of the fissure into which the intensely-heated ore has flowed. It is indeed a very common fact that the foreign minerals in the ore are precisely such as would be produced by the melting and re-crystallising of the rocky matter in contact with the vein. I may mention, as worthy of record in this place, a general fact of some scientific and much practical value, in relation to the relative position of the oxide of iron and the non-metallic minerals in the same vein. Where the vein or dyke is large, and contains much extraneous mineral matter, this latter, if the inclination is not very steep or perpendicular, forms a separate division in the vein, and almost invariably *rests upon the ore;* but where, on the other hand, the dip is nearly vertical, the earthy minerals and the ore are more intimately mingled, or the respective masses of each intersect, or enclose each other irregularly.

The origin of these different conditions of insulation of the materials is very obvious. The oxide of iron, while the whole mass of the vein was yet in a state of fusion and very fluid, would necessarily, from its greater relative weight, follow the lower wall of the fissure as it flowed to the surface, while the much lighter earthy minerals would float, as it were, upon the upper side of the ore, taking the position with respect to the latter of its scoria or cinder. This would arise wherever the slope of the fissure was sufficient to give the force of gravity much control in the distribution of the materials; but in all cases of a perpendicular vein there would be no tendency in the heavier metallic portion to collect on one side rather than on another, and therefore it and the lighter mass would mingle more promiscuously. I first detected these phenomena among the magnetic veins of Orange County, New York, where the ore is often accompanied by much white felspathic granite, the product apparently of the fusion of the felspathic gneiss of its walls; and I have become confirmed in my impression of their generality by an extensive study of the veins of iron ore of the entire chain of the Highlands, from the E. side of New York to the River Schuylkill, and of many of the great magnetic dykes of the W. side of Lake Champlain.

There are many veins which are not accompanied by any separate body of granitic matter, but contain the felspar, hornblende, or other minerals in much abundance, disseminated through the ore. These we may imagine to have acquired their solid state, at least in the portions near the surface, where alone we can observe them, from a condition of imperfect fluidity, like that of the already half-chilled lava of some volcanic eruptions which would effectually prevent the separation of the heavier from the lighter constituents. Such are some of the gneissoid iron veins of the South Mountains E. of the Schuylkill. The Long Mine on the Sterling estate, 4 miles E. of the Ramapo, in New York, is a good example of the characteristic features of these lodes of magnetic oxide of iron: it displays the outcrop of two veins, each reposing directly upon gneiss, and covered by a thick vein, or rather division of the same vein, consisting of coarse white felspathic granite.

The mode of mining those veins, where the dip is not excessively steep, is to leave numerous staunch pillars of the ore, and to remove by blasting that which intervenes. A partially columnar structure, or cleavage, is sometimes visible as in the principal vein of the Sterling Long Mine, dividing the ore perpendicularly, or nearly so, to the surfaces which confine it. It greatly facilitates the operations of the miner. This structure, so analogous to that of many basaltic and other igneous dykes, is by no means infrequent in the large veins of magnetic iron-ore, and indicates a slow and gradual crystallisation from a state of fluidity.

Of the practical utility of the general fact which I have now announced respecting the frequent presence of some form of granite or unstratified rock, and the almost invariably overlying position which it occupies, one or two simple illustrations may be interesting. The first intimation usually procured of proximity to a vein of magnetic iron-ore is by the local disturbance it produces in the magnetic compass; but as the indications of the position of the vein derived from this instrument are frequently very vague and perplexing, it is of the greatest value to have some independent geological clue to its situation. Such, approximately at least, may be found in the usually conspicuous granitic outcrop of the upper half of the vein. When this is accompanied by a strong disturbing action upon the magnetic needle, we may infer, with a high degree of probability, that a metalliferous vein, large or small, lies immediately in contact with and below the dyke, and it is then only necessary to ascertain, from an inspection of the dip and direction of the adjoining gneiss, the lower edge of the granitic dyke, to have all the data requisite for finding the outcrop of the ore with very considerable certainty.

But this knowledge of the inferior position of the ore to the unstratified rock accompanying it, I have found useful in another way. It can be applied to tracing or recovering a vein of the ore thus overlaid by a mass of granite which has suddenly eluded the miner through the effect of some transverse fault or dislocation. Where the displacement, as usual, is to the extent of only a few yards, it is very obvious that, if the fault be an *upthrow*, the gneiss upon which the ore-vein rests will constitute the wall; whereas, if it be a *downthrow*, the granitic roof will lie athwart the original course of the vein.

The following is a sufficiently minute description of the magnetic igneous veins and iron mines of this formation :—

METALLIFEROUS VEINS OF THE SOUTH MOUNTAINS.

IRON ORES OF THE GNEISS.

The gneissic belt contains in several places veins of magnetic oxide of iron. These occur as regular lodes or veins, penetrating the gneiss and other rocks almost invariably in a direction coincident with the bearing of the strata. They might be taken, therefore, for interpolated beds, but for the occurrence of occasional branches and other irregularities which establish their intrusive origin. They agree in all their features with the larger and more numerous veins in the Highlands of New Jersey and New York.

IRON MINES OF THE LEHIGH HILL.

Beginning with the part of the belt next the Delaware, the first vein we encounter is upon the Lehigh hill, about 2½ miles S. of Easton, a few rods N.W. of the old Philadelphia Road. The rock here is a mixture of quartz and felspar, with occasionally a little epidote. On the S. side of the ridge the strata are talcose. The vein of magnetic iron-ore lies in contact with a sienitic dyke, consisting largely of green sahlite. This vein was formerly mined, but the work has been long since abandoned. The ore, which is very compact, appears to have a N.W. dip.

DURHAM IRON-MINE.

Another somewhat noted locality is that of the old Durham iron-mine, which is on the top of the hill S. of Durham Creek, on the old Philadelphia Road. This mine has been neglected for many years.

Near Durham iron-works, and not far from the creek, there is a valuable vein of magnetic iron-ore, discovered a few years since, and now wrought for the furnaces. This lode varies in thickness from 2 to 14 feet, averaging about 6 feet. Its total length has not been ascertained, but up to the summer of 1856 a gangway had been driven along it for 850 feet. It ranges N.E. and S.W., and dips 45°. The ore is pronounced rich and excellent. Within a few hundred feet of this lode there is a deposit of rich hæmatitic ore, thought to be derived from it.

On the Northernmost of the two gneiss hills E. of the Saucon, and about a mile N.E. of Hellertown, a vein of magnetic iron-ore shows itself in several places, though the quantity of ore here is probably not great. It is much mixed with quartz, though we obtained some tolerably pure specimens. A sienitic dyke, composed chiefly of sahlite and hornblende, accompanies the ore, and seems to have been the chief object of attention to those who have undertaken mining here.

Fragments of magnetic iron-ore occur in many places on the surface of the bold hill of crystalline rocks S. of the Lehigh, at Bethlehem, where some search has been made for it by digging. South-west of Shimersville, near the E. end of the same ridge, a vein of green sahlite, which has been mistaken for iron ore, shows itself near the summit of a hill. Close to this spot, some true iron-ore was found by us, the source of which is probably a little N. of the sahlite. Epidote, mixed with iron ore, also occurs here. Farther W., near the summit of the same ridge, magnetic iron-ore in a talcose rock is visible, near Shuber's, 3 miles from Bethlehem; it has not been dug for. The same variety of ore, of excellent quality, is found on the surface, near the top of the N. gneissic ridge S. of Allentown, at a spot a little W. of the Philadelphia Road. A less magnetic variety is met with on the N. slope of the hill, a mile to the E. of the road. Farther to the S.W., the magnetic iron-ore shows itself in the hill 3 miles S.E. from Metztown, the spot being a little W. of the Philadelphia Road. It is on the S. side of the second gneiss ridge from the N. The ore occurs in three regular veins, dipping with the adjoining strata at an angle of 50° to the S.S.E. The S. vein is about 1½ feet thick; N. of it occurs a stratum of rock (gneiss), 8 feet across, in contact with which is the middle vein, separated near its outcrop into two branches, which at a little depth unite into one vein; this is bounded on the N. by a stratum of rock about 4 feet in thickness, and directly in contact with this is the third or N. vein, having a thickness of 2 feet. The rock which encloses these several veins is a coarse regularly-stratified gneiss, a mixture chiefly of quartz and felspar.

MOUNT PLEASANT IRON-MINES.

Some miles to the S. of the above locality, magnetic iron-ore occurs on the border of Colebrookdale and Hereford townships, in the Mount Pleasant iron-mines. In the N.E. excavation the ore occurs between sienitic rocks, and is itself a mixture of rotten sienite and magnetic oxide. It is worked open to the air in a drift 10 or 12 feet wide, ranging E. of N. The dip here is 65°, and a little S. of E. The quality of the ore is variable. A few hundred yards more to the S.W. is another mine; it includes two large excavations, pursuing apparently a regular vein or bed parallel with the strata. Two other excavations occur about 200 yards W. of S. from these. Here the bed has a nearly E. and W. direction, and may probably be the same which contains the mines just previously spoken of. This ore, more compact than that of the other mines, is stated to have made a rather red-short iron.

The next locality of importance is the old iron-mine belonging to Oley Furnace, nearly 2 miles N.W. from Friedensburg. At this spot the ore was dug from immediately under an outcrop of the Primal sandstone, the digging running parallel with it for more than 100 yards, and being 18 or 20 feet deep, and 8 or 10 feet wide. This mine, now abandoned, furnished us some specimens from the side-wall of the excavation; these are argillaceous and laminated, and of a purplish-red colour. A shaft unites the main excavation with another nearly under the first, having about the same direction, but descending more perpendicularly. This latter mine is from 3 to 5 feet wide; the wall is of metamorphic rock, chiefly felspathic and hornblendic gneiss, but sometimes entirely micaceous, and it contains, in certain places, magnetic and micaceous iron-ore. The rocks passed through in a tunnel are gneiss, sienite, hornblende, and micaceous slates.

On Pine Creek, in Pike Township, some diggings have been made for ore, about half a mile S.E. from Lobach's mill. The ore has the aspect of a talcose slate, charged with the oxide of iron; it has a laminated or rather a fibrous structure. There are several extensive mines at Boyerstown wrought chiefly by Reeves, Buck, and Company. The ore vein varies in thickness from a few inches to 20 feet. It resembles that of the Roudenbush and other mines near Reading. It dips S., and ranges E. and W. It has been wrought by shaft and slope.

Near Pricetown, on Rauzbaun's farm, an old pit or shallow shaft has been reopened. The ore is highly magnetic, and of an excellent quality, but the vein is not a promising one, being only a few inches thick.

At Roads's, nearly 2 miles E. of Pricetown, there is a vein of superior magnetic iron-ore, said to be between 5 and 6 feet thick. Its dip is perpendicular.

In Alsace Township, a vein of the ore has been opened 2½ miles S. of the canal. This vein occurs in gneiss rock, and is double, being divided by a wedge of granite, or granitoid gneiss. The strata dip S. 80°, and the vein has the same inclination. The whole thickness of the vein is about 8 feet, but the good ore measures only 4 feet, and this is in two veins of 2 feet each, the rest of the ore being very inferior.

PENN'S MOUNT ORE-VEIN.

In the district we are now describing, though not strictly within the gneiss itself, there is an important vein of igneous iron-ore, which has been wrought for some years. It is opened on Penn's Mount, about half a mile E. of Reading.

The vein apparently is injected conformably to the bedding of the Primal white sandstone, and the ore is not accompanied by any bounding wall of igneous rock, but is in immediate contact with the sandstone itself. The latter rock disintegrates quickly on exposure to the atmosphere, and develops innumerable small grains of hornblende, which speckle the yellowish-grey sand. The ore-vein ranges from the Reading Fair ground, a little S. of E., dipping 45° S. Its thickness is seldom less than 18 inches, and has been as great as 28 feet. Under this enlargement it does not appear to suffer in quality. The ore itself is of the granitoid variety, highly crystalline, containing quartz and felspar, especially the latter, in great abundance: hornblende and apatite enter also into its composition.

The vein has been wrought at its surface, outcropping in the Reading Fair ground, and for one-third of a mile E., by Eckert and Brother, the Phœnixville Iron Company, and others, on the lands of Mr Oakley and B. Davis. The principal mine is the vertical shaft of Eckert and Brother: this is sunk 142 feet to the level of a tunnel, which is cut N. 28 feet through rotten sandstone to the top of the vein. From this tunnel the vein is followed by a gangway 30 feet E. and 115 feet W. The ore is worked along the foot-wall rising towards the surface, the hanging wall or roof being supported by timbers. The length of breast to the old surface-level workings is 72 feet. The ore from this old level was obtained to a depth of 82 feet. The Phœnixville Company are now obtaining their ore from a surface-level and whin-shaft E. of Eckert's Mine. In Eckert's old level, 100 feet W. of the whim-shaft, the vein split, but the north branch vein thinned away in 100 feet.

The *Island Mine*, situated on an island in the Schuylkill, one mile below Reading, has been wrought by Eckert, Syfert, and Company, but is now, perhaps temporarily, abandoned. The vein dips about 40° N.W. It is overlaid by dense brecciated limestone, locally known as "all sorts" limestone. This is, no doubt, the Mesozoic conglomerate, which appears in the opposite bank of the river *in situ*. The N.W. dip of this rock has no doubt regulated the dip of the injected material. The under-rock of the vein we do not certainly know, but from the specimens seen, it appears to be an impure silicious limestone, or that usually termed "bastard." The surface of the island is strewn with igneous rocks, but we are informed that none are found in contact with the vein.

The iron-ore vein, which is in thickness from a few inches to 15 feet, is a heavy, fine-grained slate-blue rock, containing lime in its constitution, and decomposing rapidly on exposure to the atmosphere. When decomposing, it assumes a deep sea-green colour, and develops copperas on the surface, from the sulphuret of iron in the ore. In some specimens the pyrites have so much the aspect of sulphuret of copper that chemical evidence is required to correct the impression.

A slope has been sunk upon the vein 90 feet below the surface, and, 28 feet above its foot, gangways are driven along the vein 20 feet towards the N.E., and 250 feet S.W.

About half a mile W. of the preceding is the *Roudenbush Mine*, which, we are informed, yields its proprietors at the Phœnixville furnaces 5000 tons of ore per annum.

The vein ranges a little N. of E. Its foot-wall is white metamorphic limestone, or marble, and its hanging-wall, or roof, a dull sea-green serpentine-like rock, which on exposure soon crumbles down like ordinary shale.

The vein, dipping 36° S., is followed by a slope 280 feet beneath the surface. At the bottom, gangways are driven 200 feet W., and 400 feet E., to a fault cutting out the vein. A higher level, 160 feet from the surface, is driven 300 feet E. The ore is now taken from this level.

Like all others, this vein is exceedingly variable; while wholly or almost entirely absent in some places, in others it has been found 30 feet thick. Its average bulk will not exceed 12 feet.

The gangue-stone of the ore is a light-blue rotten limestone, from which the ore is scarcely distinguishable, except by its greater weight and deeper tint. Of the entire ground wrought, about one-half the material is sufficiently rich in iron for the furnace; the remaining rubbish is used as stopping in the old workings.

The *Wheatfield* Mining Company have opened a series of veins about 5 miles W. of that last described. At this locality there are already proved about ten veins of igneous ore, ranging N. and S., and all included within a transverse distance of 150 feet. The maximum thickness attained by any one of these veins is 8 feet. They are opened from the surface over an irregular area to a depth of about 40 feet, and have been followed along the outcrop from 50 to 110 feet. They occupy loose unstratified ground, including igneous rocks, to the depth at which they have been mined; and below that, as they are included in the beds of the Mesozoic conglomerate, they become pyritous, and are not wrought.

The ore is similar in general aspect to that of the two last-described mines. It frequently encloses fine crystals of calc-spar.

A narrow valley separates these veins as far as they have been traced N. from an E. and W. vein, which is worked by a slope. This vein dips 30° S. It is underlaid by a foot-wall of trap, and overlaid by white crystalline marble. The thickness ranges between 2 and 12 feet. There is a strong admixture of lime in the ore. The slope is sunk 78 feet, and a gangway is driven 110 feet E.

In the range of the E. and W. vein of the Wheatfield Company, but a fourth of a mile farther W., is situated the *Henry Ruth Mine.* The vein, which is, in all probability, the same, having similar walls both above and below, dips 25° S., and has exceeded 15 feet in thickness. The slope upon it is 120 feet long, and gangways are driven 45 feet W. and 60 feet E. It has been also wrought at the surface outcrop.

An analysis of some of the ores of the gneiss, including a few of those of the South Mountain range, is here appended.

ANALYSIS OF IRON ORES OF THE GNEISSIC ROCKS OF PENNSYLVANIA.

Localities.	Peroxide of Iron.	Protoxide of Iron.	Silica.	Alumina.	Magnesia.	Lime.	Potash.	Titanic and other acids.	Water.	Metallic Iron in 100 parts.	Description of the Ores.
Near Isabella Furnace, Chester County, . . .	...	76.86	...	...	...	...	...	Tit. acid, 2.39	...	59.44	Black, lustre metallic, foliated and granular, magnetic polarity.
Yellow Springs, Chester Co.,	82.91	...	3.32	1.35	...	...	...	...	13.90	57.55	Brown hæmatitic ore, lustre resinous.
Fegle's Mine, 3 miles S.E. of Metztown, Berks County, .	88.92	...	10.60	a trace	...	...	...	...	0.20	65.52	Iron-black, imperfect crystalline, splendent, magnetic polarity.
1 mile S.E. of Millerstown, Lehigh County, . .	85.50	...	12.60	a trace	...	...	...	...	1.25	63.00	Iron-black, lustre semi-metallic, imperfect rhombic crystals, magnetic polarity.
Schmultz Farm, Alsace, Berks County, . . .	57.10	24.50	12.10	4.15	0.52	0.60	..	Tit. acid, 0.75	0.28	58.95	Iron-black, imperfect crystalline, magnetic, specks of hornblende, from the richer part of the vein.
½ mile E. of Reading, Penn's Mount, ...	36.50	16.25	24.17	6.20	7.10	5.67	3.30	Phos. and fluor. acids, 0.81	...	37.00	Crystalline magnetic ore, with hornblende, felspar, quartz, apatite.

CHAPTER II.

IRON ORES OF THE PRIMAL SERIES.

The slates of the Primal series, especially the upper Primal slate, yield two classes of iron ore: one, a very ferruginous variety of the rock itself, under conditions of more or less metamorphism; the other, a class of rich brown hæmatitic iron-ore of superficial formation. To the first class belong the valuable and noted mines of Cornwall, in Lebanon County, the Jones Mine in Berks, and partially the Chestnut Hill Mine near Columbia, and some of the ore diggings near Safe Harbour. At all of these localities the ore appears to be an original constituent of the Primal slate, but to have undergone a more or less degree of segregation from the substance of the rock by some agency connected with the metamorphism of the stratum. In many parts of the mass the oxide of iron is in a crystalline condition, dispersed in small specks throughout the other mineral constituents of the rock, which retains all its original features of stratification, and which resembles very much a mica-slate, or other metamorphic schist. This highly-altered ferruginous form of the rock is also in many instances subdivided by innumerable cleavage-fissures, the effect of which has been to change the semi-crystalline magnetic iron-ore to the ordinary brown peroxide or limonite by the copious admission of the surface waters and atmosphere into the body of the rock. In some spots, long exposed to abundant soakage through the cleavage-cracks, the iron ore is not only thus changed, but is actually collected into the deep narrow clefts of the rock worn by the percolation of the waters in the direction of the cleavage, so that in a cross section of the mine we may witness the curious anomaly of the ribbon structure or laminæ of stratification dipping one way, and the plates or veins of the accumulated iron-ore, and its associated clay, dipping independently at a steep intersecting angle.

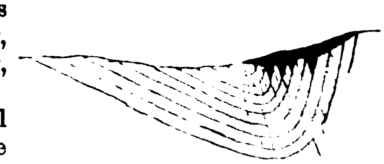


FIG. 573.

The annexed little cut (Fig. 573) exhibits a synclinal basin of the Primal slate thus percolated with ore to a certain distance from the surface in the direction of the cleavage-fissures.

An illustration of this mode of accumulation of the iron ore in the clefts connected with cleavage has been already furnished in Volume I., page 218, where a section is shown of the Rathfon Ore-bank, near Safe Harbour (see fig. 27), the only difference being, that the rock is the Auroral magnesian limestone, interstratified with talcoid slate, and not the Primal slate itself.

The other kind of ore derived from the Primal slates is the hydrated brown peroxide deposited upon the surface of the formation from the ferruginous loamy matter derived from the complete disintegration of the slaty rock. Nearly all the large deposits of the formation contain a greater or less proportion of this species of ore, and some of them consist of it almost exclusively. In the extensive open cutting called the Chestnut Hill Ore-bank, near Columbia, of which a description has already been given (Vol. I., p. 182), much ore is seen to pervade the lower layers of the altered Primal slate, while a large and dense body of the peroxide of iron has been accumulated at the very base of the formation, by a downward soaking of the surface-water collecting and concreting the ore in a dense and thick stratum or rude mass upon an impervious floor of close-grained Primal white sandstone.

The following circumstantial description of the iron mines at Cornwall, Lebanon County, shows the several phases under which both classes of the Primal ores, the segregated semi-crystalline and the concreted hæmatitic varieties, prevail.

At this locality the actions collecting the oxide of iron into its present conditions have been somewhat complicated. The ferruginous Primal slate has been metamorphosed, and its oxide of iron segregated and crystallised through the influence probably of highly-heated volcanic steam, and the same influence has produced a very general cleavage-structure. During the same action, or subsequently, numerous injections of molten hot lava, resulting in dykes of trap-rock, have invaded the stratum, and have still further changed the condition of the mass, infusing among it, probably by sublimation, some trappean mineral matter, and especially some sulphuret and carbonate of copper; and since these subterranean influences, the atmosphere, through its rains, has exerted itself through countless ages to modify still further the chemical and physical conditions of the shattered and fissured mass, and its contained oxide of iron.

CORNWALL IRON-MINES.

This great iron-ore deposit, by far the most extensive, and one of the most interesting in the State, is situated at the outcrop of the Primal upper slates, where they rise from beneath the Auroral limestone in

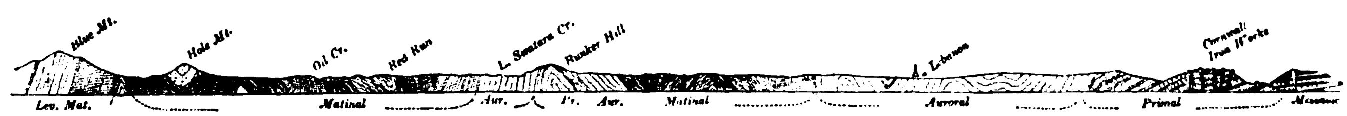


FIG. 574.—Section across Kittatinny Valley, from Blue Mountain to Cornwall, 15 miles.

Lebanon County, on the S.E. border of the Kittatinny Valley. The geological relations of these mines on the border of the Kittatinny Valley are shown in Fig. 574.

The ore strata are embraced in three hills, having a nearly E. and W. range. These hills are flanked to the N. by the Auroral limestone, and S. by the overlapping unconformable Mesozoic red sandstone, which forms a high ridge prolonged E. and W., and overlooking the valley. Their position is five miles S. of the town of Lebanon.

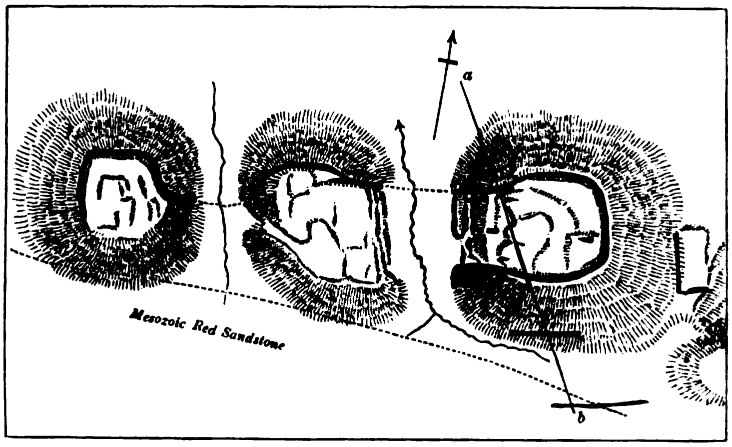


FIG. 575.—Map of the Cornwall Ore Hills, Lebanon County.

The Eastern or "Big" Hill is elevated 312 feet above the level of the creek at its base. The middle hill is 98 feet high, and the western hill 78 feet high. The peculiar features of each of these will be considered in detail.

The bounding wall of the ore in the Big Hill is a heavy dyke of trap, which varies in regard to texture and composition as the felspar or hornblendic element predominates. This massive dyke, the thickness of which seems nowhere less than 40 feet, and probably greatly exceeds this,

FIG. 576.—Section through Cornwall Iron Mines, Lebanon County, along line *a b*.

encircles the hill on three sides, the S., E., and N., somewhat in the form of a horse-shoe. The N. limb rises from the water-level at an angle of 60° or 70°; on descending to the water-level upon its S. limb, the dyke bends sharply S., and is obscured by surface debris. Besides this general outer wall of trap, there are several smaller dykes of the same material; some of these appear to be offshoots from the main dyke, and are found in one or two instances interstratified with the ore. In other cases they appear as simple isolated columns of rock, surrounded by ore, and not traceable longitudinally through the hill, as the section would imply. At water-level, on the W. side of the hill, the two limbs of the ore enclosing trap are about 400 feet asunder, but on the hill-top, as a consequence of their opposing dips, they are 500 feet, or even 600 feet apart.

The ore in this hill is nearly horizontally, though irregularly stratified, and presents every possible aspect, from slaty greenish-grey to dark green and dark ferruginous brown and black: the latter variety is found chiefly

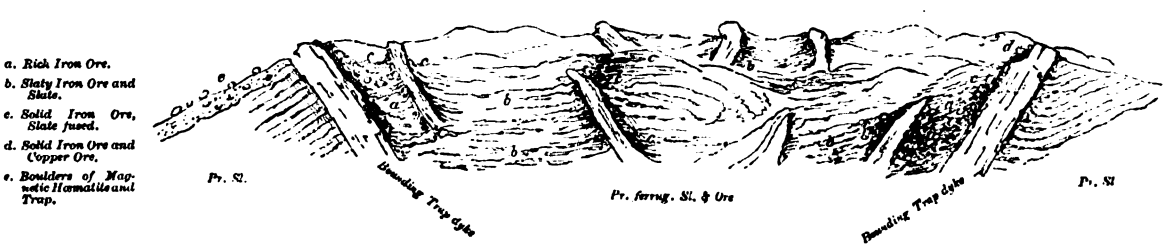


FIG. 577.—Big Mine Ore Hill, Cornwall Iron Mines, Lebanon County.

in the vicinity of the trap dykes, and large masses are strewn extensively upon the hill-sides, especially upon the N. and S. slopes. This variety, known locally as the Nigger-head ore, is very highly endowed with magnetic polarity. As we recede from the vicinity of the intrusive rock, the ore becomes lighter in hue, and more slaty in texture. In parts of the mine these slaty portions are too poor in iron to be wrought. With the exception of those portions of the ore which are closely adjacent to the trap, the mass teems with crystals of sulphuret of iron; almost every hand-specimen displays many specks and small intersecting veins of it. This pyrites increases in abundance as the mining penetrates beneath the surface, or as the ore has been unaffected by atmospheric influences.

Copper ore is found at times, in the form of green carbonate and grey oxide, impregnating the iron ore, but it does not appear as a vein, nor is it in contact with the dykes of trap, though probably introduced at the time of their intrusion.

The iron ore hitherto obtained from the Big Hill has been taken from shallow excavations at the surface; it is now wrought exclusively at the W. base, where successive benches are cut down from the surface to the railway level.

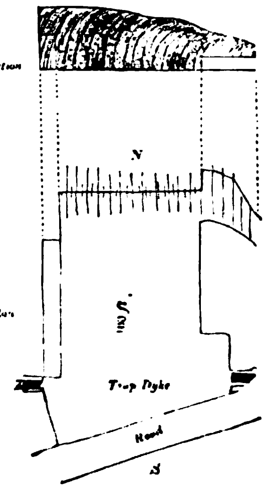


FIG. 578.—Ore Quarry, E. base of Big Hill, Cornwall, Lebanon County.

At the E. base of the Big Hill there is a small rectangular excavation (see Fig. 578) of black and yellow crumbly ore, the bedding of which is nearly vertical, ranging N. and S. parallel to the face of a trap dyke which bounds it. This wall of trap is parallel to that at the E. edge of the Big Hill, 200 yards distant: whether it is the outer face of the same great dyke has not been determined. On the E. side of the pit another dyke of trap is visible, but the excavation has not been sufficiently extensive to determine its range or amount. A third narrow dyke crosses the S. end of the excavation. The ore at this mine is granular and black, chiefly crystalline, or dark grey, in the vicinity of the trap; and in other places it is yellow and dark green, from atmospheric action.

The Middle Hill, separated from the Big Hill by a narrow valley, through which flows a small stream known as Saddler's Run, is that from which at present the ore of the district is chiefly obtained.

The N. wall of the ore is the prolongation W. of the trap dyke which forms its N. boundary in the Big Hill. This dyke ranges W. through the Middle Hill, deflecting gently S. along its W. slope; it then crosses the valley, separating this from the W. ore hill, and soon after turns N., then W., and finally curves S. round the end of the latter, and is lost to view. Owing to the S. turn of the Southern limbs of the dyke at the W. base of the Big Hill, it does not cross the valley, and does not appear in either of the two W. hills, in both of which the boundary of the ore at the surface is formed by the overlapping debris of red sandstone and conglomerate from the neighbouring hills. The general appearance and character of the ore in the Middle and Western hills is similar to that of the Big Hill. It is slaty throughout, and very pyritous; for which reason it soon crumbles under exposure. In those parts of the mine where the ore has been cut down cheese-like by the miners, the natural bedding of the mass is curiously contorted and irregular along a general horizontal plane. On the S. side of the Middle Hill, the excavation has reached the water-level. In the pit, large masses of light blue flinty and magnesian limestone are found imbedded with and surrounded by ore. They are devoid of regular form. In like manner, masses of quartz are found as bunches in the bedding of the more slaty ore. In some of these, thin scales of native arborescent copper occur, though not abundantly. The white cupreous quartz seems to be derived from a vein of that material. The limestone is evidently not *in situ*.

On the Middle Hill several small veins or bunches of copper have been wrought to a limited extent. Four of these range N. and S., with one exception dipping W. The direction of the strike is at right angles to that of the iron ore, which dips N. about 30° in this part of the mine. The thickness of these veins varies between half an inch and 3 inches. A fifth vein may be traced on an E. and W. range at the S. limit of the mine. This lode is occasionally entirely absent, but is in some places a foot in thickness, dip S. 45° to 50°. It should be remarked that these lodes of copper are thick where the iron ore is soft, and that they thin away when the bounding walls of the iron ore are hard and pyritous. The usual varieties of copper ore extracted are grey protoxide, bright red dinoxide, green and blue carbonates of copper, intermixed with sesquioxide of iron and iron pyrites; also rich specimens of the sulphuret associated with green and blue carbonates of copper. The lodes are nearly all accompanied by veins of green steatite. They have not been traced across the ore-deposit to the bounding trap-rock, but have been found within 50 yards of it, growing perceptibly thinner. When followed below the surface, they become poor in good ore, and merge into copper and iron pyrites. The annual yield in copper ore does not exceed 100 tons. It is smelted in Baltimore, and yields, we are informed, from 15 to 23 per cent of copper. The average annual product of iron ore is about 120,000 tons, but the mine is susceptible of being wrought upon almost any scale. A small ore-pit, from which no ore is at present extracted, known as the Doner Mine, is situated 1½ miles E. of Cornwall. The ore, though of the magnetic variety, appears in irregular bunches and nests. No trap injections are found in the vicinity. The deposit is quite near the limestone, and is intermixed with sand and gravel.

Those interested in the discovery of iron ore in this part of Pennsylvania should explore carefully the more metamorphosed tracts of the Primal slates, especially where these adjoin the limestone.

SURFACE IRON-ORES OF THE PRIMAL SERIES.

The Primal newer slate sustains extensive surface-deposits, of a somewhat distinctive variety, of brown hæmatitic ores, a few descriptive and theoretical observations upon which may not be out of place here. These relate not only to the ore of this formation as it is seen in Pennsylvania, but to the whole enormous outcrop of the stratum wherever it is largely developed from E. Tennessee to the Green Mountains of Vermont.

This iron ore is lodged in extensive accumulations of yellow ferruginous loam and clay, occupying hollows or basins in the surface of the Primal newer slate, at the N.W. base, or low on the N.W. slopes, of the ridges and spurs of the S. Mountains of Pennsylvania, or of their prolongation the Blue Ridge in Virginia and Tennessee, and the Green Mountains in Vermont. Diluvial waters have apparently caused these deposits of loam, into the lower parts of which the particles of the oxide of iron have been conveyed by the dissolving and transporting action of percolating waters, and there collected into irregular nodular masses of very various structure. Some of these are stalactitic, but the ore of the Primal slate is more frequently in roundish cellular lumps, and even sometimes in hollow bomb-shaped geodes. The latter often consist of crystallised fibrous hæmatite, but the earthy brown hydrated peroxide is by far the most commonly met with. The masses are distributed in the loam without definite stratification, or any apparent order, being in greatest abundance towards the bottom of the deposit.

In some of the present class of mines, though not in all, there occur, mingled with the iron ore, small masses of peroxide of manganese, and these are occasionally stalactitic in their form. The oxide of manganese is, moreover, chemically combined with the oxide of iron in much of the iron ore, and, when in any considerable abundance, is a serious hindrance to the fusion of the ore in the blast-furnace. For this reason it is that these ores have usually been less in favour with our iron-smelters than the purer varieties which overlie the adjacent tracts of the Matinal limestone. Respecting the ultimate source of the oxides of iron and manganese, it is to be sought in the ferruginous slates upon which the deposits repose. The loamy soil imbedding the ore appears to have been derived from the disintegration of the slate previously collected in a fragmentary or even pulverised condition in the depressions of the surface. Under the action of the percolating rain and springs, these materials would be converted into a mere loam, and the oxide of iron set free. Much of the iron has been originally in the condition of the sulphuret of iron, diffused in minute crystals through certain layers of the slate. The facility with which this mineral undergoes decomposition, and gives rise to hydrated peroxide of iron upon the access of atmospheric air and the rain water, is a fact familiar to chemists. This view of the origin of a part at least of the ore, accords with what is known concerning those slaty rocks which contain much sulphuret of iron.

Such strata become changed in their exposed or outcrop portions with the brown peroxide, and, where circumstances have favoured a deep and general decomposition, we find nests and seams of the peroxide associated with masses of the rock in all the intervening stages of chemical change. Among those older metamorphic micaceous and talcose schists which are sufficiently pyritous, these conditions are as frequent as among the slates, shales, and limestones of the Appalachian Palæozoic formations. The separation of the peroxide of iron from the other materials of the disintegrated slate, is sometimes so complete as to leave a white earthy residuum of finely-subdivided particles, having the character of a pure silicious clay. This occupies the interstices between the nodules of ore, and is common in the interior of the hollow masses. So entire a separation of the oxide of iron from the earthy substances as this clay manifests, must be attributed to some further action than the mere transporting power of the percolating waters. It seems to imply the operation of a *segregating force* among the particles identical in chemical nature, in obedience to which the atoms of oxide of iron have detached themselves from the other matter, and concentrated themselves around particular centres, as in other cases of nodular concretion.

ANALYSES OF SPECIMENS OF HYDROUS PEROXIDE OF IRON OF THE PRIMAL SLATES, PENNSYLVANIA.

Locality.	Peroxide of Iron.	Oxide of Manganese	Alumina.	Silica and Insoluble Matter.	Water.	Occasional Ingredients.	Loss.	Metallic Iron in 100 Parts.	Description of the Ores.
Chestnut Hill, near Columbia,	84.39	...	2.46	2.38	10.99	...	...	58.51	Brown, compact, mammillary, outer part crystalline and radiated.
Susan Ann Furnace, York County,	40.71	8.91	2.84	39.56	7.98	Phos. acid.	...	28.23	Blackish-brown, micaceous, and sandy.
Ege's Mountain Bank, S. of Carlisle Ironworks, Cumberland County,	49.80	17.55	0.10	20.10	12.0	...	.45	33.86	Dull purplish-brown, amorphous, brittle, earthy.
A mine ½ mile from Carlisle Ironworks,	27.93	a trace	a trace	3.30	2.81	Magnetic oxide 64.79	.17	65.88	Dull-black, sub-crystalline, slightly magnetic, resembles ores near trap-dykes.
Mountain Bank, Carlisle Ironworks,	70.04	3.32	a trace	16.32	10.96	...	...	48.56	Brown, mottled, rather cellular, "honey-comb ore."
Miller's Mountain Bank, Cumberland Furnace, Cumberland County,	74.08	...	0.04	12.00	12.0	...	.8	52.36	Brown, hæmatitic, and porous.
Peffers' Bank, 6 miles S.W. of Carlisle, Cumberland County,	69.04	...	4.03	12.01	14.0	...	.2	48.58	Dark brown, with ochreous spots, compact.
Mine 1¾ miles from Carlisle Ironworks,	85.65	...	a trace	4.05	8.80	...	.90	59.95	Chestnut-brown, stalactitic, pipe small.
Pond Bank used at Caledonia Furnace, Franklin County,	79.05	...	a trace	9.30	12.00	...	...	55.33	Dark chestnut-brown, hæmatitic, imperfectly crystallised.
Hill Bank, Southampton Furnace, Franklin County,	78.85	a trace	2.70	5.90	12.50	...	.05	55.19	Chestnut-brown, cellular; cells sometimes crystalline.
Hill Bank, inferior variety,	76.30	1.00	1.80	5.80	14.50	...	.60	53.41	Dark and light brown alternating, cellular and amorphous.
Montalto Furnace (lower ore), Franklin County,	75.02	...	3.03	7.00	14.0	...	.5	52.64	Dark brown, cellular; cells lined with light ochreous matter.
Montalto Furnace (upper ore),	71.00	...	2.05	13.03	12.6	...	.6	49.70	Mottled-brown and ochreous, parts compact, parts soft and cellular.
A mine 1 mile S.W. of Hughes' Forge, Franklin County,	79.10	4.00	1.40	2.80	12.0	...	.70	55.37	Dark brown, massive, compact, lustre resinous.
Pond Furnace Ore, Franklin County,	73.05	a trace	2.06	10.00	13.0	...	.9	51.35	Brownish-yellow, semi-crystalline, and mammillary, hæmatitic.

The peroxide of iron is very slightly, if at all, soluble in pure water, but is dissolved to a certain extent by water impregnated with *carbonic acid.* The superficial waters containing a portion of this acid, derived from the atmosphere, through which they have all fallen in the form of rain and snow, are capable of slowly conveying the peroxide in a state of solution from the surface to the deeper parts of the mass, where, by the gradual escape of the carbonic acid, the peroxide has become deposited. In the decomposition of the common sulphuret of iron, such as is found in pyritous slates, the sulphate of iron formed is *very soluble;* and this, pervading the surrounding mass, has gradually given up its oxide of iron by a decomposition promoted by the presence of earthy and especially of calcareous matter. The preceding analyses display the composition of the several varieties of the brown ores of this formation.

CHAPTER III.

IRON ORES OF THE AURORAL AND MATINAL SERIES.

Respecting the origin of the Auroral limestone ores, there appears to be no necessity for referring to any other agencies than those alluded to in treating of the history of the ores of the Primal series. Waters impregnated with salts of iron readily deposit the peroxide when in contact with carbonate of lime, and we might therefore look for deposits of the ore in situations favourable to the accumulation of the debris of ferruginous slates, and to the infiltration of waters charged with sulphate of iron derived from the decomposition of the sulphuret contained in such slates. Many of the layers of limestone, especially those of a slaty structure, contain much sulphuret of iron, and the great mass of the Matinal limestone formation includes a large amount of but slightly calcareous slates, more or less pyritous in their composition.

Among the circumstances which usually indicate an abundance of the limestone ore beneath the soil, it should be mentioned that one of the most essential is a considerable thickness in the deposit of ferruginous loam, clay, or other earthy matter, resting on the strata. This will, of course, be marked by a corresponding evenness of the surface; for where the beds of limestone are naked of soil in many places, the covering of earth, which must contain the ore, can nowhere be deep. Another very necessary condition is, that the earth overlying the rocks should have a large amount of the oxide of iron diffused in it. This will show itself by a characteristic bright yellow or clear brown colour. It must be observed, however, that the existence of a large quantity of oxide of iron in the deeper part of the soil will very frequently not be perceptible in the colour of the surface of the ground—the ore being confined to the lower portions of the mass—so that much good ore-ground is often neglected from want of perseverance in digging.

The iron ores of the Matinal slates are obviously traceable to sources similar to those of the ores of the Primal slates and Auroral limestone. In the Matinal slate ores, the proportion of oxide of manganese is often very great, and not unfrequently the ore passes in neighbouring beds into nearly a pure oxide of manganese. Indeed, it is chiefly in the upper part of the Matinal slates, and in the Primal slates, that this latter mineral is met with in deposits of sufficient extent to be valuable. The olive-coloured layers of argillaceous and sandy slate, forming a chief part of the Matinal newer slate, owe their colour in great part to the large amount of protoxide of manganese which they contain. In the disintegration of the rock this is dissolved, and, being converted into peroxide by exposure to the atmosphere, is deposited in irregular layers or concretions in situations favourable to its accumulation.

Having in Vol. I. page 263, expressed a hope of being able, before the completion of this work, to present some more recently-collected details of the Surface Iron Ores of the Kittatinny Valley, I here introduce the results of observations since made respecting the chief mines between the Delaware and Schuylkill rivers.

IRON ORES AND MINES OF THE KITTATINNY VALLEY.

I.—OF THE DISTRICT BETWEEN THE DELAWARE AND LEHIGH RIVERS.

Goetz Mine.—This is an old and extensive pit, and the only one from which ore is regularly obtained in the district N.E. of the Lehigh River. It is situated within the valley of limestone, 4 miles N. of Bethlehem. The excavation, which has reached a depth of nearly 60 feet, extends over two-thirds of an acre. The ore is chiefly a bright red hæmatite or hydrated sesquioxide of iron, the origin of which is clearly betrayed by numerous large masses of silicious rock found in the mine. These masses closely resemble the ore externally, and are, indeed, partially converted for some distance beneath the surface. In one part of the mine the rock was found somewhat regularly bedded over a mass of ore and clay, but it has been cut away to reach the materials beneath. In its texture it is a rather coarse sandstone of limestone-blue colour, and evidently contains lime. It may be termed a very sandy limestone, or calcareous sandstone.

The bed of ore at present mined underlies a thick mass of light-blue and ferruginous-brown clays. Its dip, which is flat near the surface, steepens to 45°, and again turns nearly horizontal at the floor of the mine. It crops out towards the N.W. In thickness the bed varies from a few feet up to 15 feet. In the S.E. parts of the mine no ore is at present excavated, and rubbish has obscured the bedding, if it has any. The clays contain disseminated masses, which may be separated from impurities by washing. The nearest rock-exposures are of limestone, dipping S.E. at a high angle. The yield of the mine does not exceed 4000 tons per annum.

II.—OF THE DISTRICT BETWEEN THE LEHIGH AND SCHUYLKILL RIVERS.

Beisel's Ore-Mine is situated on the Catasaqua and Foglesville Railroad, 5 miles from Catasaqua. It is an open pit of red hæmatitic ore, lying closely adjacent to a ridge of limestone which dips nearly vertically S.E. The ore is irregularly deposited, not in any stratified bed, but in nests or bunches, and cannot be traced to any considerable distance from the mine. The pit, which is 50 feet deep, is wrought for the Lehigh Valley Furnace, the ore being raised by an inclined plane and horse-power. A fourth of a mile S.E. of the mine rises a conspicuous ridge of calcareous slate, and at the foot of this is the

Trexell Ore-Mine, wrought by the Crane Iron Company. The ore is raised by steam-power, from a shaft sunk 60 to 70 feet. It is very irregularly disseminated through clay and earth, but little lump-ore being found. All the material raised from the pit requires washing, and the ore is not very abundant. The yield of the mine is 2000 tons per annum. In neither this nor the preceding mine has the rock-floor been reached.

Ritter's Bank is at the foot of the limestone ridge, in the prolongation of Beisel's ore-deposit, and but a few hundred yards distant. It is but recently opened, and the mine is small. In character and mode of deposit it in all respects resembles Beisel's. The ore is smelted at the Lehigh Valley Furnace.

The Guth Mine has been wrought for many years, and is now leased to the Crane Iron Company. It is situated on the W. side of the prolongation of the limestone ridge which passes Beisel's and Ritter's mines. This is apparently a monoclinal ridge of limestone dipping steeply S.E. The ore at the Guth Mine occupies a narrow trough which has been carved out of the limestone, as shown in the annexed cut. At its E. outcrop the ore was 20 to 30 feet thick, and inclined 75° W. It rests upon clay and sandy debris, and is overlaid by black clay, containing a large quantity of sulphuret of iron. This is capped by a tough white clay, which, when wet, assumes a semi-fluid condition, and soon covers the freshly-cut face of the mine. The insecure character of such a roof has prevented the mining of the ore where the increasing thickness of the covering makes it too expensive to remove it from the ore. Within 80 feet of the surface the ore-bed basins, but is somewhat thinner, and rises to the surface upon an E. dip, within 200 feet of its E. outcrop. On this side the ore has not been extensively wrought. The basin rises out within 100 feet N.E. from the pit, and the ore cannot be traced farther in that direction. In the main pit the ore is a velvety brown and black hæmatite, changing to red near the outcrop at the N.E. end of the mine. S.W. of this pit there are two others, within a few hundred feet. In the first of these a shaft, sunk to a depth of 80 feet, passed perpendicularly through 40 to 45 feet of dark-brown and black crumbly ore, dipping steeply N.W. Between this mass and that in the preceding pit the connection has not been traced, the thickness of the ore-deposit having greatly dwindled in the interval. The third opening does not merit attention; it was abandoned because of scarcity of ore. The yield of these mines is about 5000 tons per annum.

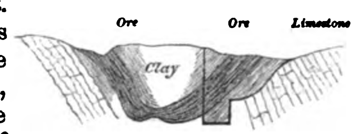


FIG. 579.—Guth Mine.

Kern & Albright's and *Hoffman's Mines*, closely adjacent to one another, are situated half a mile S.E. of Siegerville, and a fourth of a mile from Jordan Creek. The bedding of the ore in the former pit dips N.W. 20°, and rises upon the opposite dip in Hoffman's Mine. The two outcrops are about 500 feet asunder. In neither of these openings has the bottom of the ore been reached, though from 20 to 25 feet in thickness have been wrought. The ore is a brown oxide, quite regularly stratified; but the floor of the mines being covered by water, it could not be critically examined. It is capped by black clay, richly impregnated with sulphuret of iron, which is overlaid by white and variegated clays and earth. Between the two mines the ore is wrought by drifts and gangways in various directions. As is usual at the larger mines, the ore from both of these pits is raised by steam-power up an inclined plane. Hoffman's Mine, wrought for the Allentown furnaces, was not in operation at the date of our visit. Kern & Albright's, leased by the Crane Iron Company, yields from 9000 to 10,000 tons per annum. From these mines the surface slopes gently S.E. towards the Jordan, and is deficient in rock-exposures; on the N.W., however, we find the limestone dipping S.E., beneath the ore of the Hoffman pit.

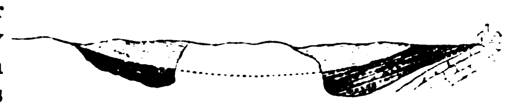


FIG. 580.—Kern and Albright's and Hoffman's Mines, near Siegerville.

At Siegerville an ore-pit was opened some ten years ago by Mr Sieger, and has been wrought by several iron companies, but is now abandoned. There is evidently a large body of valuable ore at this point, but the dilapidated condition of the mine prevented an inspection of its bedding or thickness. The dip is said to be N.W., and 68 feet depth of mining did not reach any rock-floor. The excavation extends over ½ of an acre.

Xander's old bank, the property of the Crane Iron Company, is ⅓ of a mile N.E. of Siegerville. This mine has not been wrought for six years, and is now in ruins. The ore, which is of the usual dark-brown hæmatitic variety, formed a bed dipping N.W., of a thickness varying from 12 to 20 feet. It was overlaid and underlaid by silicious pebbles. The position of this mine is near the boundary of the Auroral limestone, and the overlying Matinal slates, although these rocks are not found *in situ* in the vicinity of the mine.

Jos. Balliot's Mine and *Mickle's Mine*, separated from each other by the roadway, are situated 3 miles N.E. of Siegerville, and within one-fourth of a mile of a range of hills formed of the Matinal slates. In the former and larger pit the ore is almost exclusively of the brown variety; in the latter it is of a bright-red colour, and more crumbly character. The bottom of the deposit has not been reached. The bedding of the ore is horizontal. Beneath the upper stratum of brown ore in Balliot's pit reposes a band of black clay containing occasional masses of brown ore. These mines are very wet.

Stephen Balliot's and *Jeter's Mine* (formerly Shierey's) at Ironton, one-fourth of a mile N.W. of Jos. Balliot's, is a large excavation. From it the surface slopes gently S. towards Copley Creek; within a quarter of a mile N.W. the boundary of the Matinal slate ranges along the conspicuous ridge above-mentioned. This, as well as the other mines in the neighbourhood, seems therefore to lie among the alternating slate and limestone strata of the two formations. The gently-rounded surface of the hills, and the entire absence of rock-exposures, make it impossible to say under what precise conditions the ore has been deposited, with relation to the character and inclination of the subjacent strata. The nearest exhibition of rock displays limestone dipping N.W. towards the slate range at a moderately high angle.

The ore of this mine is of the usual brown hæmatitic variety, and is frequently quarried out in large masses; over the more solid body of the brown ore there is usually about 10 feet thickness of a more cellular honeycomb ore. The extreme depth of the pit is 50 feet, and ore has been mined throughout the distance. The floor of the deposit was not reached by a well sunk 16 feet from the deepest part of the mine. In a neighbouring smaller pit, belonging to Mr Balliot, both brown and red ore are obtained, though from different parts of the mine. The brown ore has a bedding which inclines 45° S.E. The ore-deposit at these mines is evidently a most extensive and valuable ore; but, as at present wrought, the annual yield does not exceed 4000 tons. Between it and Ritter's pit, a fourth of a mile farther N.E. along the same range, ore may be traced on the surface, and has been proved at several points. The continuity of the deposit between the two may perhaps be interfered with by a gentle rise prolonged from a knoll of limestone.

Ritter's Mine, leased by the Crane Iron Company, displays a fine body of brown hæmatite ore, varying from 30 to 40 feet in thickness, except at the outcrop, where the deposit is 12 feet thick. The dip is N.W., undulating at an average angle of 30°. The floor is of clay. Over the good ore the black clay is found capped as usual by white clay and surface materials. The depth of the pit is 45 feet, and its yield 6000 tons per annum. The limestone forming the lower slope of the slate hill dips S.E. towards the mine.

The slate ridge which forms the boundary of the valley of the Auroral limestone on the N.W. ranges S.W. from the vicinity we have last described, near the village of Foglesville in Upper Macungy Township of Lehigh County. Two miles S.W. of Foglesville it deflects S., and then N.E. for a mile as a spur, which courses S.W. as the general boundary of the limestone. The little cove of limestone thus enclosed is the seat of several rich deposits of hæmatite ore, which are extensively mined.

Sclough's Mine is situated 1¼ miles S. of Foglesville, at the N.E. end of the slate ridge to which we have just adverted. E. and S. of it the soil is all of limestone origin. The mine, though quite small, being recently opened, is interesting, as showing the hæmatite ore in several stages of development. At the pit the ore is a compact rocky brown and black hæmatite, graduating into a more rotten brown ore and ferruginous clay. In the trial-shafts sunk W. of the mine, the ore became more and more slaty, receding from the main body, and assumed the character of a rotten ferruginous slate quite valueless as an ore. The bedding of the ore has a gentle S.E inclination. The limited explorations that have been made do not warrant any judgment as to the extent or depth of the deposit. In the well sunk for water near the pit to a depth of 64 feet, black carbonaceous slaty limestone was encountered 36 feet beneath the surface, and continued to the bottom.

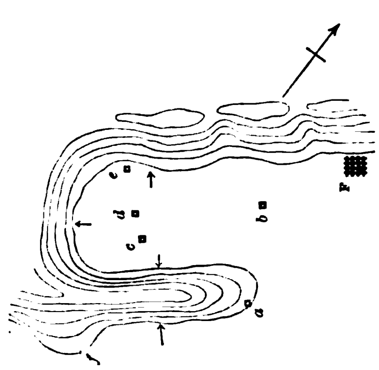


FIG. 581.

Haine's Pit is a small excavation three-fourths of a mile S.W. of Foglesville: it is now abandoned and in ruins. The ore is quite slaty in character, and apparently not abundant.

Miller's Mine is in the limestone cove S.W. of Foglesville. Like all the others, it is an open pit, from which the ore is raised by a slope plane and steam-engine. Its depth is 35 or 40 feet, extending over half an acre. There is a covering of from 5 to 25 feet of slaty debris over the irregularly-stratified ore. The bedding of the latter dips at a moderate angle S.E., but in that direction the ore rises to the surface again 100 yards distant, and was formerly wrought at the outcrop. As the bed sinks from the surface along the dip, the ore becomes more and more solid; but at places in the mine it is replaced by bodies of clay. A well sunk from the bottom of the pit to a depth of 18 feet, proved ore throughout that distance, though becoming lean at the bottom. The yield of this mine is about 2000 tons per annum. Leased by the Crane Iron Company.

Laurish's Mine, a few hundred yards W. of Miller's, is a small excavation not now wrought. Many fragments of the ore look not unlike a merely ferruginous slate externally, but when broken exhibit a close-grained brown hæmatite. The mine has been wrought for the Allentown furnaces.

Lichtenwalder's is an old pit lying close to the ridge of slate which bounds the cove on the W., and one-fourth of a mile from the last mine. The extreme depth of the pit is 55 feet. In some places the ore, all of which is a brown hæmatite, cavernous and velvety, is 40 feet beneath the surface, and at others it approaches and even outcrops upon it. There is no apparent or regular dip in the bedding of the ore, but the mass has a general inclination S.E. In parts of the mine white clay overlies the ore; in other parts surface materials are intermixed with it, in which cases washing is resorted to. The solid and softer ores are irregularly intermingled. From the deepest part of the mine, a well reached the clay bottom of the deposit at a depth of 14 feet. Yield, 3000 tons per annum. Ore delivered to the Crane Iron Company.

It is worthy of remark that in all the hæmatite ore-pits hitherto described, frequent cavernous, amorphous masses of flint rock are found disseminated, chiefly among the clays and softer ores. We also notice in the undecomposed calcareous slates which occupy the ridges bordering the ore districts, numerous crystals of sulphuret of iron.

Breinig's Mine is an old pit, now but little worked, on the S.W. prolongation of the slate range from Sclough's Mine, 2 miles N.W. of Breinigsville.

There is no appearance of any stratification in the ore, but it is disseminated through ferruginous earth, which is washed, and the ore picked out. The mine is in confusion.

Two miles N.E. of Trexlerstown are the mines of *Gachenbach* and others, formerly known as *Shoemaker's Mine.* There are several pits upon the same great body of ore, which dips rapidly (45°) towards the S.E. The ore bed has a thickness of 42 feet at the pit, including the interstratified clays: it is exclusively red hæmatite, becoming harder and more rock-like as it gains cover. At the main pit, from which ore is now raised, it has a covering of 25 feet of surface-earth and clay. This pit is 50 feet deep, but ore has been proved 24 feet below the level of the mine resting upon a cavernous limestone. All the limestone near the mine dips S.E. There is no appearance of slate. Yield, 2500 tons per annum.

Wickert's Mine is situated 1 mile E.S.E. of Texas, in Lower Macungy Township, and about 2 miles from the range of the South Mountains. The soil is underlaid by limestone, and the ore is obtained from shallow pits, and by stripping the surface. It is so mixed with clay and earth as to require washing to separate it from impurities. The ore, which is a rich brown and black hæmatite, is invariably found in small angular or formless fragments, and sometimes as hollow geodes. Occasional fragments of ferruginous slate and slaty ore betray its slaty origin, and the presumption is that the slate from which it was derived was interstratified with limestone. The locality is not now wrought, but it has yielded 2000 tons of ore.

A few hundred feet distant is a much deeper and more extensive deposit at *Gideon Andreas' Mine.* The pits have reached a depth of 20 feet, extending over one-third of an acre. Occasional masses of rich brown hæmatite are found, but the chief part of the ore is intermixed with ferruginous clays, which are washed. There is no appreciable or regular bedding of the ore. The precise yield of the mine we did not ascertain, but it probably amounts to 3000 tons a-year.

In the same immediate neighbourhood are *Yobst's*, *Christian Andreas'*, and *Weygandt's* open-pit mines. In all of these the ore is washed from ferruginous earth, with which it is so intimately associated that the uninitiated eye would fail to detect its presence. The yield from the washing is about one-fourth or one-fifth part ore.

Schmoyer's and *Rheinhart's Mines* are three-fourths of a mile N.E. of those last mentioned. In the first of these there is no regularity in the bedding of the ore, and all the materials derived from the mine undergo washing. In Rheinhart's pit the ore-deposit is embraced in an undulating belt of 18 feet. In the wells sunk for water to wash these ores, limestone is invariably encountered at a considerable depth, but its dip we were unable to ascertain. The Schmoyer Mine yields about 1000 tons per annum, delivered to the Crane iron furnaces. The product of Rheinhart's pit, about equal in amount, is smelted at the Allentown furnaces.

Near by is an old mine, now but little wrought, known as *Mark's* or *Whiteley's.* The somewhat undulating deposit is 30 feet thick, and uniformly bedded.

Sigler's Mine, 2 miles N.N.W. of Mertztown, is situated near the base of a slate ridge which projects into the limestone valley from the great slate-range beyond. The mine has been wrought many years. The stratification of the ore is very confused and irregular, though there are some evidences of a general S.E. dip. In parts of the mine the masses of ore are found imbedded in clays, and are frequently so intersected by veins of quartz as to be rejected. The present yield does not exceed 1000 tons per annum.

There are several recently-opened small pits in the same neighbourhood, but they furnish nothing worthy of especial remark. In some of them the ore is brown hæmatite, in others red.

In the vicinity of Kline's store, and elsewhere along a narrow belt ranging with the valley, ore has been proved by surface-shafts and small pits at numerous points. All of the ore derived from these openings is of the silicious brown variety, in various degrees of purity. Many specimens appear rather as masses of rotten, ferruginous, and perhaps calcareous sandstone. These masses are generally large and cavernous, containing a yellow calcareous clay within. The excavations are too limited and superficial to afford us any insight into the structural features of the limestone strata beneath these deposits.

Trexler's Mine is 1 mile S.E. of Breinigsville. It is but recently opened, and the excavation has not proceeded far, but fine large masses of brown and red hæmatite are found plenteously scattered through the rich ferruginous earth, which is washed to obtain the smaller fragments. The disintegration of the underlying rock has been deep, as is proved by a well 80 feet in depth, wherein no solid rock was encountered. The mine is upon the top of a broad undulating hill. The limestone of the neighbourhood dips S.E.

East of Trexlerstown, on the back of a broad ridge, and within a quarter of a mile, are five ore-pits; three of these are the property of Mr S. Albright, one belongs to Mr Schmoyer, and one to Mr Yoder. The ore is obtained by stripping and washing the surface-earth. It is a brown hæmatite in small fragments. The deposit is underlaid by limestone, but the rock does not crop out at the surface, nor have the excavations penetrated to it. The ore from these mines, and from Trexler's pit, is delivered to the Thomas iron-furnaces at Hokendaqua.

On Samuel Albright's land, 1 mile S.W. of Trexlerstown, a similar deposit to those above mentioned is found. None of the ore-deposits last referred to furnish any local evidences of their origin.

The Saucon Mines, the most extensively wrought for ore in the district now under consideration, are situated 3 miles S.W. of Hellertown, on the county line of Lehigh and Northampton, near the Saucon Creek. They are within the limestone valley of the Saucon, which is bordered by the ridges of the South Mountains, known as the Lehigh Hills. These mines, the property of Messrs Bahl and Gangware, consist of two pits, one a narrow excavation 250 feet long and 30 feet deep; the other a somewhat circular and shallow pit. In both mines red hæmatite ore is found intermixed with the brown, the former in irregular nodules, the latter stratified, particularly in the long pit known as Bahl's. The two varieties are found in about equal proportions in this pit, the former usually scattered through blood-red and pink clays, the latter alternating with many-coloured clays, from grey to dark brown. Most of the ore obtained from Gangware's (circular) pit is of the red hæmatite variety, but it is probable the brown ore will be found abundant when the excavation has penetrated deeper. There is no uniformity in the bedding of the ore in this pit, whereas in Bahl's the stratification has a quite regular S.E. inclination. A shaft sunk in Bahl's pit to a depth of 60 feet did not reach the bottom of the ore-deposit, but in other places within a hundred yards, mine-shafts, from 40 to 70 feet deep, encountered nothing but clay. It would therefore appear to be a purely local deposit or nest of ore, in which the materials have been laid down with some regularity. N.W. of Bahl's Mine, within 200 yards, limestone crops out, and dips gently towards the mine. One or two smaller excavations have been made within a hundred yards S.E. of Gangware's, but they have not led to any very promising results. In one a small amount of dull-brown ore was found, in the other nothing but sand and pebbles, and masses of undecomposed sandy rock. In Bahl's and Gangware's pits, fragments of rock are found undecomposed, chiefly a cherty material of greyish-blue colour and flinty texture. In the latter pit a large amount of this is found, but it was too nearly covered to admit of any conclusion respecting its true place or its dip.

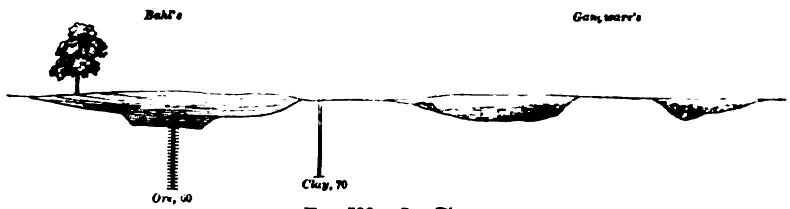


FIG. 582.—Ore Pits.

The yield of these mines is 15,000 tons per annum. The ore is delivered to the Thomas ironworks.

Moselem Mine, Berks County, 6 miles W.S.W. of Kutztown.—At this locality there are two pits, an Eastern and a Western, 200 yards asunder, situated in a narrow valley between a conspicuous slate-ridge and a lower limestone hill, in both of which the dip is N.W., the limestone passing under the slate. The E. mine is wrought chiefly for the supply of the furnaces of Seyfert, M'Manus, & Co., at Reading. The surface excavation is not large, and the ore is found in confused and irregular bunches of a few inches thickness up to 20 feet; it is intermixed with clay and earth. The ore is now obtained, in great measure, from a series of gangways diverging from a shaft at a depth of 120 feet. The ore is a brown compact hæmatite of the average quality, in lumps large and small. The annual yield of the mine is 10,000 tons of ore, raised at a cost of $1.50 per ton.

The W. mine is exclusively an open pit, excavated 80 feet deep over half an acre. The ore is delivered to the Leesport furnaces, 9 miles above Reading. As at the former mine, the ore is found in irregular nests, and requires to be excavated and washed before it is fit for the furnaces. Yield, 12,000 tons per annum; cost of mining, $1.30 per ton under ordinary circumstances. In both of these mines, but especially the latter, many fragments of slate and cherty limestone are found only partially converted into ore.

Jefferson Ore-bank, 5 miles N.W. of Reading, worked by Eckert and Brother.—This locality of brown hæmatitic ore is situated on the E. side of a hill of the Matinal-slate formation, which occupies a position within the general valley of the Auroral limestone. The ore-deposit lies within 300 yards of a narrow dyke of trap, which ranges N.E. and S.W. through a considerable distance. The general bedding of the mass dips W., or under the hill, at an angle of 30°. In thickness it varies from 2½ to 15 feet, and is underlaid at the outcrop by about 10 feet of clay, beneath which the limestone is in place. In other parts of the mine the ore is in immediate contact with the rugged floor of outcropping limestone.

The pit is an open cut, stripping the surface materials from the ore stratum. The extreme depth of the mine is 63 feet, and the ore has been mined along the outcrop for 150 yards.

A large amount of ore has been obtained in the lower ground, the surface materials of which are washed. Black oxide of manganese is found as a thin stratum, sometimes 6 inches thick in the clay, 1½ feet above the ore. Yield of ore per annum, about 3000 tons.

To exhibit the furnace yield of these ores of the Kittatinny Valley as they are smelted, under the most favourable circumstances, the following details are presented of the dimensions and production of the *Crane Ironworks* at Catasaqua, on the Lehigh River, 3 miles above Allentown. They embrace five furnaces of the following dimensions :—

No. 1. Height of stack, 45 feet; diameter of bosh, 11 feet.
No. 2. „ 45 feet; „ 13 „
Diameter of hearth at tuyeres, 7 feet 6 inches.

No. 3. Height of stack, 48 feet; bosh, 16 feet; hearth, 8 feet 6 inches.
No. 4. „ 55 feet; „ 18 feet; „ 9 feet.
No. 5. „ 55 feet; „ 18 feet; „ 9 feet.

Three furnaces are (December 1857) in operation (Nos. 3, 4, and 5). The fuel used is anthracite coal from the Lehigh region, and the blast is heated to 600° by the waste gases of the furnaces. The number of blowing engines available for use is seven: the largest of these, a new engine, is rivalled only by the great engine of the Lackawanna Ironworks at Scranton. The diameter of the steam cylinder is 54 inches, and of the blowing cylinder 93 inches, each 10-feet stroke. Two fly-wheels are attached to the shaft, each 27 feet in diameter, and weighing 30 tons.

The total product of four furnaces, in the year 1856, with the materials employed, is appended :—

	Coal, tons	Ore, tons	Limestone, tons		Iron
First 6 months	29,831	31,970	17,171	=	13,770
Last 6 months	38,070	37,609	19,757	=	17,322
	67,901	69,579	36,928	=	31,092

The ores employed are the usual hæmatitic varieties of the district, mixed with one-fourth part magnetic ore from the vicinity of Dover, New Jersey. The product in pig-metal consists of iron, Nos. I., II., and III., the latter small in quantity.

It appears from the above statement, that of the mixed ores 2.237 tons are competent to the production of 1 ton of metal, a yield from the ore a little exceeding 49 per cent.

ANALYSES OF SPECIMENS OF HYDROUS PEROXIDE OF IRON, OR HÆMATITE, OF THE AURORAL LIMESTONE, PENNSYLVANIA.

Locality.	Peroxide of Iron.	Oxide of Manganese.	Alumina.	Silica and Insoluble Matter.	Water.	Occasional Ingredients.	Loss.	Metallic Iron in 100 parts.	Description of the Ores.
Near Conshohocken,	71.50	0.50	2.55	14.30	11.0	...	0.15	49.75	Brown, cellular and ochry.
Hartman's, Northampton County,	65.60	...	1.0	17.82	14.98	...	.60	45.92	Chestnut-brown, porous and crumbly.
Brotzman's, Northampton County,	71.72	0.70	...	16.50	11.03	...	...	49.78	Mammillary, brown, with specks of silicious matter.
Dillinger's, Hellertown,	85.71	1.50	a trace	1.50	11.74	...	...	59.42	Brown, compact and also fibrous.
Rice's, 5 miles N.W. of Bethlehem,	70.25	a trace	1.55	16.40	11.40	...	.40	49.17	Porous, cellular and brittle (30 feet from the surface).
Rice's, same locality,	79.12	...	1.56	4.80	13.98	...	.54	55.38	Stalactitic, brittle, chestnut-brown colour (50 feet below the surface).
Richards's, Northampton County,	71.72	10.42	a trace	4.12	13.21	...	.53	49.72	Brown and bluish, somewhat nodular.
Moyen's, 4 miles N.W. of Allentown,	72.17	a trace	1.50	12.30	14.00	...	.03	50.51	Chestnut-brown, compact.
Moyen's (same mine as the above),	79.21	...	.75	7.50	11.0	...	.54	55.44	Stalactitic, pipes adhering, a rich chestnut-brown.
Miller's Mine, 4 miles N.W. of Alleutown,	86.59	...	a trace	3.08	11.31	...	...	60.04	Brown, stalactitic; cavities between the pipes containing yellow peroxide oxide.
Balliot's Mine, 5 miles N.W. of Allentown,	83.22	...	.21	4.81	12.40	...	...	57.61	Colour liver-brown, compact and crystalline, the latter kind analysed.
Goetz's, 5 miles N.N.W. of Bethlehem,	84.0	...	a trace	4.10	11.60	...	.30	58.80	Blackish-brown, lustrous and resinous, compact, conchoidal.
Shwartz's, ⅛ mile S.W. of Emmaus,	79.64	...	a trace	9.05	11.40	...	...	55.22	Dark brown, compact, shining.
Albright's, S. of Trexlerstown,	82.0	...	a trace	5.32	12.25	...	.43	57.40	Red hæmatite, and brownish compact ore.
A mine, 1 mile W. of Trexlerstown,	87.12	...	0.40	2.30	10.90	Sulphur, a trace.	...	61.03	Brown, compact, and stalactitic; a "pipe ore."
Breinig's, 1 mile N.W. of Breinigsville,	75.54	...	a trace	11.90	12.15	...	.41	52.87	Blackish-brown, compact; surface velvet-like.
Xander's, Lehigh County,	77.23	a trace	2.75	5.80	13.92	Lime, a trace.	.30	54.06	Brown with bright-yellow spots; cellular and brittle.
Moseler Mine, 4 miles S.W. of Kutztown,	77.20	...	2.60	8.90	11.00	...	.30	53.53	Dull brown, compact.
Gorgas Mine, 3½ miles S.W. of Harrisburg,	77.20	a trace	2.72	4.80	15.15	...	.13	54.04	Dark brown, hæmatitic.
Kerr's Fields, 8 miles W. of Carlisle,	69.0	...	4.8	13.0	13.0	...	.2	48.03	Dark chestnut-brown, compact and laminated.
Miller's Mine, 1½ miles from Miller's Furnace, Cumberland,	84.60	...	2.50	3.89	8.70	Lime, a trace.	.31	59.22	Chestnut-brown, stalactitic pipes slender; some of the ore compact.
Helm Bank, Cumberland County,	77.2	...	2.0	5.8	14.5	...	.5	54.04	Cellular and mammillary.

TABLE OF HÆMATITIC IRON-ORES OF THE AURORAL LIMESTONE—*Continued.*

LOCALITY.	Peroxide of Iron.	Oxide of Manganese.	Alumina.	Silica and Insoluble Matter.	Water.	Occasional Ingredients.	Loss.	Metallic Iron in 100 Parts.	DESCRIPTION OF THE ORES.
Clippengea Bank, Mary-Ann Furnace, Cumberland County, . .	87.09	...	.50	2.60	8.81	...	1.0	60.96	Chestnut-brown; stalactitic pipes, large.
Kresler Bank, Southampton Furnace, Franklin County, . .	75.0	a trace	2.9	9.0	13.0	...	.1	52.5	Mottled-brown, amorphous, cellular, and somewhat laminated.
Railroad Bank, used at same Furnace, ...	72.0	a trace	.8	14.7	12.0	...	.5	50.4	Brown, cellular, and compact.
Pilgrim Bank, N.E. of Shippensburg,	77.7	...	4.0	6.8	11.0	...	.5	54.39	Dark chestnut-brown; stalactitic pipes almost obliterated.
Roxbury Bank, W. of Shippensburg,	75.1	...	3.6	9.3	12.0	...	...	52.57	Pipe ore, the pipe adhering; yellow hydrous oxide in the interstices.
Green Village Bank, Franklin Co., .	82.6	...	0.9	4.2	12.0	...	.3	57.82	Brownish-yellow, long and slender pipes.
Heifner's Bank, Caledonia Furnace, Franklin County, . .	76.6	a trace	a trace	10.8	12.5	...	.1	53.62	Bright chestnut-brown, compact.
Heifner's, 6 miles from Caledonia Furnace, ...	81.6	...	a trace	6.7	11.4	...	.3	57.12	Brown; pipes closely adhering.
Middauer's, 3 miles N.E. of Waynesburg, Franklin County, . .	72.6	a trace	0.5	14.0	12.5	...	.4	50.82	Brownish-red and purplish, compact, slightly resinous.
M'Dowell's Bank, 5 miles N.E. of Mercersburg, ...	83.60	a trace	1.50	4.80	9.40	Arsenic, a trace.	.70	58.82	Bright brown, amorphous, and cellular. This is called "garlic ore."
Carrick Furnace, Perth Valley, Franklin County, . . .	59.50	8.30	5.80	17.40	8.80	...	.20	41.65	Nodular, surface mammillary, argillaceous specks.
Carrick Furnace, another specimen,	84.30	...	2.25	3.80	8.85	...	.80	59.01	Dark chestnut-brown, cellular, cells coated with a yellow ochreous deposit called "honeycomb ore."
A mine ¾ of a mile S.E. of Greenwood, in Kishicoquillas Valley, .	82.88	...	0.53	4.21	12.38	...	...	57.47	Brown, interstices lighter coloured, hard, granular, and porous, grains compact.
Bull Bank, Pennsylvania Furnace, Centre County, ...	86.40	a trace	a trace	2.30	11.00	...	.30	60.48	Chocolate-brown, hæmatitic, somewhat mottled, compact, fracture conchoidal.
Old Pennsylvania Furnace Bank, Centre County, ...	82.2	a trace	a trace	5.3	12.0	...	.5	57.54	Dark chestnut-brown, stalactitic; pipes small, and closely set.
Pennington Bank, 2½ miles S.W. of Warrior's Mark Town, . .	76.50	2.70	...	7.50	12.50	...	.80	53.50	Chestnut-brown, compact, and cellular, coated with red oxide.
Pennington Bank, same locality, Huntingdon County, . . .	84.80	...	1.50	3.00	10.0	...	.70	59.36	Rich brown, compact, and close-grained, rather columnar.
Pond Bank, Pennsylvania Furnace, Huntingdon County, . . .	76.50	...	2.55	11.40	9.10	...	.45	53.55	Rich brown, closely adhering slender pipes, brittle.
Springfield Furnace Ore-bank, Morrison's Cove, ...	79.06	3.0	0.3	4.8	12.0	Lime, a trace.	.3	55.72	Dark brown, cellular, the cells coated with a bluish-black glaze.
Bombshell Bank, Rebecca Furnace, Morrison's Cove, ...	84.22	.41	0.65	6.43	8.25	...	...	58.95	A section of a hollow geode or bomb, fibrous hæmatite.
Red Bank, 3 miles S.W. of Rebecca Furnace, Morrison's Cove, . .	57.2	...	a trace	32.1	9.8	Lime, a trace.	.9	40.04	Bright reddish-brown, compact, and jaspery.
Sarah Furnace Ore-bank, 4 miles S. of M'Kee's Gap, Morrison's Cove,	76.5	a trace	a trace	11.7	11.6	...	.2	53.55	Blackish-brown, cellular and concentric layers of hæmatite.
Hillman's Mine, near Marble Hall, Montgomery County, ...	77.10	a trace	1.25	10.25	11.5	...	...	54.0	Brown, cellular, and compact; fracture rough.
Mine near Margaretta Furnace, York County, ...	72.20	1.0	2.50	11.25	12.5	...	.55	50.25	Brown, compact, surface ochreous; has a rough and sandy aspect.
Swartz's, 2 miles S.W. of Hanover, York County, ...									

TABLE OF ANALYSES OF IRON ORES OF THE MATINAL SLATES, PENNSYLVANIA.

LOCALITY.	Peroxide of Iron.	Oxide of Manganese	Alumina.	Silica and Insoluble Matter.	Water.	Occasional Ingredients.	Loss.	Metallic Iron in 100 Parts.	DESCRIPTION OF THE ORES.
M'Naughton's, 1½ miles W. of Mercersburg, ...	69.60	...	.73	9.20	20.0	...	.47	48.72	Dull brown, cellular (a bog ore).
Lourey's Knoll, Hanover Ore-bank, 2½ miles N.E. of Hanover Furnace, Bedford County, . .	80.20	a trace	3.20	2.80	12.90	...	.90	56.14	Dark chocolate-brown, compact, and semi-crystalline.
Hanover Ore-bank, another (specimen), ...	73.6	a trace	2.0	11.5	11.5	Lime, a trace.	.14	51.52	Dull brown, compact, a greenish-black, blotches on the surface.
Hanover Ore-bank (a poorer specimen), ...	36.71	a trace	14.46	32.36	16.47	...	...	25.45	Brick-red and opalescent, brittle and granular.

CHAPTER IV.

IRON ORES OF THE SURGENT SERIES.

In the detailed description which I have given of the Surgent rocks, the series was shown to contain generally two, and in some localities three or four, separate beds of the peroxide of iron. The several horizons which these occupy have been pointed out, and their features and dimensions given at their numerous outcrops. Two of these layers of ore, the so-called " Fossiliferous Iron-ore" of the Surgent ore-shales, and the " Hard Ore" of the Surgent iron-sandstone, are almost coextensive, as we have seen, with the entire range of the Surgent formation throughout the Appalachian Chain in Pennsylvania, rising to the surface in each of its many belts. A careful study of the same series in other States has enabled me, with the aid of Professor William B. Rogers, to identify both of the above-mentioned beds of ore in numerous lines of outcrop far beyond the limits of Pennsylvania, in Western New York in the one direction, and through Virginia, as far as the Cumberland Gap, in Tennessee, in the opposite.

All of these bands of ore retain their special features and composition throughout the immense space which embraces them, with a constancy which is very remarkable, and from which we must infer a very wide diffusion and equality in the formative actions which produced each thin and well-characterised layer. They are variable, of course, in their thickness, and only in particular districts attain the dimensions, and possess the degree of richness which confers an economical value on beds of ore. But where they are thus developed—as, for example, in Montour's Ridge—they embrace, as we have seen, an extraordinary mass of mineral wealth.

These regularly-bedded ores of the Surgent series are to be regarded as among the permanent constituent strata of the formation, and as having originated, with the other sedimentary materials, in the form of very extended but thin sheets of ferruginous matter, covering at successive epochs the wide floor of the quiet Appalachian sea. Whence all the oxide of iron was derived which mingled with the earthy deposits of clay, sand, carbonate of lime, and the fossils of these deposits, is a question which the present state of research scarcely enables us to answer. Perhaps we are authorised, from a consideration of the physical changes which seem to have occurred at the close of the Matinal period, to refer its origin to a wide expanse of newly-upraised land of Primal and Matinal sediments, impregnated with a certain proportion of ferruginous matter, and to suppose that these parts, freshly exposed to active erosion and waste by atmospheric agents, in supplying a part at least of the materials of the Surgent strata, contributed, by steady accumulation, a copious amount of the salts of iron in solution to the waters of the Levant ocean. We have only to imagine, in the next place, the operation of certain well-known chemical reactions, such especially as would arise upon the sudden introduction of calcareous matter, to perceive a sufficient cause for the extensive precipitation of a definite quantity of the iron in the form of the peroxide.

This explanation derives some countenance from the independent evidence afforded,—by the more calcareous and fossiliferous nature of these ore-beds, compared with the strata which embrace them,—that the epochs of the deposition of the iron ore were also the periods of most copious supply of carbonate of lime.

To this source we may ascribe, with some probability perhaps, a large portion of the peroxide of iron in these layers; but we must not overlook another train of causes, operating since the elevation of the strata, to contribute in certain situations an increased supply of this ingredient. An enormous quantity of ferruginous matter, both in the shape of sulphuret and peroxide of iron, is diffused throughout the substance of the slates, shales, and marls in contact with these layers of ore; and the infiltering waters have probably conveyed some of this, chiefly in the condition of sulphate of iron, into the ore-bed, where the carbonate of lime of the fossils would convert it into the peroxide. That such has been the origin of a part of the iron in the "fossiliferous ore" of some localities, is indicated by the general richness of the ore in peroxide, in all situations where the position of the outcrop, the slope of the ground, and the thickness of the covering slate, are favourable to a copious infiltration of the surface-water.

But I must here advert to another much more instrumental cause of inequality in the proportion of iron, compared with the other constituents—I mean the *removal*, by infiltrating water, of a part or all of the soluble portion of the ore, chiefly its carbonate of lime, both diffused and in the shape of innumerable organic remains. The fossils, chiefly shells and joints of the Crinoidea, constitute in many instances fully one-half of the weight of the ore in its original unaltered condition, as the reader can ascertain by inspecting the Table of Analyses of the Surgent Fossiliferous Ores, and comparing the amount of carbonate of lime of the compact specimens with that of the soft or porous ones. It is obvious that a given bulk of the ore must retain, after the abstraction of this large quantity of calcareous matter, very nearly twice its former per-centage by weight of its principal ingredient, the peroxide of iron. A study of the circumstances which chiefly influence or control this dissolution of the carbonate of lime is therefore of the highest practical importance, since only through a competent knowledge and application of these conditions to his particular localities can the proprietor of a tract of this ore foresee the relative amount of the soft or chiefly valuable variety which his ground is likely to contain.

The whole value of the Surgent ore-beds, so far as the quality of the fossiliferous ore is concerned, depends upon the depth *below its outcrop* to which the dissolving process has extended; for experience has now confirmed the views which I ventured to express in my annual reports, that the stratum cannot be profitably mined, in the present condition of the iron manufacture, much below the level to which this surface action has penetrated.

What, then, are the conditions of outcrop that principally promote the thorough and extensive filtration of the waters along the slope of the ore stratum? The most favourable state of things is a coincidence in the dip of the ore-bed with the inclination of the ground above it. In this case, nearly the whole of the rain which falls upon the hill-side finally penetrates to the layer of ore, and, passing through the thin covering of slates, carries with it an additional amount of oxide of iron. A strict parallelism between the ore-bed and the surface seldom prevails over any considerable tract, almost never on the side of an anticlinal or monoclinal ridge, and scarcely anywhere but at the end of a broad anticlinal ridge like that which terminates Montour's Ridge east of Bloomsburg, where there is a truly extraordinary quantity of the softest and richest ore arching the point of the hill in a gentle curve, and nowhere overlaid by a thicker covering than from 10 to 20 feet of the slate. Where the dip of the ore is considerably steeper than the slope of the surface, the thickness of the overlying rocks rapidly increases as the bed descends, until its mass becomes too great to be penetrable by the atmospheric waters. In all such cases the ore, as we trace it downwards, grows progressively less soft, porous, and rich in iron, more and more of the substance of the fossils remaining undissolved, until we reach a point at which the stratum is in its original condition, with its maximum quantity of the carbonate of lime, and therefore its minimum of peroxide of iron. It should be observed that this limit is by no means as far beneath the outcrop, even under the moderate dip of 30°, with the surface sloping 15°, as many persons imagine. Much observation along the ore-belts of Montour's Ridge and other districts, persuades me that, under these conditions, the soft ore ceases, on the average, at a distance of 30 or 40 yards from its actual outcrop. Where the bed of fossiliferous ore dips *into* the hill, or in a direction contrary to the slope of the ground, the surface-water flows across its outcrop without entering it, and the stratum in this case receives a very small supply of infiltering water, so that not unfrequently the ore is compact, and full of its organic remains, to within a few feet of the soil.

To those interested in the many iron furnaces now erected, which depend, in part at least, for their supply, and mainly for the quality of their iron, upon this admirable variety of ore, the following calculations, based upon the foregoing data, will not be without their value. Assuming the average thickness of the main bed of the fossiliferous ore to be 16 or 18 inches, each square yard of the stratum will contain about one ton; and if the average width of the breast of soft ore be taken at 35 yards, then one mile of continuous outcrop must furnish the amount of 61,600 tons. It should be borne in mind, however, that several circumstances, besides the mere relative slope of the ore and of the surface, may influence the amount of percolation, and produce locally wide deviations from the above estimated width of the soft outcrop ore. Such are especially any irregularities in the contour of the ground, in the form of ravines, or knolls and swells; and again, any local contortions or dislocations in the strata. In regard to the silicious ore-beds of the Surgent series, both those of the iron sandstone and the Surgent older slate, the quality of the ore is very uniform, being but little influenced by the accident of proximity to the surface. Possessing but few fossils, and only a comparatively small proportion of calcareous matter, these ores are not susceptible of the purifying process so essential to the so-called "fossiliferous ores;" and hence, as far as their richness in iron is in question, it is of small importance what way the strata dip in relation to the slope of the surface. The direction of the dip will much affect, however, the extent to which the outcrop of the bed may be uncovered, but can thus influence only to a trivial extent the facility and cheapness with which it may be mined. When the "hard ore" is of equal or nearly equal thickness with the "fossiliferous ore," and contains as much as 30 per cent of iron, it is obvious that it will long outlast the latter in most of the localities where at present they both abound. Not deteriorating materially as it descends, and outcropping higher upon the flanks of the ridges, in consequence of its holding a lower place in the series, the supply of this variety of ore may be regarded as liable to few fluctuations, and to be almost inexhaustible.

The average cost of mining the soft fossiliferous ore, at and near its outcrop, exceeds 2 dollars per ton, while that of removing the "block ore" of the iron sandstone is from 1.25 to 1.75 dollars per ton.

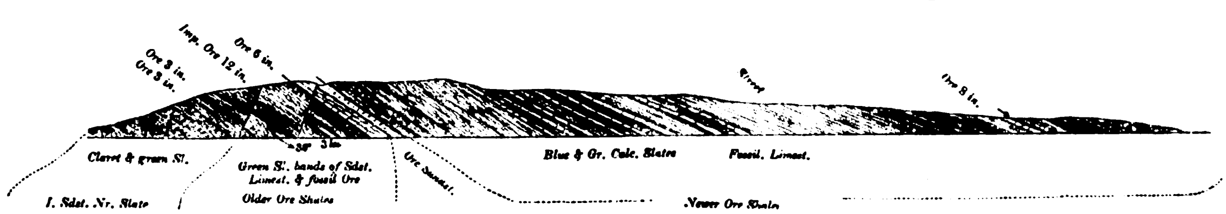


Fig. 583.—Surgent Fossiliferous Ore Group, Hollidaysburg, Blair County.—1 *inch* = 200 *feet*.

The accompanying section exhibits the fossiliferous ore group, or Surgent calcareous shales, under the type they assume near Hollidaysburg. It is taken from a railroad-cut near the town. The ore occurs, it will be seen, in very thin layers, and these are intersected by trivial faults.

ANALYSES OF SPECIMENS OF IRON ORE OF THE SURGENT SERIES, PENNSYLVANIA.

Locality and Variety.	Peroxide of Iron.	Oxide of Manganese.	Alumina.	Silica and Insol. Matter.	Water.	Occasional Ingredients.	Loss.	Metallic Iron in 100 Parts.	Description of the Ores.
1. Smith's Gap, Kittatinny Mt., Dauphin Co., . . .	68.00	...	6.60	13.30	11.70	...	.40	47.06	Dark mottled-brown, coarse-grained, sandy-looking ore, imbedded in brown hæmatite.
2. Danville, Columbia County (Levant iron sandstone),	70.63	...	.57	23.77	2.57	Carb. of Lime, 2.46	...	48.97	Brick-red, somewhat fossiliferous, has the grain and aspect of a red sandstone. Called the "hard ore."
6. Danville (calcareous fossiliferous ore), . . .	30.34	a trace	...	2.64	1.80	Car. Lime, 62.43, Car. Mag., 2.79	...	21.03	Dark purplish-brown, slaty, micaceous, fossiliferous.
7. Bloomsburg (compact calcareous, fossiliferous ore), .	61.30	...	a trace	2.80	2.20	Car. Lime, 33.17	.53	43.00	Very similar to the last.
8. Bloomsburg (soft, porous, fossiliferous ore), . .	85.10	...	5.0	7.10	2.10	Carb. Lime, a trace	.40	60.00	Dark, reddish-brown, soft, gives a red powder, is full of pits and casts of fossils.
9. Landisburg, Perry Co. (fossiliferous ore), . . .	76.45	1.50	1.25	14.40	5.70	..	.70	53.51	Dull brown, slaty, micaceous, highly fossiliferous.
3. Turtle Creek, Union Co., (Levant iron sandstone), .	37.64	...	a trace	59.0	3.20	...	.16	26.32	Pink colour, compact, coarse, and silicious, resembles the "hard ore" of Danville.
10. Mifflin, Juniata Co. (fossiliferous ore), . . .	70. 0	a trace	a trace	24.24	5.40	...	.40	51.10	Chestnut-brown, coarse, slaty, granular, micaceous, and fossiliferous.
4. Little Cove, Franklin Co., (Levant iron sandstone), .	30.38	...	1.20	67.0	1.42	...	...	21.06	Dark red and brown, granular and sandy, looks like a coarse red sandstone; is the "hard ore."
11. Little Cove, N.W. side, 4½ miles N. of Warren Iron Works (fossiliferous ore), .	83.0	a trace	6.0	5.3	5.1	Lime, 0.5	...	58.1	Reddish-brown, laminated, porous, fossiliferous.
5. Dickey's Mt., N.W. side, half a mile S.W. of Hanover Forge, Bedford Co. (Levant iron sandstone), . .	52.0	a trace	a trace	39.3	9.0	...	...	36.4	Dark brown, coarse, earthy; variety, Levant iron sandstone.
12. Matilda Furnace, near Jack's Narrows, Huntingdon Co.,	74.76	a trace	5.06	13.04	3.82	Lime, 1.35, undetermined matter, 2.11	...	51.84	Reddish-brown, powder red, porous, fossiliferous (upper part of fossiliferous ore).
13. Matilda Furnace (lower part of the same), . . .	44.07	a trace	1.39	52.33	2.62	Lime, 0.49	...	30.56	Brown, fracture rectangular, brown oxide of iron, cementing coarse grains of sand (lower part of fossiliferous ore).
14. Lick Hill, Woodcock Valley, Bedford Co. (used at Hopewell Furnace), . . .	46.50 part Carb. of Iron.	...	4.80	16.30	1.0	Car. Lime, 31.01	.39	27.72	Pale-red, highly fossiliferous; carbonate of lime of fossils visible.
15. Hopewell Furnace Mine, Bedford Co. (softest kind,)	78.05	.68	4.50	13.85	3.0	A trace of Lime	...	54.95	Brown, powder purple-brown, soft and brittle, fossiliferous, has some red micaceous oxide.
16. Hopewell Furnace Mine (same bed, compact kind), .	55.2	.5	1.0	8.8	2.5	Car. Lime, 31.4	.6	38.64	Reddish-grey; powder light brown; micaceous, fossiliferous.
17. Near Barre Forge, Huntingdon Co. (lower part of vein),	43.55 Prot. Carb. Iron, 3.56.	.50	.50	3.0	1.50	Car. Lime, 46.76	.63	32.2	Reddish-grey, fossiliferous; the fossils not all dissolved out.
18. N.E. of Barre Forge (average of the vein), . .	57.0	.60	1.40	7.50	2.0	Car. Lime, 32.10	...	39.9	

CHAPTER V.

IRON ORES OF THE PRE-MERIDIAN AND MERIDIAN SERIES.

The Pre-meridian and Meridian Series in Pennsylvania are accompanied by certain characteristic iron-ores, each having its own particular kind. The ore of the limestone is most abundant in Huntingdon and Bedford counties, but only in two or three localities does it exist in sufficient quantity to repay the pursuit. It is usually scattered in the soil overlying the limestone, in the form of compact lumps, having a laminated structure and a light chestnut-brown colour. The shallowness of the earthy deposit, resting upon the usually sloping surface of the formation, and the small amount of ferruginous loam in it, sufficiently account for the absence of large accumulations of the ore.

The Meridian sandstone exhibits a greater number of productive localities of ore. These seem to occupy two distinct positions in relation to the formation. One species of the ore is found in connection with the lower or more ferruginous portion of this porous stratum, usually near the junction of the coarser more arenaceous beds with the soft calcareous laminated yellow layers. It would appear to have been the product of filtration through the looser upper beds, the oxide of iron having been arrested and precipitated on coming into contact with the more impervious and calcareous layers beneath. Thus, in Chestnut Ridge, Huntingdon County, there is a bed of ore, about 2 feet thick, near Chester Furnace, occupying precisely the line of junction of these two members of the formation. Not unfrequently the ore is lodged in a body of ferruginous clay, near the contact of the limestone and sandstone, all the materials of which are, however, traceable to the sandstone. This is the position of a valuable ore-bed near Alleghany Furnace, 6 miles from Tuckahoe, in Huntingdon County, in which the ore consists almost entirely of the stalactitic variety, some of the stems or pipes being of great size and beauty. Much of this ore, from the lower portion of the Pre-meridian sandstone, is more or less manganesian: it contains more ore, in proportion to the surrounding impurities, than usually occurs in the ores of the Primal and Auroral formations.

Another variety of ore of this series is restricted to the upper limit of the sandstone, occurring not unfrequently precisely at the junction of this rock and the overlying Cadent black slate. It is not extensively developed in Pennsylvania, and is to be seen chiefly in the belts S. of the Juniata, especially in Bedford County. But in Virginia, and particularly among the ridges W. of the great valley in the James River region, it occurs in numerous and productive openings. It is there spread, in an almost continuous stratum, over wide areas, and marks very distinctly the junction of the sandstone with the slate. In many localities the mass consists of little more than the upper layers of the Meridian sandstone, strongly impregnated with peroxide of iron, and graduating into a material much too coarse and sandy to be of value in the smelting furnace. In Pennsylvania the better kinds of this ore are often in massive chunks, and are hæmatitic; but these chunks, when met with on the surface of the sandstone, contain in some localities much compact *chert*, which effectually destroys the usefulness of the ore.

The position of this ore, and the highly-pyritous character of the overlying slates, especially the layers in contact with the sandstone, point at once to the source of the oxide of iron, and render it needless to enter into chemical details, which would be but a repetition of the explanations already given.

TABLE OF ANALYSES OF IRON ORES OF THE PRE-MERIDIAN SERIES.

Localities.	Peroxide of Iron.	Peroxide of Manganese.	Silica and Insoluble Matter.	Alumina.	Occasional Ingredients.	Water.	Metallic Iron in 100 Parts.	Description of the Ores.
Tuckahoe, Huntingdon County,	71.50	a trace	20.40	2.50	...	5.00	50.00	Brick-red, cellular, brittle.
Tuckahoe, Alleghany Furnace Bank, ...	69.80	a trace	18.40	2.30	...	8.70	48.86	Brownish-yellow; cells lined with pulverulent oxide.
Same locality, ...	82.20	8.00	6.00	a trace	...	4.00	57.54	Bluish-brown, earthy, compact, from near the base of Pre-meridian sandstone.
Same locality (pipe ore), . .	86.91	...	1.93	0.22	...	10.44	60.26	Pipe ore; stems large, surface iridescent.
One mile S.W. of Bell's Furnace, Tuckahoe, ...	73.28	a trace	12.88	5.52	...	9.38	50.81	Chocolate-brown, lustre resinous, makes a weak iron.

CHAPTER VI.

IRON ORES OF THE CADENT AND VERGENT SERIES.

The Cadent and Vergent rocks contain important bands of iron ore, differing essentially in their composition. They are limited to certain districts within the range of the formations to which they belong, nor do they occur together in the same region. The lowest of these ores is most fully developed in the Lewistown Valley, between Lewistown and the Southern State line, and in the belts adjoining it. It occupies a position in the Cadent lower black slate, only a few feet or yards above the calcareous beds or cement layers, and from 50 to 100 feet above the upper layers of the Meridian sandstone. Between the Juniata River and Maryland, in the localities where it has its maximum expansion, it varies in thickness from 3 or 4 feet to 10 or even 12 feet, having the form of a series of solid grey layers, separated by thin seams of slate. In its native condition, unaltered by the atmospheric action which has everywhere changed it at its outcrop, this ore is a ponderous, bluish-grey, or lead-coloured proto-carbonate of iron, sometimes breaking into square masses, and sometimes of a more slaty or laminated structure. It does not effervesce when touched with acids; when roasted, it becomes reddish-brown, and is then strongly attracted by the magnet. The analyses will display the prevailing composition of this ore.

It is only when the stratum has been long exposed at its outcrop to atmospheric action, converting it into the brown peroxide of iron, by which it assumes a wholly different aspect, that it has the form hitherto worked by the furnaces situated near it. This ore, at its outcrop, is of a dark hazel-brown colour, a smooth grain, and a cellular structure. That which is derived from the rectangularly-cleaving portion of the solid bed is in square masses, with large squarish cells, often glazed and iridescent on their inner surfaces, and either entirely empty or partially filled with a pure bluish clay. Sometimes, where the bed has been so protected as to have escaped extensive atmospheric action, this conversion to the brown peroxide is only partial, a solid nucleus of the bluish proto-carbonate forming the interior of the lump, while the peroxide occurs only on the surface, in the form of a crust of greater or less thickness. Between this crust and the undecomposed nucleus, the earthy particles originally in that portion of the proto-carbonate, which has been converted into the peroxide, having been deserted by the iron in assuming its new state of concretion, lie loose in the intervening space, and form a grey dust when dry, and, when moist, a tenacious clay. This travelling of the atoms of oxide of iron from the interior to the circumference of the mass, in all cases where a proto-carbonate of iron undergoes conversion to the peroxide, is a highly curious fact, not devoid of a practical as well as a scientific interest.

It is probable that this bed of ore extends, either partially or uninterruptedly, for considerable distances, in nearly all the synclinal basins where the lower beds of the Cadent series occupy the summits of the sandstone ridges between Lewistown and Shirleysburg. The ore-banks at present worked are in these positions. The ore occurs in Little Cove, and at Pennock's furnace, Huntingdon County, in precisely the same geological relations; but to what extent it prevails throughout the long line of intermediate country, nearly 35 miles in length, we have at present no means of ascertaining. The discovery of the true nature and exact position of this iron ore furnishes an interesting illustration of the utility of geological researches systematically prosecuted. The ore having been previously dug at the outcrop only at remote and insulated points, no general clue to its position, applicable in practice, had been detected, nor was it probable that any could be, until the order of superposition had been minutely and methodically studied. No sooner was this done, however, than we perceived that all the outcrops of the ore, accidentally discovered in the formation, belonged to one solid and extensive band, regularly interstratified in the lower part of the Cadent black slates, accompanied by such well-marked features in the adjoining rocks as to render the tracing of its course, with proper skill and knowledge, a matter of ease and certainty.

The ore of the Vergent series is a widely-distributed stratum, having a very continuous range through parts of Lycoming, Clinton, and Tioga counties, but not developed in any thickness in other portions of the State. Its place in the series is near the top of the Vergent shales, or more properly in the alternating group by which the Vergent and Ponent strata graduate into each other. It seems to attain its maximum thickness on Larry's Creek, in the Alleghany Mountains, where the principal bed is about 3 feet thick. East of Lycoming Creek it gradually thins away, and it also vanishes in the other direction at the Susquehanna, not being traceable beyond Farrandsville. It is found as far North as the Tioga River.—(See Vol. I. pp. 310, 311, for some detailed descriptions of it.) This ore is of a dull purplish-red colour, and is arenaceous and granular, the peroxide of iron encrusting the grains of silicious sand, so as to impart to it a somewhat oolitic aspect. It contains organic remains, chiefly two or three species of the bivalve shells characteristic of the upper part of the Vergent shales; but it is by no means as rich in fossils, and therefore in calcareous matter, as the fossiliferous ore of the Surgent series. A large excess of silicious matter in the ore greatly impairs its value for the smelting-furnace. This ore closely resembles the celebrated Cleveland ore of Yorkshire, England, a bed 14 feet thick in the oolite formation. Its qualities will be readily inferred from the analyses contained in the following Table:—

TABLE OF ANALYSES OF IRON ORES OF THE CADENT AND VERGENT STRATA OF PENNSYLVANIA.

Localities.	Carbonate of Iron.	Peroxide of Iron.	Oxide of Manganese.	Silica and Insoluble Matter.	Alumina.	Carbonate of Lime.	Water.	Metallic Iron in 100 Parts.	Description of the Ores.
Cadent Black Slate.									
Six miles W. of Pinegrove, .	...	37.00	...	45.90	4.20	1.50	11.25	25.90	Mottled-brown, slaty, cellular, fossiliferous.
Walter's Bank, ½ mile W. of Brookland Furnace, Lewistown Valley, ...	...	66.00	a trace	18 80	5.80	...	9.00	46.20	Brown, hæmatitic, velvet-like.
Mercy's Bank, 1½ miles S.E. of Newton Hamilton, .	...	65.40	a trace	20.50	4.60	...	9.00	45.78	Dull-brown, laminated, cellular, and silicious.
¾ mile W. of Chester Furnace, Huntingdon Co., .	...	66.92	14.64	7.57	1.93	...	9.48	46.40	Mottled, dark brown, compact, soft.
Warren Ore Bank, Little Cove, Franklin County, .	...	67.60	a trace	18.80	a trace	...	12.70	47.32	Dark brown, hollow lumps.
Brown Furnace, Little Cove,	80.55	...	...	17.00	1.50	...	1.00	38.80	Bluish-grey, nodular, and compact.
Cadent Newer Shales.									
Two miles W. of Pinegrove,	...	32.00	...	60.00	0.50	1.00	6.00	22.40	Dull, reddish-brown, slaty, cellular, fossiliferous.
Lycoming Creek, front of Alleghany Mountain, .	...	48.80	a trace	49.38	a trace	a trace	1.68	33.83	Chocolate-red, powder red, fossiliferous, granular.
Larry's Creek, Lycoming County, ...	...	61.20	...	32.30	3.00	1.30	2.20	42.84	Purplish-brown, powder red, fossiliferous, sandy.
N.W. side of Big Scrub Ridge, 2¼ miles S.W. of Bedford Turnpike, . .	...	84.54	...	2.85	a trace	...	12.00	59.17	Mahogany-brown, compact, hæmatitic (a surface ore).
Big Ore, base of Warrior's Ridge, Woodcock Valley, .	...	75.22	a trace	7.75	2.50	Org. Matter 2.80	11.45	52.65	Ochreous-brown, earthy, vegetable fibres.

CHAPTER VII.

IRON ORES OF THE UMBRAL SERIES.

The Umbral red shale of the bituminous coal region is accompanied throughout nearly its entire outcrop along the Alleghany Mountain, and towards the N.W., by a very peculiar variety of iron ore, which, in certain localities already described, is destined to become of much economical importance. This ore occurs high in the formation, usually not more than a few feet below the bottom of the Seral conglomerate. It is the grey and mottled carbonate of iron described in the chapter upon the Umbral strata. The ore is of somewhat various external features, but its most prevailing character is that of irregular knotty nodules of a mottled red and whitish or grey colour. These lumps, which are usually imbedded in a soft reddish shale, are often, especially near the outcrop of the stratum, coated with a brown crust of the peroxide of iron. On Lycoming Creek, the purer specimens of the ore, consisting principally of the crystalline carbonate of iron and silica, are internally of a pinkish-yellow colour, with a velvet-like aspect. In other districts, as that of Tioga River, near Blossburg, the ore is in regular continuous layers, certain parts of which are mottled, and have almost an oolitic structure.

It is only in certain local tracts of country that this interesting ore is rich enough in iron, and thick enough to be of value to the manufacturer of iron; but where it can be used, the metal procured from it is of remarkable excellence. The chemical nature and geological relations of this ore are very similar to those of the carbonate of iron of the coal strata, and the conditions under which it originated were obviously very nearly identical with those which produced that variety. I shall therefore reserve what I have to say respecting the source of the iron, until I come to speak of that of this still more important variety. Beside the nodular crystalline carbonate now described, the Umbral shales contain, especially in their S.W. outcrops, as in Somerset and Fayette counties, a species of ore identical with the ordinary compact or earthy carbonate of the Coal-measures. This latter kind belongs to a small subordinate group of coal-bearing rocks, which, in the districts mentioned, underlie the true Seral conglomerate, or constitute its lowest member, indicating a gradual transition from the Umbral series.

ANALYSES OF IRON ORES OF THE UMBRAL RED SHALES OF PENNSYLVANIA.

Localities.	Carbonate of Iron.	Peroxide of Iron.	Oxide of Manganese.	Carbonate of Lime.	Carbonate of Magnesia.	Silica and Insoluble Matter.	Alumina.	Carbonaceous Matter, &c.	Water.	Metallic Iron in 100 Parts.	Description of the Ores.
Savage's Mines, Trough Creek, Huntingdon Co.,	...	88.09	...	...	...	a trace	...	...	11.0	69.93	Reddish-brown, compact, and jaspery.
Hopewell Furnace (Old Bank), Trough Creek, .	...	60.00	a trace	0.40	...	32.10	2.50	...	4.50	42.00	Red and brown, nodular.
Hopewell Furnace, Terrace Mount Mine, .	...	84.00	a trace	...	...	2.30	a trace	...	13.50	58.80	Dull chocolate-brown, compact.
Ralston, Lycoming Co., .	65.00	...	...	0.72	...	28.80	1.00	...	4.28	32.06	Ash-grey, spathose.
Astonville, Frozen Mine, Lycoming County, .	68.00	...	...	0.60	...	28.70	0.80	...	1.50	32.80	Pinkish-yellow, velvet-like, minutely crystalline.
Farrandsville (Lower Red Shale), ...	...	68.40	...	a trace	...	25.60	3.60	...	2.00	47.88	Purplish-red, compact, nodular, sub-crystalline.
Johnson Hill, Blossburg, .	29.84	...	a trace	...	...	66.80	0.50	...	2.56	14.42	Light-grey, pinkish, spathose.
Bennett's Branch, 1¼ miles above Warner's, Clearfield County, . . .	82.20	6.50	...	...	...	6.65	1.00	...	3.40	44.22	Dull-grey, compact.
Bennett's Branch, same locality, ...	63.80	...	1.00	...	...	30.90	0.75	...	2.75	30.28	Grey, light, compact, and coarser than the above.
S.E. of Blairsville, Indiana County, ...	37.80	...	...	5.50	7.50	37.80	7.60	...	3.50	18.27	Mottled-red and green, nodular, somewhat spathose.
Hill's, W. side of Chestnut Ridge, Indiana County, .	...	51.25	a trace	2.00	...	36.50	5.96	...	4.00	35.87	Cinnamon-brown, nodular.
Garey's Mine, Fayette Co.,	84.14	2.78	a trace	3.00	...	...	0.75	...	5.00	40.62	Dove-colour, externally brown, nodular, close-grained.
Garey's Mine, same locality,	35.50	...	...	2.50	1.35	15.55	2.80	...	2.00	38.22	Greyish-blue, kidney-formed, close-grained.
Chestnut Ridge, Pennsylvania Canal, Westmoreland County, . . .	...	61.50	...	a trace	a trace	31.44	1.25	...	5.20	41.05	Purplish-brown and greenish, jaspery.
Hare's Valley, Huntingdon County, . . .	...	97.54	...	...	...	3.12	0.18	...	...	67.63	Purplish-red, massive, micaceous, unctuous (a surface specimen).

There is still another, but much more local deposit of iron ore in the series, occupying the very horizon which separates the Umbral red shale from the underlying Vespertine conglomerate. This ore is limited to the synclinal basin of Trough Creek in Huntingdon County, where it has the form of massive lumps or nodules enclosed within the very lowest beds of the red shale. It is usually a very dense and compact form of the ordinary brown peroxide of iron, and for the most part contains too large a proportion of foreign matter, particularly silica and manganese, to permit it to yield a good cast-iron. When smelted alone, the product has invariably been a weak or "cold-short" metal. This ore has been derived apparently from the ferruginous matter diffused through the highly-coloured layers of shale in the inferior portion of the Umbral red shale. Another ore of the Umbral series is the interesting deposit seen in the valley of Stafford Meadow Brook, and which has been already sufficiently described at page 358 of this volume. It resembles the Trough Creek ore both in its chemical aspect and its stratigraphical position. The preceding Table displays the prevailing composition of the several ores here described as appertaining to the Vespertine series.

CHAPTER VIII.

IRON ORES OF THE COAL STRATA.

In the Coal-measures of Pennsylvania we meet with the proto-carbonate of iron, the characteristic iron-ore of the coal-formation, under a great variety of forms and minor shades of composition. The Table of Analyses of these ores will serve to exhibit the chemical constitution of the whole series, and to show certain important general differences between those of the different districts of our vast coal region. By an inspection of these numerical results, it will be seen that, as a class, our carboniferous ores contain but a small amount of alumina, and are therefore not entitled to be called argillaceous iron-ores: the analyses, on the contrary, make it apparent that their chief impurity is silica, the proportion of which on the average is not, however, materially greater than in the clay ironstones of Europe, although the amount of alumina is considerably less. The average quantity of silica is 23 per cent, and that of alumina 2.2 per cent. A very conspicuous and important difference is noticeable between the ores of the anthracitic coal-basins and those of the bituminous: the former are of a coarser texture, and for the most part less rich in iron, and this difference is principally owing to the presence of a larger proportion of silica and insoluble matter. In the anthracite ores the average proportion of silica is 28 per cent, while in the bituminous ores it is shown to be 18 per cent. From this greater preponderance of the silicious ingredient, these anthracitic ores are more difficult of reduction in the furnace, and demand a larger proportion of limestone flux. One main obstacle to their successful use, in some instances, arises from the firm adhesion of a portion of the surrounding shale to the surface of the nodules, the result of the cementing and indurating action to which all the rocks of the anthracitic region have been subjected from subterranean heat. Beyond the difference in the silica here referred to, there are no other essential points of disparity between the two classes of ores; both contain carbonate of lime in nearly equal proportion, and derive from the presence of this flux a partial corrective of the silica and other earthy impurities. Both of these groups of ores have among their constituents frequently two or three per cent of the carbonate of magnesia, an element which we might naturally look for in association with the carbonate of lime, when we reflect upon its general abundance in the several limestone formations, and the proofs they afford of the general prevalence of this ingredient in the ancient Appalachian waters. The carbonate of manganese likewise constitutes from one to three per cent of the weight of many of these ores, but this element and the carbonate of magnesia are seldom present in sufficient quantity to impede essentially the fusion of the mineral where a sufficiently copious blast is employed, and the fuel used is either coke or anthracite.

Of particular beds appertaining to this widely-diffused class of ores, two layers are sufficiently important and peculiar to merit in this place a special but brief notice. One of these is the so-called Blackband of the Bear Valley Basin, the geological facts respecting which have been already presented. In its chemical composition this ore differs in no very material point from the celebrated and very valuable blackband ore of Scotland, as any analysis of the latter will show. The sole injurious ingredient in the anthracitic blackband is its sulphur, but the considerable amount of "coaly matter" diffused through the ore will tend to facilitate the burning off of at least a part of this in the process of roasting.

Another feature of difference, but probably not a very important one, between the Pennsylvanian and the Scotch blackband, is in the bituminous nature of the coaly matter contained in that last named, and of which the anthracitic ore is necessarily destitute. This bituminous matter, by its diffusive flame and its constituent hydrogen, is perhaps the most efficient agent in the removal of any sulphur in such an ore that Nature could provide, and hence one reason of the general excellence of the blackband iron of Scotland.

The other layer of ore to which I wish to advert, is the much more extensive stratum appertaining to the lower Coal-measures of the bituminous series of Western Pennsylvania, and described in my account of that district as the limestone or buhr-stone ore. It is, as I have already amply shown, a regular and widely-extended stratum of the proto-carbonate of iron, of superior purity and richness. Overspreading, as it does, a wide geographical area in the fifth and sixth bituminous basins, embracing parts of the Clarion and Alleghany rivers, and a large portion of Armstrong, Venango, Clarion, Mercer, Butler, and Beaver counties, it has already,—since attention was first drawn to it as a continuous and traceable seam of ore, in my Fourth Annual Report,—become the basis of numerous and extensively-distributed ironworks, and is destined to be hereafter one main element in the future rapid march of wealth and manufactures in Western Pennsylvania. This ore consists generally of a mixture of the peroxide and proto-carbonate of iron, the latter predominating, except near the outcrop, where the ore is composed almost exclusively of the brown hydrated peroxide, and is of various tints of brown and red. Its structure is often cellular, the irregular cavities being surrounded by a thinner or thicker crust of the ore. In other instances, it occurs in large masses in which the ore is intimately mingled with the chert upon which it reposes, and is full of drusy cavities, lined with minute crystals of quartz, tinged red, brown, and pink by the oxide of iron. These cavities sometimes contain water. Though this seam of ore accompanies the limestone over considerable spaces of country, it is not strictly continuous, but occurs rather in large patches of various thicknesses. The bhur-stone and the iron ore would seem indeed to replace each other, the one most abounding where the other is deficient. For the chemical composition of this ore, see the analysis in the Table which follows. The great importance of this valuable deposit to the growing wealth and enterprise of the Western part of the State is beginning to be appreciated, I need hardly, therefore, dwell upon it farther than to mention the following circumstances in its favour: Its richness far exceeds that of the nodular variety common in the slate of the Coal-measures, and will bear comparison with much of the best ore found in the limestone valleys S.E. of the Alleghany Mountain. Another merit is the facility with which it may be smelted, either alone or when mixed with the nodular or ball ore, and particularly with the bog ore, found so abundantly in Venango and Clarion counties. In the thicker parts of the deposit it is a nearly pure semi-crystalline proto-carbonate of iron, a variety well known to be susceptible of extremely easy reduction. It is, morever, recommended by the readiness with which it can be traced, arising from its accompanying closely the fossiliferous limestone, which is an excellent landmark. The buhr-stone assists the discovery of it in a still greater degree, the fragments of that peculiar rock being so easily recognised. Besides these important facts, it should be mentioned that a workable seam of coal occurs above the ore and limestone, and another beneath them at a moderate interval. The importance of this triple association of the materials necessary in the manufacture of iron to the future wealth of our Western counties, must be obvious to every one who adverts to the incalculable advantages which Great Britain has derived from the same fortunate union.

The ores of the Coal-measures display at their outcrop two very distinct varieties as to their chemical composition—namely, the brown peroxide and the carbonate of iron—though it is more than probable that nearly all of the peroxide has been originally derived from the other kind. The carbonate, which is a compound of the protoxide of iron and carbonic acid, after long exposure to the air, absorbs an additional amount of oxygen, losing at the same time its carbonic acid, and is thus converted into the brown oxide or hæmatite. This change may be witnessed in all its stages in many of the more exposed beds, the nodules in some cases being merely coated with a thin shell of the peroxide, and in others altered to a considerable depth, leaving but a small central mass of carbonate; and again, in other instances, where the exposure has been still longer and more complete, the whole has been transformed into the brown ore.

The carbonate ore is invariably more or less calcareous, as already intimated, and in many cases contains so large a proportion of carbonate of lime as to be in fact a ferruginous limestone, a condition especially seen in the buhr-stone ore. When the above-described change has arisen, the ore is found to have lost the greater part of its original calcareous matter, and hence the resultant brown ore is comparatively exempt from that ingredient. To explain this effect, it is only necessary to advert to the solubility of carbonate of lime in the percolating surface-waters, and to the fact that the carbonic acid escaping from the carbonate of iron, in its conversion into the peroxide, would greatly aid in the solution and removal of the calcareous matter.

Respecting the origin of the carbonate of iron in these ores, it is sufficiently evident from the texture of the nodular ore itself, and of the slates surrounding it, that the whole mass of each ore-bearing bed was primarily deposited as a fine calcareous and ferruginous mud, in which was included a large amount of organic matter, especially the fragments of the carboniferous vegetation, and in some cases certain species of shells. In these deposits the iron was at first probably in the state of peroxide, as in nearly all finely-pulverised and long-exposed sediments. By the slow decomposition of the organic materials, a part of the oxygen of the peroxide would be withdrawn to combine with the carbon and hydrogen of the organic substances, and the iron would be thus left in the state of protoxide. At the same time the carbonic acid formed by the oxidation of the carbon would unite with the protoxide, and give rise to the proto-carbonate of iron. As long as any organic matter remained in the mass, this change would continue, and in this way the whole of the peroxide of the original sediment may be conceived to have been converted into carbonate. The same action now continuing, though in a slighter degree, must tend to protect the carbonate from the decomposing action of the atmosphere, and thus in many cases to retard its conversion into the brown oxide.

The nodular form of the ore is evidently a subsequent result, and must be referred to the agency of a concreting force among the particles by which the carbonates of iron and lime, previously diffused in a uniform manner throughout the mass, have been gathered around certain centres. Some of the superficial beds of brown ore resting upon the outcrop of the coal-rocks, would seem to be derived rather from the sulphuret of iron diffused in the adjoining slates, as in cases previously mentioned, than from the decomposition of the nodular carbonates.

These have nothing of the continuous regularity of the layers of the nodular ore, and they bear a strong resemblance to the loose ore-deposit of the older Appalachian slates.

In further elucidation of this interesting subject, I take the liberty of introducing here a valuable brief essay

ON THE ORIGIN AND ACCUMULATION OF THE PROTO-CARBONATE OF IRON IN COAL-MEASURES, &c.

BY PROFESSOR WILLIAM B. ROGERS.

This compound, as we know, where mined in the Coal-measures, presents itself in courses of lenticular nodules and interrupted plates usually included in carbonaceous shales, and in the fire-clays which underlie the seams of coal, and in such cases it often forms a heavy ore containing but little earthy or organic matter mixed with the proto-carbonate; but it is also frequently met with in a *diffused condition*, pervading thick strata of shale and shaly sandstone, and causing these rocks to present in their different layers all the gradations of composition from a poor argillaceous and sandy ore, to beds of sandstone and shale, with little more than a trace of the ferruginous compound.

On comparing the different subdivisions of a system of Coal-measures, we may remark certain general conditions connected with the abundance or with the comparative absence of the proto-carbonate in the strata.

One of these is seen in the fact that *the lenticular ores and strata impregnated with proto-carbonate of iron are in a great degree restricted to such divisions of the carboniferous rocks as include beds of coal, or are otherwise heavily charged with carbonaceous matter.* This is well shown on comparing together the four subdivisions of the carboniferous rocks of the great trans-Alleghany coal region, as classified under the head of the Seral Coal Series of the Pennsylvania and Virginia geology. In the first of these, designated as the older Coal-measures, the proto-carbonate is found in larger amount, both in the shape of layers of lenticular ore, and diffused through the substance of the shaly strata. In the next division above, distinguished as the Older Barren Shales, and which, as the name implies, is comparatively devoid of carbonaceous matter, much less of the proto-carbonate is met with. In the third group, that of the newer Coal-measures, the ore again abounds; and in the uppermost division or Newer Barren Shales, it has a second time almost disappeared.

The connection between the development of the proto-carbonate in the strata, and the presence, either now or formerly, of a large amount of carbonaceous or vegetable matter, becomes even more striking on a detailed examination of particular beds. Thus in the coarse sandstones of the Coal-measures which are comparatively destitute of vegetable remains, we find little admixture of the proto-carbonate. On the other hand, the fine-grained flaggy argillaceous sandstones, which are often crowded with the impressions and carbonised remains of plants, are at the same time more or less impregnated with this ferruginous compound. So again, the soft argillaceous shales, in the midst of which the lenticular ore so frequently presents itself, show by their dark colour and included impressions of plants, as well as by actual analysis, that they are richly imbued with vegetable matter. Nor do the nearly white fire-clays, which in many cases enclose thick courses of the lenticular ore, form any exception to this law; for although, in their present state, they contain little or no carbonaceous matter, the marks of innumerable roots of Stigmaria, and parts of other plants which everywhere penetrate the mass, show that at one time they must have been crowded with vegetable remains.

A further and yet more striking proof of the influence which the contiguous vegetable matter has had in the formation of the proto-carbonate is seen in the fact that the most productive layers of the ore are commonly met with quite near to the beds of coal, and that frequently courses of the nodules are found in the carbonaceous shales or partings which lie in the midst of the seam itself.

While the strata, including the proto-carbonate, are thus distinguished by the admixture of more or less carbonaceous matter, they are *also remarkable for seldom exhibiting a distinctly red tint.* Presenting, where not weathered, various shades of greenish-grey and olive and bluish-black, they only become brown or red where, by exposure to the air, the proto-carbonate has been converted into the sesquioxide of iron. On the other hand, those divisions of the Coal-measures which have been but slightly charged with vegetable matter—as, for example, the Barren shales of the Seral coal-rocks before alluded to—contain much red material both in distinct strata and mottling the general mass, and are throughout more or less impregnated with the sesquioxide.

A like general law as to colour would seem to apply to the other great groups of sedimentary rocks which include, in particular beds, accumulations of vegetable or other organic exuviæ. Thus in the new and old Red-sandstone formations, which generally include so large a proportion of sediment coloured by the red oxide of iron, organic remains are of comparatively rare occurrence, and, when present, are met with almost exclusively in the grey, and olive, and dark-coloured strata which are interpolated in certain parts of the great masses of red material. This relation is beautifully shown in the middle secondary rocks of the Atlantic Slope, which extend in a prolonged belt from the Connecticut Valley into the State of South Carolina. In the strata of red sandstone and shale which form the chief part of the mass, vegetable or animal exuviæ are almost entirely absent; but the remains of fish and impressions of carbonised parts of plants occurring in this group of deposits are found imbedded in layers of greenish and olive sandstones and dark bituminous shales. So in the S. parts of the belt in Virginia and North Carolina, where these rocks include seams of coal and extensive beds of sandstone and shale, containing the remains of plants, the usual red colour is found to give place to the grey, olive, and dark tints of the old Coal-measures, and layers of proto-carbonate of iron show themselves in the vicinity of the coal-seams.

Taken in mass, the red and mottled strata of the unproductive Coal-measures, or of the other groups of red rocks above alluded to, would no doubt be found to contain, in an equal thickness, as large an amount of iron as the coal-bearing strata which include the layers of carbonate—the difference being, that in the former case the metal remains for the most part diffused through the rock as a sesquioxide; while, in the latter, having assumed the condition of proto-carbonate, it has to some extent been concentrated in particular layers or strata. According to a rough estimate of the amount of carbonate ore included in the lower Coal-measures of the Laurel Hill region of Virginia and Pennsylvania, derived from a detailed examination of the ores and associated strata at several points, it may be safely assumed that the equivalent of sesquioxide of iron would not amount to one-third of one per cent of the whole mass of this portion of the Coal-measures, and a proportion not exceeding this is deducible from the measured sections of ore and accompanying rocks in the carboniferous strata of other tracts subjected to a similar calculation.

But even allowing a quantity three times as great as this to cover the diffused carbonate, and the oxide in some cases mingled with it, we should have only about one per cent to represent the proportion of ferruginous matter in the entire mass—an amount undoubtedly much less than what exists in many of the strata of red and purple shales and shaly sandstones of the carboniferous series, or of the groups of red rocks geologically above or beneath it.

In attempting to explain the origin of the proto-carbonate under the conditions above described, it is important to keep in view the fact of the diffusion of this compound through many of the strata as a general constituent, and the frequent preservation even in layers of the ore of the lamination of the contiguous rock. The supposition of its being a chemical deposit formed from springs charged with carbonic acid, and holding proto-carbonate in solution, is evidently inconsistent with these conditions, and not less so with the fact of the great horizontal extension of individual beds of ore and impregnated shaly rocks.

In view of these various considerations it may be concluded—

First, That throughout the Coal-measures and other groups of rocks above mentioned, as well in the portions containing coal and diffused vegetable and animal matter as in the barren parts, the original sediment was more or less charged with sesquioxide of iron; and,

Second, That this sesquioxide in the presence of the changing vegetable matter with which certain of the strata abounded, was converted into proto-carbonate, which remained in part diffused through these beds, or by processes of filtration and segregation was accumulated in particular layers.

It is well known that during the slow chemical changes by which vegetable matter enclosed in moist earth is converted into lignite or coal, both light carburetted hydrogen and carbonic acid are evolved, and that these gases are even eliminated from coal-seams and their adjoining carbonaceous strata. The reducing agency of the carbon and hydrogen, as they separate in their nascent state from the organic matter, is capable, as we know, of converting certain sulphates into sulphurets, and even more readily of transforming the sesquioxide of iron into protoxide. The latter change would doubtless be favoured by the affinity of the carbonic acid present in the mass, for the protoxide thus formed, and in this way the sesquioxide would be entirely converted into the proto-carbonate of iron.

Conceiving a like process to have operated on a large scale in the Coal-measures or other strata containing, when deposited, a mixture of sesquioxide of iron and organic matter, we have a simple explanation of the general conversion of this oxide into carbonate, and of the loss of the reddish colouring in which these materials more or less participated. As these actions must be supposed to have commenced in each stratum as soon as the organic matter contained in it began to suffer chemical change, we may conclude that the formation of the proto-carbonate was already far advanced in the earlier strata when only beginning in those deposited at a later period. Each layer of vegetable matter, as it was transformed into coal, would not fail to impregnate the adjoining beds of shale and sandstone with the proto-carbonate, and thus the development of this compound was, as it were, coeval with that of the coal.

The gathering of the diffused proto-carbonate into bands and courses of ore began, no doubt, as soon as the production of this compound had made some progress; but it probably continued until long after the completion of the chemical changes above described, and indeed it is possible that in some strata it is not yet entirely finished. In this process, which finds a simple explanation *in the combined action of infiltration and the segregating force*, it can hardly be questioned that *the carbonic acid* pervading the mass of sediment acted *a very important part.* The large amount of this gas evolved from the beds of vegetable matter undergoing change would impart to the water of the adjoining strata the power of dissolving the diffused proto-carbonate, which being then carried by infiltration through the more porous beds, would accumulate above and within the close argillaceous or shaly layers, forming in some cases bands of rock ore, in others, courses of nodular and plate ores. Of these, the former would seem to have resulted from the accumulation by *gravity* of the dissolved carbonate in the substance of sandy shales near the upper limit of the more impervious beds, while we may regard the latter as having been collected in all directions from the general charge of proto-carbonate accumulated in the argillaceous mass, its mobility in the dissolved condition greatly aiding the gathering process of the *segregating force.*

The following Table presents, in a condensed view, the chemical constitution of all the chief varieties of the iron ore of the several coal regions:—

ANALYSES OF THE CARBONATES OF IRON OF THE COAL-MEASURES OF PENNSYLVANIA.

Localities, Anthracitic Basins.	Carbonate of Iron.	Peroxide of Iron.	Carbonate of Manganese.	Carbonate of Lime.	Carb. of Magnesia.	Silica and Insoluble Matter.	Alumina.	Carbonaceous Matter, &c.	Water.	Metallic Iron in 100 Parts.	Description of the Ores.
Tunnel N. of Gate Vein, Pottsville,	80.85	...	...	1.00	3.86	9.08	2.06	1.02	2.00	39.09	Close-grained, blue, fracture slightly conchoidal.
N. American Mines, Pottsville,	39.82	...	a trace	1.00	2.35	50.80	2.80	Sulphur, a trace, Carb. 120	2.00	19.21	Texture coarse, unctuous; spots of iron pyrites.
Below Rabbit-Hole Vein, Pottsville,	63.30	...	a trace	1.50	1.60	25.00	3 20	Carb. 122	1.50	32.6	Lenticular, nodular, blue.
Below a bed of coal at Pottsville,	67.80	...	1.00	0.39	a trace	29.00	1.30	...	.50	33.9	Slate-blue, hard, rough.
M'Carty's Tunnel, Pottsville,	26.02	19.36	a trace	0.07	4.04	46.40	2.08	...	1.00	26.39	Slate-blue, slightly unctuous, micaceous.
False Salem Vein, Guinea Hill, Pottsville,	56.20	...	a trace	a trace	0.3	39.30	2.80	.50	.20	32.48	Compact, earthy, micaceous.
Guinea Hill, Pottsville,	63.3	...	...	a trace	1.4	32.0	2.80	...	.40	30.66	Externally in concentric laminæ.
Guinea Hill, 14 inches, Pottsville,	67.69	...	...	1.26	2.0	21.0	1.60	1.00	1.40	34.72	Blue, compact, unctuous.
Mann and Williams' Tunnel, Pottsville,	72.00	...	a trace	2.08	1.52	21.50	1.60	1.00	3.00	36.00	Blue, slaty, unctuous.
Mann and Williams' Tunnel, Pottsville,	79.20	...	a trace	a trace	a trace	15.0	2.60	Sulphur a trace, Carb. 1.30	1.60	42.8	Blue, earthy, unctuous.
Guinea Hill, another bed, Pottsville,	31.53	31.31	a trace	...	...	31.08	a trace	...	6.06	37.14	Externally concentric, brown; internally hard, blue, meagre; both analysed.
Rabbit-Hole Vein, Pottsville,	48.33	15.06	2.03	3.11	5 11	20.25	1.28	1.81	3.02	33.35	Dull bluish-black, compact.
St Clair Tract, Pottsville,	42.38	21.32	3.64	...	...	27.63	a trace	...	5.03	34.86	Externally concentric, brown; internally compact; blue, average of all.
St Clair Tract, Pottsville,	66.67	2.55	a trace	8.25	a trace	13.90	2.25	...	6.10	33.96	Slate-blue, compact.
Mount Laffy, Pottsville,	39 54	14.57	0.50	a trace	a trace	40.00	...	...	4.60	32.52	Brownish, compact, meagre.
Mount Laffy, another bed, Pottsville,	45.50	...	1.00	6.00	7.50	30.00	2.25	Bi-Sulphuret of Iron, 0.60	7.00	22.05	Blue, compact, crystals of yellow iron pyrites.
Mount Laffy, another bed, Pottsville,	39.54	15.56	0.30	a trace	a trace	39.00	0.50	...	4.50	31.50	Brown, slaty, slightly unctuous.
Zachariah's Run, Pottsville,	31.07	14.37	1.25	...	2.20	44.80	1.00	...	5.00	25.05	Bluish, slaty, micaceous.
Zachariah's Run, Pottsville,	35.13	28.10	2.39	0.92	8.79	21.62	0.91	...	1.00	41.88	Dark blue, slaty, and compact, more external brown crust.
Port Carbon,	...	53.56	1.08	...	...	36.01	a trace	...	9.35	37.14	Dull brown, laminated, with clay.
Summit Mine of Lehigh,	...	37.40	...	a trace	a trace	45.65	18.60	Carb. acid a trace.	4.00	22.98	Slate-blue, compact, nodular, conchoidal, rusty.
Mount Eagle, Black Spring Gap, Dauphin County,	73.94	10.36	2.95	...	2.07	6.63	...	1.54	1 99	42.22	Nearly black, slaty.
Near Shamokin,	56.90	24.90	a trace	a trace	...	16.05	1.00	...	1.50	44.87	Dark blue, compact, and slaty, surface rusty.
Shamokin Mines, another bed,	74.50	...	a trace	5.40	a trace	14.30	2.80	...	2.50	35.98	Bluish-black, close-grained, conchoidal.
Shamokin Mines, a third bed,	63.20	...	1.00	...	a trace	31.15	1.50	...	1.50	30.52	Blue-grey, coarse, subcrystalline.
Shamokin Mines, a fourth bed,	58.00	8.45	4.50	a trace	a trace	15.44	4.50	Org. Matter 1.50	7.50	45.92	Slate, blue internally: kidney ore, compact, surface rusty.
Shamokin Big Mountain,	...	79.50	a trace	...	...	4.80	a trace	Org. Matter 2.50	12.50	55.65	Light chestnut-brown, cellular; a surface specimen.
Near Wilkesbarre,	37.00	1.20	1.00	1.50	0.50	38.00	3.00	1.50	4.50	30.10	Bluish-grey; externally rusty, slaty.
Lackawanna Valley,	39.10	14.05	1.00	2.00	1.00	33.10	2.00	Carb. Matter, 2.00	5.00	32.50	Bluish, conchoidal, unctuous.

TABLE OF ANALYSES OF THE CARBONATES OF IRON—*Continued.*

Localities, Bituminous Districts.	Carbonate of Iron.	Peroxide of Iron.	Peroxide of Manganese.	Carb. of Lime.	Carb. of Magnesia.	Silica and Insoluble Matter.	Alumina.	Carbonaceous Matter, &c.	Water.	Metallic Iron in 100 Parts.	Description of the Ore.
Karthaus, Clearfield County (near the conglomerate), .	19.86	34.80	a trace	4.50	...	30.40	1.70	...	8.20	33.95	Mottled-brown, nodular concentric, crust hæmatitic.
Paint Creek, Cambria Co., .	60.90	12.60	...	3.00	...	14.74	2.00	...	6.50	38.22	Buff and slate-blue, sparry, compact.
Near Clearfield Creek, Clearfield County, . . .	50.48	12.79	a trace	0.70	2.43	29.01	...	...	4.59	32.77	Mottled-grey, nodular, sparry.
3 miles S.W. of Clearfield, near the river, . .	56.83	13.21	1.13	...	1.26	24.41	a trace	...	3.16	36.11	Dark blue, rusty, compact, semi-crystalline.
Same as above, another variety, ...	66.37	20.49	2.25	1.07	2.08	6.10	a trace	Sulphur, a trace.	1.64	45.64	Dull blue, compact; drusy cavities, with quartz and pyrites.
Bear Creek Hill, Blossburg, Tioga County, . . .	44.79	8.41	0.88	...	1.99	37.28	0.34	...	6.23	27.05	Mottled-reddish and grey, compact and oolitic.
Blossburg, same bed as above,	...	26.69	0.32	...	0.44	59.36	1.88	...	10.52	18.51	Dingy-brown, internally ochrey in concentric earthy layers.
Warner's, Bennett's Branch, Clearfield County, . .	55.82	...	...	5.0	...	36.80	a trace	...	2.0	26.95	Light grey, oolitic.
Bennett's Branch, above Warner's, ...	73.81	4.24	a trace	a trace	...	14.46	1.00	Org. Matter, 0.50	5.50	38.59	Dull blue, concentric, earthy.
Bennett's Branch, Limestone Vein, ...	55.10	9.50	...	5.80	5.40	18.90	2.10	...	3.00	34.72	Blue-grey; kidney-shaped balls.
Blairsville, Westmoreland County, ...	71.19	...	...	3.50	2.72	17.55	2.10	...	2.70	34.37	Bluish-grey, compact, coarse, and semi-crystalline.
Blairsville, a different variety,	67.20	7.48	...	3.24	1.50	12.34	a trace	...	8.0	37.24	Dove-colour, smooth, nodular.
Lockport (Bog-ore), Westmoreland County, . .	...	77.00	4.50	...	...	4.0	1.50	Org. Matter, 1.22.	12.0	53.90	Brown, ochreous, porous (Bog-ore.)
Lockport, Westmoreland Co.,	69.0	...	...	7.80	a trace	20.44	a trace	...	2.40	33.32	Dove-colour, nodular, conchoidal, close-grained.
Lockport, Westmoreland Co.,	45.30	...	2.30	32.0	4.50	9.45	1.25	...	6.0	21.86	Slate-blue, compact, slightly conchoidal.
Phipps' Furnace, Scrubgrass, Venango County, . .	96.00	...	a trace	a trace	...	2.10	0.50	a trace	1.0	41.30	Slate-blue, externally brown, compact ball-ore.
Rockland Furnace, Venango County, ...	79.90	...	0.05	2.60	...	14.80	0.50	Org. Matter, a trace.	2.0	38.05	Blue, externally brown, nodular, compact.
Kutcher's, Clarion County, .	76.30	...	0.50	6.0	...	13.30	1.0	...	2.0	59.03	Buhr-stone ore, bluish-grey, compact, conchoidal, spathose.
Kutcher's, another specimen,	87.04	...	...	4.06	...	5.08	0.05	...	1.05	54.14	Dull-red, mottled, soft, and porous, outcrop-ore.
Lucinda Furnace, Clarion County, ...	...	78.22	1.50	...	...	4.80	0.54	...	14.20	54.75	Chestnut-brown, cellular, burnt-stone ore.
Madison Furnace, Clarion County, ...	...	76.1	...	a trace	a trace	7.70	3.60	...	12.50	53.27	Dull-brown, cellular, internally compact, burnt-stone ore.
Porterfield's Furnace, Clarion County, ...	25.30	45.04	1.00	1.78	...	21.50	0.70	...	4.00	35.03	Reddish-brown, oolitic, nodular, concentric crust.
Porterfield's Furnace, Clarion County, ...	...	79.20	1.00	...	...	5.30	a trace	...	14.00	55.44	Brown, slightly cellular.
Deal Bank, 1 mile S. of Shippensville, Clarion County,	...	83.00	2.00	...	...	2.81	a trace	...	12.50	58.10	Purplish-brown, hæmatitic, cellular.
Buffalo Creek, Armstrong County, ...	68.32	...	a trace	15.54	1.35	10.58	a trace	...	4.00	32.95	Internally brownish-blue, externally brown; nodular, compact.
Buffalo Creek, Armstrong County, ...	54.33	...	...	a trace	a trace	40.90	0.50	...	4.00	25.34	More silicious than the foregoing.
Bog Ores:											
Smuller's Furnace, Bog-ore, Venango County, . .	...	80.12	0.50	...	...	3.80	a trace	Org. Matter, 2.00	13.00	56.07	Brownish yellow, soft and pulverulent (bog-ore).
Hickory Furnace, Butler County, ...	...	78.60	0.40	...	...	4.80	a trace	Org. Matter, 2.00	14.00	55.02	Cinnamon-brown, brittle, with plates of hæmatite (bog-ore).

SKETCH OF THE GEOLOGY OF THE UNITED STATES.

To appreciate correctly the geology and mineral resources of Pennsylvania, it is necessary that we should estimate them in their relations to those of the rest of the great area of the middle zone of the continent, of which the State forms but a portion. With a view, therefore, to co-ordinate it with the whole, and with the geology of other quarters of the globe, and for the sake of illustrating local phenomena, which can only be rightly understood through a broad survey of the entire field, I offer to the reader, as an appendix to the foregoing special description of the State, the following general sketch of the Geology of the United States.

The geological formations of the United States comprehend both sedimentary and igneous rocks of all ages, from the earliest gneissic and granitic masses of the primordial crust, to the latest depositions and eruptions of the post-tertiary and existing times. The sequence of formations is, however, not so full as in Europe, there being a few important geological periods not represented by any strata hitherto discovered on the American Continent. This is a fact of much theoretical interest, as it implies that the crust movements were not always coincident in time, nor in the same directions, on the opposite sides of the Atlantic. While the American stratigraphical column is deficient in some members of the great series of deposits found in Europe, it is apparently more full than the European in the subordinate formations composing certain great groups which the two possess in common.

The comparative geology of the two continents will be learned from the following Table, which, omitting any ultimate analysis of the rocks into formations, represents only the great natural groups, or larger series of sedimentary deposits, and gives the co-ordination of these members of the two scales with each other.

Periods represented by European Strata.	American Equivalents.
RECENT	Represented on a grand scale, especially in the alluvial deposits of the present rivers.
QUATERNARY	Represented by extensive terrestrial, alluvial, lacustrine, marine, and volcanic deposits.
PLEISTOCENE	Represented by terrestrial deposits, with bones of extinct mammalia, by boulder-drift, and the Lawrentian marine clays and sands.
PLIOCENE	Represented by shelly sands on the Atlantic seaboard from Virginia to Texas, and by similar and other marine deposits in California, and by fresh-water deposits in Nebraska.
MIOCENE	Represented by marine beds in New Jersey, Delaware, Maryland, Virginia, and Carolina, and extensively in Oregon and California; also by fresh-water strata in Nebraska.
EOCENE	Represented by extensive marine clays, sands, and limestones, along the seaboard of the Southern States; by wide fresh-water basins in the plains E. of the Rocky Mountains; and by marine deposits in the Pacific slope in California.
CRETACEOUS	Diffused extensively from New Jersey to Alabama, and thence Westward to the Rocky Mountains, under the form of sands, clays, marls, and soft grey limestones, layers of gypsum, and beds of the characteristic greensand.
WEALDEN	Probably not represented in North America, though suspected to occur near the Judith River on the Missouri.

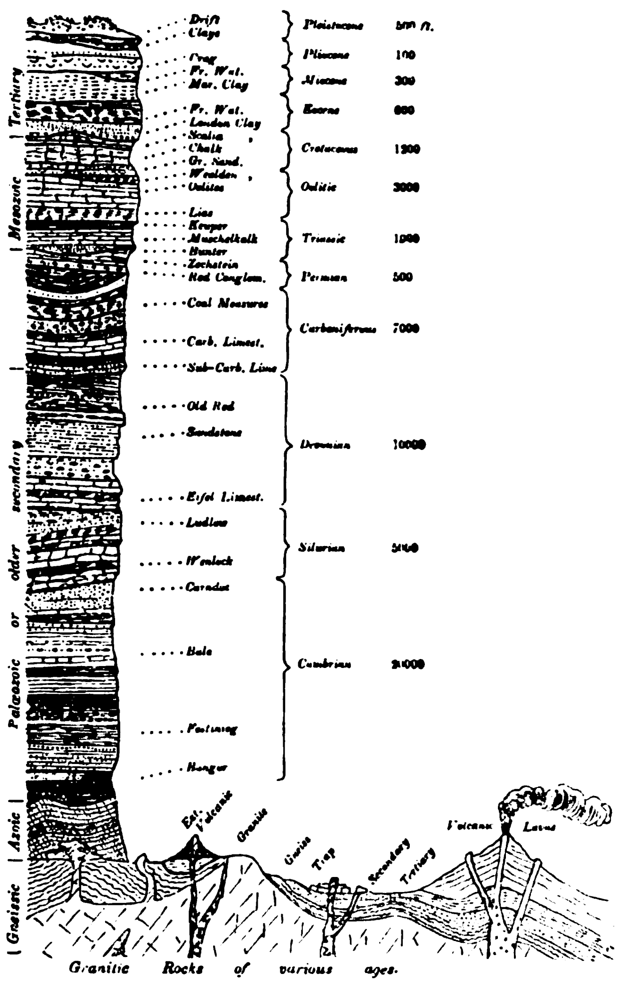


FIG. 584.—Synoptic Diagram of the European Formations.

Periods represented by European Strata.	American Equivalents.
JURASSIC	Represented in Virginia and North Carolina by a group of bituminous coal-measures, and in the valley of the Connecticut and on the Atlantic Slope, from the Hudson River to North Carolina; and again, in Nova Scotia and Prince Edward Island, by belts of a red shale and sandstone formation.
TRIASSIC	Not represented by any formations yet discovered, unless, perhaps, by the above supposed Jurassic red sandstone, &c.
PERMIAN	Supposed to be represented by deposits overlying Coal-measures in Kansas and Illinois, and believed to be in the BlackHills andGuadaloupe Mountains.
CARBONIFEROUS.	Represented very extensively in the United States by Coal-measures and other carboniferous strata, from the Appalachian Mountains to the Missouri River, and within and W. of the Rocky Mountains.
DEVONIAN	Formations of Devonian date occur, widely diffused and under great development, from the Appalachians to the Rocky Mountains, both as respects their thickness and the variety of their organic remains.
SILURIAN	Strata of Silurian age are found extensively distributed in the Appalachians and in the Western States, and likewise in the Rocky Mountains.
CAMBRIAN, OR OLDER SILURIAN.	Strata of Cambrian or Older Silurian age abound in the United States, from the Atlantic Slope to the Rocky Mountains, and probably to the Pacific chain; but, like all the other older Palæozoic series, they are extensively overlaid and concealed by formations of later date.
AZOIC, OR SEMI-METAMORPHIC.	Rocks of the Azoic series, or the Semi-Crystalline strata, next earlier in date to the first fossiliferous formations, abound in the Atlantic Slope, in the Rocky Mountains, and in the Sierra Nevada, and coast-ranges of California.
HYPOZOIC, OR TRUE METAMORPHIC.	The Gneissic or ancient Metamorphic Rocks occur extensively on the Atlantic Slope, especially in New England, also in the Lawrentian water-shed N. of the St Lawrence and Great Lakes, and likewise in the Rocky Mountains, and in the great chain of California and Oregon.
IGNEOUS ROCKS...	The Igneous Rocks of the United States, and the territories adjoining, are recent volcanic eruptions of the volcanoes of Oregon and California and Mexico, and similar volcanic ejections of various tertiary dates; also tertiary and middle secondary basaltic and trappean emissions in great abundance on the Pacific side of the continent; and along the Atlantic Slope, extensive outbursts of trap, of apparently Jurassic age, and there and in the Rocky Mountains numerous dykes and outflows of Plutonic rocks, of all earlier periods, to the most ancient granites and greenstones, contemporaneous with the earliest Hypozoic strata.

Looking at the general features of the Geological Map of the United States, and the territories adjoining, and viewing the more prominent points in the geological structure of this middle portion of North America, we perceive it to consist of five great natural areas: two of them, the largest and most irregular, include nearly all the tracts of the more ancient or Hypozoic and Palæozoic rocks, while the other three contain the chief part of the newer secondary and tertiary, or Mesozoic and Cainozoic deposits. Of the two older areas, the more Eastern embraces all that great division of the United States and the British Provinces which spreads from the Atlantic coast, and S. of New York from the Atlantic plain, W. to the Missouri River, or approximately to the longitude of 97° W., and which, in a N. and S. direction, extends from the termination of the Appalachian Chain in Alabama, and from the Washita River, in Northern Texas, to the Northern limit of the United States, or the territory of Hudson Bay. Throughout this extensive district, which comprises about one-half of the total breadth of the continent in these middle latitudes, there are scarcely any formations of a later geological age than the Upper Coal-measures, if we except certain relatively small strips and patches of Pleistocene tertiary bordering some of the Northern lakes and rivers, and that wide and general superficial covering, the Boulder-Drift, which only partially conceals the more ancient rocky strata, and which is therefore not represented by any special colour on the Map, except in the outline of its lower or Southern border. The other, or more Western region of the ancient rocks, includes the Rocky Mountains and their spurs, the table-land of Northern Mexico, and the whole chain of California, from the peninsula of that name to the Northern and Western ridges of the Sierra Nevada and the Pacific coast range. This area lies approximately between 105° and 123° of W. longitude. It is far less compact than the Eastern or Atlantic region, being much subdivided by numerous and large patches of the Cretaceous strata, stretching round the Rocky Mountains into the desert plateaus W. of them, and by still wider tracts of modern tertiary deposits, covering the vast arid plains and slopes of Oregon, Washington, Utah, and California, from the Wahsatch Mountains to the foot of the Sierra Nevada. This large, irregular, mountainous, and desert tract, includes rocks of all ancient epochs, from the earliest Hypozoic to the Coal-formation inclusive, and abounds in igneous rocks of yet more various ages, from the earliest Plutonic injections to the latest erupted sands and ashes of recently-expired or still living volcanoes.

Of the three areas of the more modern formations, chiefly Cretaceous and Tertiary, the central one, immeasurably the largest, may be defined as spreading from the Southern termination of the Appalachian Hills in Georgia and Alabama, W. to the table-lands of Mexico, N.W. to the E. foot of the Sierra Nevada of California, and the Cascade Chain of Oregon, and N. by the broad plain of the Upper Missouri, to an undefined limit in the N. part of the Continent, in the desert steppes which lie beyond that river, and E. of the Rocky Mountains. The Eastern and central portions of this enormous field of Tertiary and Cretaceous strata, the sediments of a great inland sea, now for the most part a succession of elevated sterile plains and high semi-rainless deserts, is only here and there interrupted by the intrusion of detached patches or island-like masses of the older rocks; but the W. division of the tract, or that between the Rocky Mountains and the Sierra Nevada, is much more cut up and diversified by mountain-spurs and outstanding hills and ridges of the older formations. The scenery of this division of the continent, from the plains E. of the Rocky Mountains to the great Pacific Sierra, being thus composed of extensive horizontal table-lands, deeply gashed by the passage of ancient waters, and of high protruding mountains of every variety of contour, embraces landscapes which are, perhaps, the grandest and most picturesque to be found upon the continent.

The two remaining natural geological areas are the two oceanic belts, chiefly tertiary, which fringe respectively the Atlantic and the Pacific slopes. The Easternmost of these—an extension, properly, of the great central, Newer-Secondary, and Tertiary region—stretches from the S. point of the Appalachians, in a gradually-contracting belt, along the Atlantic seaboard, as far to the N.E.

as Long Island and Martha's Vineyard. It embraces the whole of Florida, and all the lower country of Georgia, of the two Carolinas, and of Eastern Virginia, Maryland, Delaware, and Southern New Jersey. It is nowhere diversified by outbursts of igneous rocks, or the protrusion to the surface of any of the ancient formations, but is characterised throughout by the monotonous features of a low, very level plain, intersected by broad and generally tidal rivers and estuaries, and fringed along a great extent of its sea margin by extensive low swamps.

The other zone of modern or Tertiary strata, that of the narrow Pacific slope of Oregon and California, spreading from the base of the Sierra Nevada and Cascade Mountains to the shore of the Pacific, is much more diversified and interrupted in its physical features than the belt bordering the Atlantic. Consisting of sedimentary formations of geological dates corresponding to that belt, excepting that hitherto no strata of the Cretaceous age have been discovered in it, it has been so severely and frequently invaded by crust movements, and by actual volcanic eruptions, as to have acquired, over a large portion of its length, an excessively rugged surface and diversified structure.

With this general view of the constitution and aspect of the five great geological areas into which, for convenience of description, we have divided the part of the continent occupied by the United States, we shall pass to a more detailed account of the special geology of each division.

HYPOZOIC AND AZOIC METAMORPHIC ROCKS.

Commencing our description with the oldest formations, and observing the ascending chronological order, the first two systems of rocks recognised are those known as the Metamorphic strata. This large class includes, in reality, two, and in some districts, three distinct systems of altered sedimentary rocks, all greatly metamorphosed by igneous action, and plicated and contorted in their bedding, and therefore difficult of stratigraphical analysis. These several metamorphic series are nevertheless distinguishable, when closely investigated, by not merely their differences of crystalline constitution, but by the great horizons of unconformable contact which separate them, amounting to breaks of parallelism both in strike and dip.

GNEISSIC ROCKS.

Description of the Rocks.—The oldest of these systems is that of the true Gneissic or most ancient Hypozoic metamorphic rocks. It consists of the highly-crystallised or true Gneiss in all its varieties—quartzose, felspathic, micaceous, and hornblendic, with fully-developed or typical mica-schist, talc-schist, chlorite-schist, and the other crystalline schists usually classed with the genuine or older Gneiss. Intruded among these strata are numerous veins and dykes of the true igneous or Plutonic rocks of various relative ages, but those which especially characterise this gneissic system are the Granitic and Sienitic rocks, the most ancient of the Plutonic class. Predominant above all the crystalline strata associated with it, is a massive Sienitic gneiss, or thick-bedded gneissoid rock, having in its composition an excess of felspar and quartz. The more micaceous varieties of the true Gneiss of the United States are frequently distinguished by an abundance of the mineral, garnet.

Semi-metamorphic or Azoic Strata.—There probably exist more than one extensive or at least wide break in the succession of strata between the Gneissic series and the overlying

Fossiliferous Palæozoic formations. Indeed, since the early years of the geological surveys of Virginia and Pennsylvania, two such have been partially recognised on the Atlantic Slope in those States, and subsequently the Canadian geological survey has brought to light two horizons of discontinuity, apparently identical with these, insulating a middle metamorphic series of chloritic and epidotic schists, and highly-altered conglomerates, from the Gneissic rocks below them, and from the Palæozoic strata above. This intermediate or Azoic semi-metamorphic system of strata —recognised since 1839, E. of the Blue Ridge in Virginia—consists mainly, along the Atlantic slope of the Southern States, of various coarse talcoid and chloritic schists, semi-porphyritic arenaceous grits and conglomerates, and jaspery and plumbaginous slates, all penetrated extensively by metalliferous veins and dykes, particularly of gold-bearing quartz, and by dykes of porphyritic greenstone, epidote, and other older Plutonic rocks. Nevertheless, it is impossible, in the present early stage of minute field research, to define with any accuracy, over large spaces of country, the upper and the lower limits of this more or less independent semi-metamorphic system ; and it is especially difficult at present to separate it from the overlying genuine Palæozoic formations, into which, indeed, this series may probably graduate in many districts without any physical break at all. The Azoic sediments were succeeded by the Palæozoic, in some quarters apparently with, in some without, the interruption of a disturbance of levels, with undulation amounting to mechanical unconformity. In view of this uncertainty respecting the true limits of the older groups, no attempt is here made to define, in the regions of the Metamorphic rocks, more than two systems—the genuine or older gneissic, and the later or semi-metamorphic strata, the latter including both the supposed middle series, or true Azoic strata, and the proper Palæozoic formations altered in type. This merging of these two latter groups under one series is made indispensable by the absolute impossibility of ascertaining at present the true base of the Palæozoic system, for the history of geology forbids us to believe that research has yet detected the actual horizon of the dawn of animal and vegetable life upon our globe. The tint selected to represent those Azoic and altered older Palæozoic rocks on the Map no doubt covers likewise some tracts of the genuine Hypozoic or Gneissic strata, for nowhere, even along the Atlantic Slope, have all the outcrops of the latter been as yet detected, and accurately mapped. As a general rule, it will be found that the lower or non-fossiliferous Palæozoic formations occupy those parts of the semi-metamorphic belts which lie most contiguous to the zones of genuine fossiliferous strata, while the true Gneissic rocks, involved in the same general plicated tracts, occur on the side most remote from those upper boundaries, namely, for the Atlantic Slope on the E. or S.E. margin of the semi-metamorphic belt.

Along all the Northern border of the Great St Lawrence Basin, there stretches, from the Strait of Belle-Isle almost to the Missouri River, a broad irregular zone of ancient Gneissic and granitic rocks, represented in pale pink upon my Geological Map of the United States. In this imperfectly-explored belt, both in certain districts in New England and elsewhere, the folds or troughs of the Gneiss undoubtedly contain many outlying remnants of semi-metamorphic strata, some pertaining to the Azoic system, some to the Palæozoic ; but no data at present exist for any definition of their local boundaries ; and therefore in this portion of the map, the pink colour must be interpreted as representing all the metamorphic rocks—both those of the true Hypozoic and those of the Palæozoic classes.

Metamorphic Palæozoic Strata.—The metamorphic and semi-metamorphic rocks, which are referable with the least ambiguity to the true Palæozoic system of formations, are the three lowest series or groups of that system, often greatly disguised both as respects their structure and their original composition, by innumerable plications and cleavage-joints, and by a pervading condition of crystallisation of their materials. The lowest group—the Primal series, so called, of the geological surveys of Pennsylvania and Virginia—extending almost the whole length of the Atlantic Slope, from the Blue Ridge of the Southern States to the Green Mountains, and even to Gaspé, has especially been subjected, in all its S.E. outcrops, to thorough metamorphism. But great alteration from igneous action has extended in like manner to the two other series—the Auroral and Matinal groups, constituting with the Primal the older Palæozoic system of the country. Under their more altered type, some of the strata of the oldest or lowest of the Primal slates have the aspect of semi-talcose, chloritic, and micaceous, and even hornblendic schists, with porphyritic, epidotic, and roofing slates; the Primal white sandstone has the aspect in some cases of vitreous quartz rock, in others of a stratified felspar; the impure or earthy magnesian limestones at the passage of the Primal into the Auroral series, has the crystalline structure of coarse granular yellowish and white dolomite and marble, with seams and partings of crystalline scaly talc; and the Auroral blue limestone possesses the aspect and texture of white and mottled crystalline marble, with semi-plumbaginous laminæ; while the grey sandstone of the Matinal series has that of a highly-indurated semi-porphyritic grit, the more argillaceous Matinal shale being in the condition of indurated semi-crystalline clay-slate, partially talcose or nacreous, and intimately pervaded with cleavage. A characteristic feature of all these metamorphic deposits is a close plication or compressed undulation of the strata. This is seen in the steep dips, which agree approximately in their direction over wide belts, and even extensive tracts of country. The alternate foldings of the beds do not take place about axis-planes that are perpendicular, but about planes that incline at angles of 60° or 70° to the horizon. Still farther to confuse the true order of the strata, they are generally pervaded by countless planes of cleavage, which likewise dip with the imaginary axis-planes, or geometric planes, bisecting the anticlinal and synclinal folds. Throughout the Atlantic Slope, in the chain of the Green Mountains of Massachusetts, Vermont, and Canada, this plication observes a remarkable constancy in its direction, the axis-planes dipping, with few exceptions, towards the S.E., or the quarter of the more ancient rocks and chief igneous disturbances and dislocations of the country. These close plications, approaching to parallelism, are only the extreme local exhibition of a great general undulation, with parallel lines of elevation and depression, affecting the entire Atlantic Slope and Appalachian Chain in a stupendous system of waves, which everywhere progressively dilate and flatten down in a N.W. direction.

In the great Pacific Chain this law of close plication has not yet been wrought out in geological sections, but, judging from the universal parallelism of the dip of the strata, and its great steepness, we doubt not that a similar structure will be found to exist in that wide zone of mountains.

Geographical Distribution.—The Metamorphic and Semi-metamorphic strata, thus defined and explained, constitute, it will be observed, two great zones, diverging respectively S.W. and W. from the Gulf of St Lawrence. One is a coast belt, the zone of the Atlantic Slope, extending from Newfoundland through Nova Scotia, New Brunswick, and the New England States, between the waters of the Atlantic and the St Lawrence, and prolonged more inland through New York, New Jersey, Pennsylvania, and the Southern States, to the end of the Appalachian hills in

Georgia and Alabama. It constitutes a large irregular tract between the Atlantic Ocean and the Connecticut River in New England—the hills of Maine and New Hampshire abounding in Plutonic rocks and minerals. The main Gneissic zone terminates at the estuary of the Hudson, but its N.W. axes are prolonged across that river, forming the chain of the Hudson highlands, and, with diminished breadth and elevation, extending to the river Schuylkill in Pennsylvania. From the Delaware River the great Southern zone of Gneiss ranges to Baltimore, Washington, Richmond, Augusta, and onwards, maintaining its position on the S.E. border of the Atlantic Slope to Wetumpka in Alabama. Parallel belts and spurs from this main zone extend, at various intervals, towards the N.W., in the middle of the Atlantic Slope, but throughout the tract the typical Gneiss is subordinate in development to the crystalline schists of equivocal, though probably later age. The other more irregular belt starts from the N. coast of the St Lawrence Gulf, runs S.W. parallel with the river of that name, to the great lakes, and then, deflecting towards the N.W., sweeps the N. shores of Luke Huron and Lake Superior, and reaches the Lake of the Woods, where one great spur of it runs off to the S.W., nearly to the Missouri River, the main zone still holding on N.W., with a gradual Northward inflection towards the Arctic coasts of the continent. The first of these we shall call the Appalachian or Atlantic Metamorphic Belt, while the other may claim the name of the Lawrentian—the Lawrentine Mountains constituting a portion of this zone of uplifted rocks. An extensive tract of Hypozoic and Palæozoic metamorphic rocks occupies the N. part of Wisconsin, and the adjoining part of Michigan between the Mississippi River and Lake Superior. It seems to be a spur from that portion of the Lawrentian gneissic zone which bounds Lake Superior on the N.E.

Standing out somewhat from the metamorphic region of the Atlantic slope of New England, there exists in the N.E. angle of New York, between Lake Champlain and Lake Ontario, a broad rugged district of these older crystalline formations, surrounded on all sides by the most ancient of the fossiliferous Palæozoic strata. The district of the Adirondack Mountains occupies the angle at the forking of the two long primary zones we have been describing, and serves in a measure to unite them. It embraces both hypozoic and greatly-altered palæozoic masses. Other insulated exhibitions of the ancient metamorphic rocks occur to the West of the Mississippi, in three or more detached areas, or local igneous axes ; namely, in the Ozark Mountains in the State of Missouri, in the Washita Hills W. and S. of the Arkansas River, and in Central Texas, on the Rio Colorada, S. of the little river San Saba. Still more detached than the last-named from the main palæozoic region of Eastern America, is that of the Witchita Mountains, which rise N. of the Red River from out of the broad cretaceous plains of Northern Texas.

In the great Primary region of the W. half of the continent, there exist numerous tracts of the metamorphic strata, both Gneissic and altered Palæozoic, with probably others of intermediate age, containing the Granitic and other ancient Plutonic rocks, which so invariably accompany these formations. Long and important outcrops of the true gneissic strata occur throughout nearly the entire range of the Rocky Mountains, including their S. spurs in New Mexico. These rocks especially abound in the main axis of the chain which divides the head-waters of the Missouri from the great Columbia of the Pacific ; also in the Wind River Mountains, a prolongation of the same, and in the Cœur d'Alene, or Bitter Root Mountains, W. of the main axis. They prevail likewise in the Big Horn range near the Yellowstone, and in the central parts of the Black Hills. From the N. fork of the Nebraska, to the sources of the Rio Pecos near Santa Fé, the highest serrated crests of the Rocky Mountains, and the chief axes of nearly all the flanking ridges, exhibit, we believe, the gneissic and granitic rocks in extensive outcrops ; and the same is true of the Guadaloupe, Christabelle, and other insulated ridges, which rise out of the cretaceous plains near the Rio del Norte in New Mexico and Texas. To the West of the Rocky Mountains the Gneissic rocks show themselves in some of the higher axes of the great Wahsatch range E. of the Utah Desert, and in several of the ridges of the Humboldt Mountains in the centre of that vast sterile tract. On the W. side of the continent, these ancient strata appear extensively at intervals from the Columbia River to the Californian peninsula, especially at the E. base and in the higher crests of the Sierra Nevada ; also in the Coast Mountains, in the San Barnardino Mountains, in the chain of Lower California, in the Colorado Desert, and in the Mexican chain of Sonora. Even in the volcanic chain of the Cascade Mountains of Oregon, and in still more insulated exposures in the volcanic desert of the Columbia River, and in the Tertiary country of the Pacific Slope, these ubiquitous rocks peer to the surface in numerous localities.

Minerals.—In the Gneissic belts magnetic iron-ore and sulphuret of iron abound. Magnetic oxide of iron is found in great veins or dykes in these districts, especially where the typical Gneiss exists in greatest preponderance, and where it has been much convulsed, as in the Adirondack Hills and the outlying spurs W. of Lake Champlain, and in the Hudson highlands, extending from Connecticut across New York and New Jersey to Reading on the Schuylkill. These dykes vary in length from 100 feet to more than a mile. Some have the form of huge flattened oval columns lying obliquely between the strata, but not conforming to their dip. The chief portions of these metalliferous injections actually cut the strata, though for long spaces they may seem to conform to their bedding. The semi-metamorphic Azoic rocks are richer in metallic ores than the early Gneissic. In the Atlantic Slope these ancient crystalline schists contain numerous veins of the ores of lead, copper, zinc, iron, and other metals. They enclose the quartz veins which form the matrix of the gold of California and the S. Atlantic States, and embrace the trappean outbursts, which contain the great masses of copper ore on the borders of Lake Superior, which all appear to have been injected during the deposition of the earlier Palæozoic strata.

PALÆOZOIC FORMATIONS.

The Palæozoic or Ancient Secondary Formations constitute probably one-half of the total area of the United States, and the bordering possessions of Great Britain on the N. They, along with the Hypozoic rocks, underlie, indeed, so large a portion of the whole surface of North America, as to entitle this continent, in comparison with Europe, where they are very subordinate in extent of area to the later Secondary and Tertiary deposits, to be styled geologically the Old World rather than the New. A Palæozoic sea appears to have spread itself from the Hypozoic belt of the Atlantic Slope, across the entire breadth of the present continent, to the Rocky and Californian Mountains, and N.W. over the region of the present basin of the Mackenzie River, even as far as the existing border of the Arctic Ocean. This we may call the Appalachian Palæozoic basin, from the mountain-chain on its S.E. border, in which the sediments of this side of that ancient sea are so extensively and wonderfully exposed. It appears to have been separated from another Palæozoic basin, which occupied all the N.E. tracts of the continent, and had apparently its centre in the great mediterranean sea of Hudson Bay, and its ancient borders in that long semicircular zone of Primary or Hypozoic rocks which sweeps from Labrador, N. of the St Lawrence and the Great Lawrentian lakes, by Lake Winnipeg, Lake Athabasca, and Great Slave Lake, to the Arctic coast between the Coppermine and Great Fish rivers.

The Appalachian Palæozoic deposits of the E. half of the United States are naturally grouped by their organic remains, and the characters of their sediments, into Fifteen distinct series or sets of formations, extending from the deposits which witnessed the very dawn of life upon the globe, to those which saw the close of the long American Palæozoic day, or from the lowest fossiliferous strata to the uppermost beds of the coal series. These fifteen different compound formations. the accumulations of as many successive sedimentary or formative periods, are distinguished by their special physical composition and structure, and by their organic types. In the region of their thickest development, or in the Appalachian Mountains, where the whole system embraces both deep-sea and land-derived or shore-formed accumulations, the total thickness of these slowly-collected sediments, the graves of so many successive generations, is not less than 30,000 or 35,000 feet. The names we have assigned to the fifteen main Palæozoic series —those which have been employed in the geological surveys of Pennsylvania and Virginia—are terms significant of the different natural periods into which the day divides itself, from earliest dawn to latest twilight, and which are metaphorically expressive of the relative dates of production of the several formations. These periods, applicable only to the American Palæozoic day, are the Primal, Auroral, Matinal, Levant, Surgent, Scalent, Pre-Meridian, Meridian, Post-Meridian, Cadent, Vergent, Ponent, Vespertine, Umbral, and Seral,—signifying the periods, respectively, of the Dawn, Daybreak, Morning, Sunrise, Ascending-Day, High-Morning, Forenoon, Noon, Afternoon, Waning-Day, Descending-Day, Sunset, Evening, Dusk, and Nightfall. A nomenclature based on time is, for many reasons, preferable to the inexpressive ones in vogue, which rest on local geographical names, or narrow and inconstant palæontological characters, and is certainly preferable to the geographical nomenclature of the European Palæozoic formations, which, devised for the deposits of a wholly different ancient basin, are inapplicable to the subdivisions of the American strata, with which there is no such strict equivalency or co-ordination as to warrant their having the same appellations.

The three earliest formations, or rather series of strata—the Primal, Auroral, and Matinal—are the near representatives in geological time of the European Palæozoic deposits, from the first-formed fossiliferous beds to the close of the Bala group; that is to say, they are the proximate representatives of the Cambrian series of Professor Sedgwick. The formations of the next four periods—the Levant, Surgent, Scalent, and Pre-Meridian—are the very near representatives of the true European Silurian deposits, regarding this series as commencing with the May Hill formation—Upper Caradoc sandstone of England—or the horizon which separates the middle from the older Palæozoic divisions. Throughout nearly every explored portion of the Appalachian or American Palæozoic basin (certainly from the Atlantic Slope to the Missouri River—that is, half-way across the continent) there exists both a physical and a palæontological *break* in the succession of the strata at the contact of these two great divisions of the Palæozoic system. This horizon of discontinuity in the ancient deposits, and in the assemblages of the once-living forms which they imbed, is so marked, and so general, as to make it one of the two primary planes by which the whole Palæozoic system of the country arranges itself into three principal divisions. The other horizon is one of somewhat corresponding degree of sharpness, and of wide extension. It is that at the base of the carboniferous strata. Separated by these two breaks or planes of interruption into three large natural divisions, we have the entire Palæozoic system, composed of a Lower Palæozoic division, comprising the three oldest series—the Primal, Auroral, and Matinal—a Middle Palæozoic series, consisting of the rocks of the nine central periods—the Levant, Surgent, Scalent, Pre-Meridian, Meridian, Post-Meridian, Cadent, Vergent, and Ponent —and an Upper Palæozoic division, embracing the true Carboniferous formations of the Vespertine, Umbral, and Seral series, or coal-rocks.

Between the Silurian and the Devonian equivalents there is a much less abrupt plane of separation than the one which divides the Silurian from the Cambrian; that is to say, there exists a greater relative interchange of fossils, and with it, in many districts, a closer blending of the sedimentary deposits than we discern crossing the other platform below. This causes, indeed, some ambiguity in the determination of a proper horizon for provisionally separating the Devonian from the Silurian. Guided by the general *facies* of the fossils—the Mollusca especially—the Meridian or Oriskany sandstone is regarded by some palæontologists, on the original suggestion of M. de Verneuil, as the base of the Appalachian-Devonian deposits; while other naturalists incline to begin the Devonian period at the commencement of the Post-Meridian shales and limestones which overlie or succeed that rock.

The Meridian and Post-Meridian strata—the first a coarse sandstone, characterised by very peculiar brachiopodous shells; the last a blue-and-yellow limestone, marked by distinctive fossils, most of them of Devonian, but some of them of Silurian or Ludlow types—are to be received as representing approximately the older ages of the European Devonian. The next or fourth group of formations in our scale—the uppermost of the Middle Palæozoic—includes the Cadent, Vergent, and Ponent series: the Cadent, a mass many hundred feet in thickness, of dark bituminous shales, with a few calcareous beds; the Vergent, a body of bluish shales and imbedded grey argillaceous sandstones, in some districts more than 3000 feet thick; and the Ponent, a still thicker mass of red shales and argillaceous red sandstones, with a few pebbly beds, having in its greatest development a thickness amounting to even 5000 feet. This group of formations blends in its fossils the characters of the later Devonian and Carboniferous rocks of Europe.

Between this fourth group of the Appalachian formations, or the top of the Middle Palæozoic division, and the succeeding or Carboniferous deposits, it is easy enough to trace the plane of demarcation throughout the Appalachian basin, as far W. at least as the W. disappearance of the older strata under the overlapping cretaceous ones; but this horizon is far more clearly defined physically than palæontologically. A true break in the sequence of actions and in the scale of time—not everywhere marked by actual unconformity or want of parallelism of the dip, but very generally indicated in the discontinuity of the series, such as an omission of one or more of the upper formations of the underlying group—follows the base of the Vespertine, or lower Carboniferous formation, throughout a very large area of the E. half of the continent.

Yet notwithstanding this widely-extended change in the physical geography of the Appalachian sea, affecting the depth of its waters, changing the nature of its sediments, and even shoaling and draining large tracts of its previous bed, the revolution in its marine inhabitants was less complete than that which occurred where the Devonian deposits gave place to Carboniferous ones. Careful and extensive comparisons of the American middle and upper Palæozoic fossils with the European organic relics of the same periods, made by the ablest palæontologists, demonstrate beyond a doubt that, palæontologically, the Carboniferous fauna commences low in the Devonian strata; and we have ourselves established a like early beginning to the typical terrestrial flora, deemed hitherto so characteristic of the true Carboniferous strata. Defined by organic remains alone, the Carboniferous formations of North America exhibit, then, no very clear or recognisable base; and our classification rests mainly on the suddenness of the change from marine to terrestrial forms, and on the rapid coming in for the first time of those remarkable and distinctive physical conditions of the surface, especially that amazing vegetation, and those vast humid plains, by whose agency the characteristic strata of the period, the great coal-seams, were accumulated.

Having thus indicated the general nature of the Appalachian-Palæozoic deposits; our classification and nomenclature of these, the larger subdivisions of the system; and correlated these subdivisions with the great European-Palæozoic series or systems, so called, we present the following synoptic description of these as they exist in the Appalachian Chain, advancing, as on all occasions, from the older to the more modern.

PRIMAL SERIES, OR POTSDAM SANDSTONE OF NEW YORK.

Description.—The Primal series, under its fullest and most diversified condition, or that which it wears in the Appalachian Chain, in Pennsylvania, Virginia, and Tennessee, is a thick fourfold group, composed of two slates and two great arenaceous rocks in alternation—(1.) The highest or Primal newer slate is a greenish and brownish talco-argillaceous slate, sometimes very soft and shaly. In Pennsylvania it has a thickness of about 700 feet. (2.) The next, the Primal white sandstone, is a compact white and yellowish fine-grained vitreous sandstone, often containing specks of kaolin. This rock, which is of easy recognition and of an immense range, has a thickness, in some parts of the Blue ridge of Virginia, of at least 300 feet. This is the Potsdam sandstone of New York. (3.) The Primal older slate is a brown and greenish-grey sandy slate, containing much felspathic and talcose matter. It has hitherto disclosed no fossils. The thickness of this bed, in the Atlantic slope in Pennsylvania, is several hundred feet, and in the Blue Ridge of Virginia is not less than 1200 feet. (4.) The Primal conglomerate, the lowest of the yet distinctly-recognised formations of the Primal series, is a heterogeneous conglomerate of quartzose, felspathic, and slaty pebbles, imbedded in a talco-silicious cement. The thickness of this rock in Virginia and Tennessee, N. of which it has not been discovered, is at the least 150 feet.

In New York and the North-Western States, this series presents a materially different type—the Primal white sandstone being almost the sole representative.

Thickness.—The thickness of the entire series is considerably more than 2000 feet.

Geographical Distribution.—In its geographical distribution, this Primal series ranges coextensively, or nearly so, with the other formations of the older Palæozoic division to be presently traced; that is to say, it shows two great continuous outcrops, one stretching S.W. along the Appalachian Chain, and the other W. from the St Lawrence, through New York, Canada West, Northern Michigan, Wisconsin, and Minnesota, beyond the Mississippi. It is probably likewise brought to the day in the anticlinals of Missouri, Arkansas, and Texas, which elevate the gneissic strata on which it rests. Besides these, its more unequivocal exposures, this group possesses extensive outcrops in various parts of the Atlantic Slope, from the British Provinces on the N.E., S.W. to the State of Georgia. Some of these have been already, as in Pennsylvania, regularly traced and mapped; but for the most part, these Eastern exhibitions of the Primal series are so disguised by metamorphism, so folded, so cleavage cut, and so crystalline, as to be very difficult of geographical delineation. While, therefore, the geologists who have explored the Atlantic Slope are convinced of the presence there of large tracts of the above-described and of still inferior Primal rocks not hitherto brought into the stratigraphical column, their boundaries are not yet sufficiently known to be more than approximately represented on any Geological Map. A considerable portion of the long belts delineated on my Map of the United States as semi-metamorphic slates below the Palæozoic system, both along the Atlantic Appalachian Slope and in the mountain zone of California, consists undoubtedly of these Primal strata disguised by igneous action. The copper-bearing rocks of Lake Superior pertain to this series. The Primal sandstone has lately been discovered in the Black Hills, and doubtless prevails extensively in the Rocky Mountains.

Fossils.—Only the two higher of the above-described Primal strata have yet revealed any fossils: the Upper or newer Primal slate, a peculiar fucoid; and the Primal white sandstone a characteristic stem-like perpendicular form of doubtful affinities, and one or two brachiopodous molluscs, especially a lingula. In Wisconsin and other N.W. localities, this formation contains several species of trilobites, and abounds in lingulæ, obolus, and an orbicula. Trilobites have lately been found in it on Lake Champlain.

Equivalents.—These strata seem to be on the horizon of the lower Festiniog group or *lingula* flags of England, and equivalent to the obolus and lingula sandstone of Sweden and Russia. They represent, too, the primordial zone of Bohemia, and are therefore on the horizon of the very dawn of discovered life.

AURORAL SERIES, OR BLACK RIVER, AND CHAZY LIMESTONE AND CALCIFEROUS SANDSTONE OF NEW YORK.

Description.—The Auroral limestone, the thickest and most widely extended of all the Appalachian limestones, is a light-blue and bluish-grey compact limestone, usually containing, with the carbonate of lime, from 10 to 30 per cent of the carbonate of magnesia. In many parts of the great Appalachian valley, especially in Virginia, it possesses thick beds of chert. The whole mass has a thickness of not less than 2500 feet in the central part of the Appalachian chain, but it is much thinner in the N.W. States, being at several points not more than 100 feet thick.

The Auroral calciferous sandstone of New York is a coarse grey calcareous sandstone, frequently containing small drusy cavities holding crystals of quartz and of calc-spar. This is a much thinner formation than the main limestone which it supports, being in few places more than 80 or 100 feet thick.

Thickness.—The thickness of the entire series is not less than 2600 feet.

Geographical Distribution.—In its geographical distribution this calcareous group follows closely the Matinal series, with which it is in contact, extending quite as far as it to the S.W., and ranging beyond it in the region of the Upper Mississippi. It is traceable even more continuously from the valley of the St Lawrence by both its great zones of outcrop, which mark respectively the S.E. and the N. shores of the Old Appalachian sea, than the series which overlies it. This latter has in part been washed away from certain synclinal troughs, as that of the St Lawrence, where the deeper Auroral series has been protected and preserved. The formation dipping W. from the Appalachians beneath the great coal-field just reappears in the Ohio and Tennessee great anticlinal, and shows itself again widely in Missouri on some of the uplifts to the W. of the Mississippi.

Fossils and Equivalents.—This great limestone group is less abundant in organic remains than the series which succeeds it, though it has already furnished nearly 100 species, a large proportion of which are restricted to the formation, only five or six being common to it and the Matinal rocks above. Only one or two of these species being identical with any European Palæozoic forms, the group cannot strictly be said to have any European palæontological equivalent. Yet we are entitled, from its place in the system, and from the general facies of the organic remains, to place it upon the horizon of the Festiniog group, or Middle Cambrian of Sedgwick, a part of Murchison's Lower Silurian.

MATINAL SERIES, OR TRENTON LIMESTONE AND HUDSON RIVER SLATE GROUP OF NEW YORK.

Description.—We come now to the uppermost of the three great formations or series constituting the older or lower division of the Appalachian Palæozoic rocks. The Matinal slate formation, or upper division of the series, is a very thick group of argillaceous strata, which have the form of bluish-grey shales, imbedding in their higher portion many strata of argillaceous sandstone, and even some layers of dark-grey silicious conglomerate, and containing in many places, as the lowest member, a dark-blue and even black carbonaceous fissile slate. In some parts of the great Appalachian valley, both in Pennsylvania and Virginia, much red and brown slate alternates with yellow shale in the central and higher parts of the formation. Near the Delaware Water Gap and elsewhere, this middle portion, much metamorphosed and intersected with cleavage-planes, yields a very excellent roofing-slate. In Pennsylvania and Virginia, where this mass appears to be in greatest strength, its maximum total thickness is perhaps 2000 feet.

The Matinal limestone,—the Trenton limestone of New York,—the lower division of the series, is a dark-blue soft argillaceous limestone, containing interposed layers of blue calcareous shale. Many of the limestone bands are excessively fossiliferous. The thickness of this formation in Pennsylvania and New York amounts in some localities to 500 feet, though generally it is less.

These two very distinct divisions of the series maintain their independent types throughout the whole of the Appalachian Chain, where the one appears to have been for countless ages the muddy bottom of a continually-shoaling sea, and the other, which preceded it, the limestone bed of the same ocean, while it was deeper and less invaded by land-derived sediments. In the great anticlinal, which brings the Matinal strata to the day on the Ohio River, they consist of alternating fossiliferous shales and flaggy limestones. This blue-limestone formation of Ohio represents the Matinal slate group.

From Wisconsin W. and S., another limestone formation, the Lead-bearing or Galena limestone of the Mississippi, is intercalated between the Matinal limestone and the Matinal slate of this series.

Thickness.—The maximum thickness of the whole series is upwards of 2500 feet.

Geographical Distribution.—This widespread formation extends the entire length of the Appalachian Chain, from the estuary of the St Lawrence by the valley of Lake Champlain and the Hudson River, and thence by the same Appalachian valley, prolonged through New Jersey, Pennsylvania, Maryland, Virginia, Tennessee, into the interior of Alabama. To the N.W. of this great line of outcrop it reappears in several beautiful anticlinals in the Appalachians of Pennsylvania and Virginia. On the St Lawrence, above Montreal, the main trough of the formation forks, and another outcrop starts off towards the W., ascending the St Lawrence, skirting the

N. shore of Lake Ontario, passing through Georgian Bay of Lake Huron, and the more Northern of the Manitoulin Islands, and sweeping round the N. and W. sides of Lake Michigan, through Green Bay and Winnebago Lake, and thence W. through Wisconsin, until it reaches the Mississippi River. A connecting trough unites the two main zones through the valley of the Mohawk and E. shore of Lake Ontario, so that the gneissic and granitic mountain region of northern New York is entirely encircled by this and the other formations of the older Palæozoic division. Besides these two main outcrops, the series presents itself, in other more local ones, more centrally in the Appalachian basin. It appears in two large patches on the great anticlinal which traverses Middle Ohio, Kentucky, and Tennessee, and shows itself still farther W. on the Missouri, and encircling the anticlinals of the older metamorphic rocks, the Ozark Mountains in Missouri, the Washita Hills in Arkansas, and the San-Saba granitic hills in Central Texas. The Matinal limestone does not everywhere accompany the Matinal shale formation along its great S.E. outcrop; but to the W. of the Appalachian valley it is the more persistent rock of the two, extending into Iowa, beyond the Mississippi, and constituting, indeed, in many parts of the West, the sole representative of the Matinal series. In the large hydrographic basin of Hudson Bay, N. of the Lawrentian Primary or Gneissic zone, this group of older Palæozoic rocks does not reappear, but it shows itself farther W. in the palæozoic basin between Lake Winnipeg and the Rocky Mountains, especially on its E. side.

Fossils.—All the formations of this series are rich in organic remains, some of which are common to the upper and lower strata, but the greater number of the species are restricted to their own deposits. It is remarkable that very few, probably not three per cent, are common to these formations, and to any of the strata which overlie them. The highest organisms hitherto found in these widely-extended rocks are some trilobites, cephalopods, and molluscs; no fishes, nor remains of any vertebrate animals, having ever been detected.

European Equivalents.—The nearest British representatives of these Matinal strata seem clearly to be the Llandeilo and Bala rocks—Lower Silurian of Murchison, or Upper Cambrian group of Sedgwick—the Orthoceratite limestone of Sweden and Russia representing them in Northern Europe.

LEVANT SERIES, OR MEDINA GROUP OF NEW YORK.

Description.—Succeeding the Matinal, and preceding the Surgent in order of time, is another triple formation, here called the Levant series. The upper member of this consists of white and light-grey fine-grained hard sandstone, alternating near its upper limit with beds of red and greenish shale, the sandstone covered with peculiar fucoids in great profusion. This division, in Pennsylvania, measures between 400 and 500 feet. The middle member is a soft argillaceous brown sandstone and red shale. Its greatest development is in the mountains which cross the Juniata River, where its thickness is from 500 to 1000 feet. The third, or lower member, is a hard greenish-grey massive sandstone, embracing in its E. outcrops, as in the Kittatinny and Shawungunk Mountains, thick beds of silicious conglomerate, made up chiefly of the wreck of the previously-formed and disturbed older Palæozoic rocks. This division varies in thickness, in Pennsylvania, from 200 to 700 feet. The uppermost and middle of these is the Medina sandstone of the New York Survey.

Thickness.—The maximum thickness of the whole series is about 2200 feet.

Geographical Distribution.—Tracing them in their geographical distribution, the Levant rocks follow the outcrop of the Surgent series, next to be indicated, W. to Lake Michigan, and S.W., along the Appalachian chain. But in the latter direction, the Levant white sandstone prolongs itself beyond the termination of the Surgent shales, displaying itself in great force in the Clinch Mountain of Tennessee, and other Appalachian ridges, as far as Alabama. The Levant red shale, or middle member, is in full dimensions on the Niagara River, and crosses the peninsula of Canada West. Some of these rocks occur in the Green Mountain chain, and nearer the Atlantic, in the State of Maine, and Province of New Brunswick.

Fossils.—Very few organic remains occur in this group, but those which do are characteristic. The chief marine forms are shells, conspicuous among which is a *lingula*. But more instructive still are the strange fucoids, forms of an ancient marine vegetation, which invariably accompany the upper strata.

European Equivalents.—The Mayhill sandstone, or upper Caradoc, the terminal or lower member of the Wenlock group of England, seems to be on the parallel of this Appalachian Levant series, which is therefore the equivalent of the base of the European Silurian system, if we accept Professor Sedgwick's classification; or the Upper Silurian, if we embrace Murchison's. That it is the base of the American middle palæozoic formations, appears from many considerations, physical and palæontological. The conglomerates mark an ancient shore, and indicate a period of great disturbance and uplift of the earlier Palæozoic strata, accompanied by an almost total change in the organic forms.

SURGENT SERIES, OR CLINTON GROUP OF NEW YORK.

Description.—The next natural group of strata, ascending, the Surgent series of the Pennsylvania Survey, or Clinton group of the New York, is a diversified formation, composed, when fully expanded, of three groups—an upper one, consisting of variegated red marls or calcareous shales; a middle one, of an alternation of shales and argillaceous fossiliferous limestones and calcareous sandstones, with one or two remarkable seams of fossiliferous iron ore; and a lower group, composed of greenish and yellowish fissile slates, weathering olive and claret-coloured, and including in its central part beds of red, very ponderous, ferruginous sandstone, usually containing two or three thin layers, sufficiently rich in the peroxide of iron to be extensively available as an iron ore.

Fossils and Equivalents.—The more calcareous middle member abounds in organic remains, shells, corals, echinoderms, trilobites, &c., all of them of forms significant of an equivalency in age to the Wenlock and other formations at the base of the Upper Silurian series of Europe.

Geographical Distribution.—This series exhibits its maximum thickness and complexity in the central parts of the Appalachian chain in Pennsylvania, gradually diminishing S.W. through Virginia to Eastern Tennessee, where it seems to expire. Traced W., it crosses New York from the neighbourhood of the Helderberg Mountains to the Niagara River; thence sweeps N.W. across Canada West to the Manitoulin Islands of Lake Huron; thence W., by Mackinaw, by the N. shore of Lake Michigan, to Green Bay, and Southward down the Lake Coast in Wisconsin, where it appears to thin out, no part of the formation having been discovered to cross the Mississippi. This N. outcrop, in ranging thus towards the W., displays, what so many of the other formations exhibit, a gradual change from a shore to a mid-sea type, the shales and sandstones becoming progressively less in volume, and the limestone relatively augmenting. A bed of limestone, and another of calcareous shale, are all that represent it on the Niagara River; and in Wisconsin it is composed of little else than a thin stratum of fossiliferous limestone, which is there in contact with the Niagara limestone, with which it has been confounded. It is barely traceable on the borders of the dome-shaped anticlinal of the older palæozoic rocks in S. Ohio and N. Kentucky, and does not appear in that of Middle Tennessee. In the N.E. part of the Atlantic slope and Appalachian chain, the formation presents itself in some outcrops in the Green Mountains, and in the basin S.E. of them in New Brunswick and the State of Maine, but under a less expanded type than that which it assumes in Pennsylvania and New York.

Thickness.—On the Juniata River, in Pennsylvania, the whole series has a thickness approaching 2400 feet, which is probably its maximum in the country.

SCALENT SERIES, OR ONONDAGO SALT AND NIAGARA LIMESTONE GROUPS OF NEW YORK.

Description.—The series next in order consists strictly of two formations—the upper one a group of gypseous marls and shales, the lower one a compact limestone surmounting grey calcareous shales. The gypseous marls, or Onondago salt group of New York, is a mass of grey or ash-coloured calcareous shale, alternating in its upper part with beds of argillaceous and silicious limestone, some layers of which are curiously pitted with small angular cavities, the nests of solitary crystals of sulphate of lime and carbonate of strontia. Gypsum abounds in this formation, both diffused and in thin seams, and near the surface, in large insulated lenticular masses or cakes.

Geographical Distribution.—The stratum is imperfectly represented in the Appalachian chain S.W. of New York; but it ranges through that State, through Canada West, and through the Western and Northern States almost as far as the Mississippi.

Equivalent.—This formation appears to possess no true equivalent among the rocks of Europe; but as the Scalent limestone below it, and the Pre-Meridian limestone above it, are both on the parallel of the Wenlock group of Great Britain, it is obvious that it belongs to the Wenlock period.

Description.—The other or lower division of the series, the Scalent limestone—the Niagara limestone of New York—is a double formation of limestone and shale, consisting, in its upper division, of a sparry very compact grey limestone, some bands of which are extremely fossiliferous. In its lower portion it is a bluish calcareous shale, somewhat pyritous, and containing a few fossils. The great difference in the susceptibility to erosion of these two strata is the cause of the remarkable terrace and cataract of the Niagara River.

Thickness.—The thickness of the Niagara limestone gradually augments from E. to W.: its maximum is in the region of the Mississippi, being there, it is believed, nearly 1000 feet thick.

Geographical Distribution.—It ranges W. from near the Hudson. The formation traverses the lake peninsula of Canada West, the N. and W. shores of Lake Michigan, the S. part of Wisconsin, and N. part of Illinois, the whole breadth of Iowa, and only disappears where it is overlapped near the Missouri by the Western cretaceous deposits. It rises in the Ohio anticlinal, at the Falls of the Ohio, and appears in Kentucky and Tennessee. It has but little development anywhere in the Appallachian Mountains.

Equivalent.—The Scalent series is on the parallel of the Wenlock formations of Great Britain.

PRE-MERIDIAN SERIES, OR LOWER HELDERBERG LIMESTONE OF NEW YORK.

Description.—The formation which holds the next position in the ascending order is a somewhat diversified limestone formation, consisting usually, in its lower portion, of shales and thin flaggy layers of limestone; in its middle member, of a fossiliferous and sometimes sparry compact grey and blue limestone, containing layers and nodules of chert; and in its upper division, of a dark ash-coloured calcareous sandy shale.

Geographical Distribution.—In the Appalachian chain this rock ranges from near the Hudson S.W. to Tennessee. Its N. outcrop stretches from the same neighbourhood Westward, expiring within 100 miles W. of the River Hudson.

Thickness.—The thickness of the entire formation seldom exceeds 300 feet, and throughout long tracks the rock is very thin.

Fossils and Equivalents.—These marine limestones and shales abound in characteristic organic remains, many of them generically and even specifically identical with the shells, corals, trilobites, and other fossils distinctive of the Wenlock formation of Great Britain, evidently their nearest equivalent in the European system. No remains of fishes, nor vestiges of any vertebrate animal, have ever been discovered either in this formation or in any of the strata beneath it. It may be regarded as the uppermost deposit of the Silurian ages in the Appalachian sea.

MERIDIAN SERIES, OR ORISKANY SANDSTONE OF NEW YORK.

Description.—This is a remarkable arenaceous formation, interposed between the Post-Meridian and Pre-Meridian limestones. The upper member of the series, a rock of rather restricted range in New York and New Jersey, is a calcareous and argillaceous thin-bedded sandstone or grit, characterised in its lower layers by a peculiar fucoid, resembling somewhat a cock's tail. Its thickness, on the Delaware River in New Jersey, is about 300 feet. The sandstone, the principal member—called in the New York Survey the Oriskany sandstone—is a coarse yellowish calcareous sandstone, graduating near its upper limit into a fine-grained quartzose conglomerate, and becoming in its lower beds a coarse arenaceous limestone.

Fossils.—Its distinctive fossils are large brachiopodous bivalves.

Thickness.—The greatest thickness of this sandstone in New York and Pennsylvania is less than 200 feet.

Geographical Distribution.—This formation ranges through the Appalachian chain, is exposed in many outcrops from New York to E. Tennessee, and extends W. from near the Hudson through New York, a distance of about 300 miles. There is no exact equivalent for this stratum among the formations of Europe, though its nearest place in the scale of strata is probably that of the lower Ludlow rocks of England.

POST-MERIDIAN SERIES, OR UPPER HELDERBERG LIMESTONE OF NEW YORK.

Description.—Beneath the Cadent older black slate there lies, throughout the N. States, from near the Hudson, W. through New York, New Jersey, Pennsylvania, Ohio, Upper Canada, Michigan, Indiana, Illinois, Kentucky, Missouri, and Iowa, a widely-expanded marine limestone, the Upper Helderberg, or Corniferous and Onondaga limestone of New York. In Canada and the Western States it is a straw-coloured and light-grey rock, often sparry and sometimes oolitic. It is the upper part of the cliff limestone of the West. In its more Eastern exposures it is generally bluish. It contains nodular chert.

Fossils.—This rock contains many fossils, and some beds of it consist almost entirely of corals and shells, and it is evidently the product of an immensely-extended coral reef. It is the lowest American formation in which there are any remains of fishes: these are large ganoid species, resembling those of the European Devonian rocks.

Thickness.—Its maximum thickness, which is in the Western States, is about 350 feet; but its average depth does not exceed one-third of this.

Equivalents.—The nearest European representative of this rock is the English Ludlow formation; but it contains numerous Devonian fossils, and even some carboniferous ones. It is therefore not exclusively a Silurian equivalent. The occurrence of Productus and Pentramites shows that even carboniferous races tenanted the waters of the Appalachian sea of the Post-Meridian period.

CADENT SERIES, OR GENESSEE, HAMILTON, AND MARCELLUS GROUPS OF NEW YORK.

Description.—This series, like the succeeding one, has its greatest expansion in the Appalachian chain and in Southern New York, and declines steadily in thickness in spreading into the Western States. From New York to Eastern Tennessee it is a group of three formations. The upper or later, the Cadent newer black slate (Genessee slate of New York), is a brownish-black, and in some regions a bluish-black very fissile slate, characterised by numerous small and delicate molluscs, chiefly of Devonian, but some of them of Carboniferous genera, and likewise by remains of a true terrestrial vegetation, generically identical with that of the Coal-measures. This rock has a thickness, in some parts of Pennsylvania, of 300 feet. The middle member or formation, the Cadent shales, the Hamilton group of New York, is a bluish-grey, brownish and olive-coloured clay shale, with thin beds of dark-grey sandstone, sometimes calcareous. It abounds in fossils, especially bivalve shells and corals. Its greatest thickness in Pennsylvania is about 600 feet. The lowest or Cadent older black slate (Marcellus shale of New York) is a black and highly-bituminous slate, graduating upwards into a dark-blue argillaceous shale, surmounted, in some districts, by greenish sandy shales. A thin argillaceous limestone generally occurs near the bottom of the black slate in Pennsylvania, Virginia, and Tennessee. The fossils of the formation are some of them identical with those of the Cadent newer black slate. Many of them are diminutive, and some minute vegetable forms are possibly terrestrial. In Pennsylvania the thickest exposures of this member of the formation measure nearly 300 feet.

Geographical Distribution.—These Cadent strata have their greatest development in the valleys of the Appalachian chain in Pennsylvania and Virginia. Like so many of the other shore-formed deposits of this part of the Appalachian sea, they manifest a gradual reduction of thickness in the S.W. direction, becoming much attenuated before they reach Eastern Tennessee, but, unlike others, one member at least of the series stretches to the W. and N.W. over an enormous distance. The black slate of the Western States shows a continuous outcrop the whole way W. across New York to Lake Erie, and thence S. across Ohio and Kentucky to the anticlinal of Middle Tennessee, which it everywhere fringes. It encompasses, on the E., in like manner, the wide basin of carboniferous strata encircling the Indiana and Illinois coalfield, and, in another belt, crosses the peninsula of Michigan, from the lake of that name to Lake Huron. It seems to thin away by the time it reaches the Kankakee River, on the N. edge of the Illinois coalfield, and in a more Southern latitude in the neighbourhood of the Tennessee River. Rocks of this age are believed to occur in a narrow outcrop bordering the carboniferous basin of New Brunswick.

Fossils.—The Cadent strata are the oldest American formations in which remains of a true terrestrial vegetation have as yet been discovered. Besides these, which are rare, they contain numerous species of mollusca and other marine forms, several of which are identical with European Devonian and Carboniferous species, many being found in no other rock. Goniatites and other carboniferous genera characterise the Cadent black slate both in Pennsylvania and the Western States.

Thickness.—The entire Cadent series is about 1200 feet thick.

These Cadent strata are represented in the Western States, from Southern Ohio both S.W. and N.W., by only one rock, a fissile black slate, which may represent either the upper or lower Cadent formations, but which is generally regarded as the Cadent newer black slate, or Genessee slate of New York. Reposing immediately upon the Postmeridian limestones, and surmounted in turn by the Vergent strata, and W. of the Ohio anticlinal by the Older Carboniferous or Vespertine, and having a very extensive distribution, it constitutes an important stratigraphical horizon. If this black slate be the oldest of the Cadent rocks, the absence of the others establishes an extensive hiatus between it and the Vergent. If, on the other hand, it represents the Cadent newer black slate, a like hiatus exists in the absence of the middle and lower Cadent formations.

Equivalents.—The nearest equivalent of these Cadent strata among the European formations would appear to be the Older Devonian rocks of the Eifel, but, as presently to be intimated of the Vergent, these Cadent strata all contain some carboniferous forms.

VERGENT SERIES, OR CHEMUNG AND PORTAGE GROUPS OF NEW YORK.

Description.—This formation is in two divisions, the upper called, in the New York Survey, the Chemung Group, a thick mass of grey, blue, and olive-coloured shales, and grey and brown sandstones, the sandstones predominating in the upper part, and the shales abounding in fossils, especially Brachiopoda. The lower division, the Portage group of New York consists of a rather fine-grained grey sandstone, in thin layers or flags, parted by thin bands of soft blue shale. Its characteristic fossils are Fucoids, or ancient sea-weeds.

Thickness.—On the Juniata River, in Pennsylvania, the upper rock has a thickness of 3200 feet, while that of the lower amounts to 1700.

Geographical Distribution.—These strata extend South-westward as far as Tennessee, and probably Alabama, and Westward to Ohio, Kentucky, Middle Tennessee, and Missouri. But their equivalents, if they have any farther West in the Appalachian palæozoic basin, have not been ascertained. Vague indications of this series appear in the Rocky Mountains.

Equivalents.—A comparison of their organic remains teaches us that these strata are most nearly represented in Europe by the Eifel strata of the Devonian series. They possess several true Carboniferous species.

PONENT SERIES, OR CATSKILL GROUP OF NEW YORK.

Description.—In its fullest development—viz. in Pennsylvania and New York—this is a thick mass of alternating red shales, and red and grey argillaceous sandstones, some of which, in the upper strata, are sparsely sprinkled with white quartz pebbles.

Geographical Distribution.—This rock steadily declines in thickness towards the W., and thins down entirely upon reaching the Alleghany River. South-westward, it extends in several interrupted outcrops along the Appalachian chain as far as Eastern Tennessee, but under a gradually declining thickness. It is absent throughout all the Western States, and even along the Western outcrop of the Appalachian coal-field on the Alleghany River, and South-westward. Nowhere throughout the Western States has any true equivalent or representative of it been discovered; and we are forced to the conclusion, therefore, that a movement of the bed of the Appalachian sea took place at the close of the middle palæozoic periods, preventing a deposition of Ponent strata, and causing here a break in the sedimentary succession, or scale of geological time.

Thickness.—The maximum thickness of the Ponent beds in Eastern Pennsylvania is not less than 5000 feet, and they thin to nothing in a distance of 200 miles.

Fossils and Equivalents.—Few organic remains exist in this formation; but those few, such as the *Holoptychius*, are eminently distinctive of the age of the European Devonian, especially of the Old Red Sandstone of Great Britain. No remains nor footprints of reptiles have ever been discovered in the Ponent strata.

VESPERTINE SERIES, OR LOWER CARBONIFEROUS STRATA.

Description.—In its South-eastern outcrops in Pennsylvania and Virginia, this series is a thick mass of white, grey, and yellow sandstones, alternating with coarse silicious conglomerates, and dark-blue and olive-coloured slates. In some localities it includes beds of black carbonaceous slate, and one or more thin beds of coal.

Geographical Distribution.—The Vespertine, or Lower Carboniferous series, has apparently a much less extensive distribution Westward, from its E. outcrops in the Appalachian chain, than the Umbral series which rests upon it. From the district of its maximum development around the anthracite coal-basins of Pennsylvania, we trace it with a rapidly-diminishing bulk duly N.W., until it thins away altogether upon reaching the Alleghany River. Upon the N.W. border of the great Appalachian coal-field it has no existence whatever; but it ranges S.W. from the anthracite country to a far greater distance, following especially the E. margin of the general coal-field, maintaining more nearly its thickness across Virginia and Tennessee. Passing beneath the Cumberland Mountain and its spurs in Alabama, this stratum takes on, like so many others, a less littoral or sandstone type for a more marine or limestone one; and emerging to the day once more in central Kentucky and Tennessee, it begins to assume the characters of a fossiliferous, sandy, and argillaceous limestone. Under this form it underlies the Umbral limestone in Indiana and Western Kentucky, and on the Mississippi and Missouri rivers. In its W. outcrops the stratum is apparently much thinner than the purer limestone group above. How far it spreads to the W. of the Mississippi River has not yet been ascertained. Possibly this formation, and not the Umbral limestone, is the equivalent of the lower Carboniferous group, or gypseous red sandstone of Nova Scotia and Cape Breton. In the absence of more distinctive proofs of equivalency from organic remains, we are entitled to infer that the lower carboniferous strata of the Provinces represent both the Umbral and the Vespertine rocks of the Appalachian basin.

Fossils.—Where it has its E. or ancient shore type, the only organic remains are fragments of coal plants, for the most part specifically different from those of the upper or true Coal-measures. In the Western States it abounds in crinoids and molluscs. To the N.W. of the Appalachian chain, in Northern Pennsylvania and Ohio, this formation grows more argillaceous, and gradually thins away; and on the S.W. outcrop of the great Appalachian coal-field in Kentucky and Tennessee, and in its outcrops circling the great Western coal-fields, the whole mass exhibits a more marine type, its material being chiefly a fossiliferous limestone, filled with oceanic forms, and a grey and yellow sandstone. In the Western States this rock is called the sub-carboniferous limestone.

Thickness.—In Pennsylvania its maximum thickness exceeds 2000 feet.

Equivalents.—This formation belongs to the same period, apparently, as the oldest carboniferous slates of Ireland, or the lowest carboniferous rocks of Europe.

UMBRAL SERIES, OR MIDDLE CARBONIFEROUS STRATA.

Description.—Along the Appalachian chain, this series, in its fullest development, is a triple group, the lowest members consisting of buff, greenish, and red shales, with some sandstone; the middle of a thick mass of light-blue limestone, sometimes oolitic; and the upper of blue, olive, and red calcareous shales, containing massive strata of grey and brownish sandstone. This is the type in Virginia. In Pennsylvania the whole stratum consists of soft red shales and argillaceous red sandstones. In the Western States the principal formations are a light-blue and yellowish limestone, replete in marine organisms, and a grey and yellow sandstone.

Geographical Distribution.—Tracing the Umbral series through its principal outcrops, we find it bordering the several coal-fields of the Eastern British Provinces, under the type of a very diversified group of red shales and sandstones, with conglomerates, calcareous and gypseous marls, and thick beds of limestone, and layers of gypsum; the whole having a maximum thickness of about 6000 feet. Entering the true Appalachian region, we meet the Umbral red shale first in Pennsylvania, and trace it with a gradually declining thickness from its maximum of 3000 feet on the Schuylkill, Southward to the borders of Maryland, where it becomes more calcareous and variegated and fossiliferous, and receives as a middle member the Carboniferous limestone. Advancing in this direction, the limestone gradually augments in thickness, while the upper and lower groups of shale as gradually thin down. But far to the S.W., on the Green Briar River of Virginia, each of the three divisions has a thickness exceeding 1000 feet. The N. outcrop, on the other hand, consisting alone of the red shale and sandstone, grows rapidly thinner as it ranges Westward under the successive anthracite and semi-bituminous coal-basins of Pennsylvania, thinning away entirely at the sources of the W. Branch of the Susquehanna. The Umbral or Carboniferous limestone, if followed as a single formation, first shows its extremely attenuated feathered edge on the Alleghany Mountain, at the sources of the Conemaugh in Pennsylvania. Thence, augmenting Southward, as already said, through Maryland and Pennsylvania, it ranges in great force, though in a narrow outcrop, along the S.E. border of the great coal-field through the latter State, Virginia, Eastern Tennessee, and Northern Alabama, to the termination of the mountains. This rock does not exist at the W. margin of the Appalachian coal-field anywhere in Northern Pennsylvania, or in Ohio; but when we enter Kentucky it gradually developes itself between the Seral and Vespertine strata, and soon becomes a conspicuous formation in the W. escarpment of the Cumberland Mountain, the whole way across Kentucky, Tennessee, and Northern Alabama, expanding widely to the W. in the latter State.

Passing to the other carboniferous districts farther W., this limestone, divided from the broad intervening region, reappears first to the N. in a slender outcrop, encircling the S. half of the coal-field of central Michigan. Leaping a second wide interval, it again shows itself, enclosing the whole of the great coal-field of Illinois, Indiana, and Western Kentucky. There it is comparatively thin at its N. outcrop, but along the E. margin of the coal-field it gradually thickens, and widens its area as it advances S., until, on the Ohio River, and round the S. side of the basin, it acquires a great development. We may next trace it along the S.W. and W. borders of this coal-field, from the Ohio River along both sides of the Mississippi, past the mouth of the Missouri, and skirting the upper Mississippi as far N. as the Red Cedar River of Iowa, near which the anticlinal belt divides, one outcrop turning E. round the Illinois coal-field, the other W. to enclose that of Iowa. From the Mississippi River, between the Ohio and the Missouri, it spreads largely through Southern Missouri, encircling the wide elliptical anticlinal district of the Ozark Mountains, and older Palæozoic rocks at their base. On the W. side of the great W. coal-field of Iowa, Missouri, and Arkansas, this formation once more emerges from under the coal strata, and spreads over a wide belt from their W. border to the E. margin of the unconformably overlying cretaceous deposits of the plains of Nebraska and Kansas. Thickest towards the S., this great marine stratum covers almost continuously the wide district which separates the S. termination of the Appalachian coal-field in North Alabama, from the S. border of the Illinois coal-field in Western Kentucky. Throughout the whole broad area over which we have thus far traced it, we witness a thinning-off in a N.E. direction. While its thickness, on its S. and S.W. outcrops, is in several places from 1000 to 1200 feet, it is no more than 390 feet in Iowa, is much less than this in Northern Illinois, and fines away entirely, in passing under the Michigan coal-field, from its attenuated W. outcrop; and we have seen that in Ohio and Pennsylvania it has no existence.

This widely-diffused formation is not restricted to the E. palæozoic region of the continent, but exists largely developed in the other more insulated ancient tracts of the W. side. It occurs in the Black Hills, in the Rocky Mountains, and in many of the isolated ridges of New Mexico, in which that great chain dies down, and it has been met with extensively in several of the mountain systems still farther W., as in the Wahsatch chain of Utah in the Humboldt Mountains of the Salt Desert, extensively on the Rio Gila, and in the table-lands of Sonora; and it has been detected even in the Sierra Nevada of California. Too little is at present known of the Rocky Mountains and the country W. of them, to permit that detailed separation of the palæozoic system there, which is practicable for the Appalachian basin E. of the central prairies. Recent researches indicate a carboniferous limestone near Fort Laramie, and in the Black Hills; but whether it belongs to the Umbral Series or to the Coal-measures is doubtful.

Thickness.—The maximum thickness of the whole series in Pennsylvania and Virginia is about 3000 feet. In the Western States the limestone exceeds 1000 feet.

Fossils.—Everywhere the fossils are generically identical with those of the great carboniferous limestone of Europe. The Umbral red shale of Pennsylvania contains almost no animal remains, and very few vegetable. It does, however, present, on some of the ancient shore-surfaces, beautifully-distinct footprints of ichthyoid reptiles, and trails of brachiopodous molluscs, and also impressions of a few peculiar aquatic plants. The Umbral limestone, and the variegated shales into which the red shale graduates towards the S.W., abound, on the contrary, in organic remains, corals, crinoideæ, brachiopods, and other molluscs. In Nova Scotia the marine beds contain likewise remains of ganoid fishes.

SERAL SERIES, OR COAL-MEASURES.

Description.—The Coal-measures of the United States and the N.E. British Provinces consist of argillaceous and silicious sandstones and quartzose conglomerates, of clay shales of nearly every colour and texture, of fire-clays and coal-slates, of argillaceous limestones, chiefly of marine origin, and of numerous seams of coal. This coal-bearing group is underlaid throughout nearly all the coal-fields of the country, from Pennsylvania to Alabama and Missouri, by a coarse silicious conglomerate or millstone grit, which also in some localities contains thin seams of poor coal.

Geographical Distribution.—The E. half of the continent contains five great coal-fields, distributed at intervals from Newfoundland to Arkansas. 1. The first, or most Easterly, is that of the E. British provinces—Newfoundland, Nova Scotia, Cape Breton, and New Brunswick—originally a wide coal-field broken into patches by uplifts of the older strata, and by the waters of the St Lawrence Gulf. The surface, covered by the coal-measure of the Provinces, is probably about 9000 square miles; but apparently only one-tenth of this area is productive in coal. 2. The second, which I have called elsewhere the great Appalachian Coal-field, commences in Pennsylvania, and extends S.W. to near Tuscaloosa in Alabama. This includes several outlying lesser basins—those, for example, of anthracite coal in Eastern Pennsylvania. It has a total area of about 70,000 square miles. 3. The third is the smaller coal-field of the centre of Michigan, equidistant from Lake Huron and Lake Michigan. The area of this may be given at about 15,000 square miles. It is very deficient in coal. 4. The fourth is the great coal-field lying between the Ohio and Mississippi anticlinals, and spreading in the form of a wide elliptical flat basin, from Kentucky N. through Indiana and Illinois, to Rock River. This possesses an estimated area of 50,000 square miles. 5. The fifth, and most W., is a long and large coal-field occupying the centre of the great basin of carboniferous rocks, which spreads from the Mississippi and Ozark anticlinals W. to the visible limit of the Palæozoic region, where it is overlapped by the Middle Secondary and Cretaceous deposits of the prairies. The N. limit of this coal-field is in Iowa, on the Iowa River; the S. is near the Red River, on the W. confines of Arkansas; and the total area of the great irregular basin is not less than 57,000 square miles. In a S.W. direction from the S. point of this last coal-field, are three or more small detached patches of coal-bearing strata, surrounded by the superficial cretaceous deposits. These are probably only the denuded outcrops of one long subterranean basin, prolonged from the main one through Western Arkansas and Northern Texas. Besides these chief areas of coal belonging to the E. half of the continent, there would seem to be some localities of this formation bordering the Rocky Mountains, and in the region of the Wahsatch chain of Utah. But so many of the reputed cases of coal discovered in the interior of the continent have proved, upon a geological scrutiny, to be deposits of lignite of the cretaceous and even the tertiary age, that we are cautious, in the present imperfect stage of the evidence, about assigning any of these to the true Carboniferous formation.

Summing up the several areas here defined, we perceive that the broad coal-fields of North America occupy the enormous space of at least 200,000 square miles, or more than twenty times as large a surface as that which includes all the known coal-deposits of Europe, or probably of the E. continent.

Thickness.—Comparative measurements of the thickness of these several deposits of the American Coal-measures, indicate a marked reduction from the E. towards the W. Those of the Nova Scotia field, as measured at the South Joggins, Bay of Fundy, show a thickness of nearly 3000 feet; those of the S.E. anthracite basin of Pennsylvania an average thickness about as great; while the central portion of the great Appalachian bituminous basin has a depth not exceeding 2500 feet. Those, again, of the Illinois basin are probably not thicker than 1500 feet; while the last, the Iowa and Missouri basin, is evidently much shallower, its total depth not surpassing probably 1000 feet.

In Nova Scotia, the coal-fields contain, in the Joggins section, in all about fifty seams of coal, only five of which, however, are of workable dimensions: these are equivalent to about 20 feet of coal. In the deepest anthracite basin of Pennsylvania, that of the Schuylkill, there are, where the formation is thickest, about 50 seams in all; but 25 of these have a diameter exceeding 3 feet, and are available for mining. In the great Appalachian coal-field there appear to be about 20 beds in all, and 9 or 10 of these are of workable size. Again, in the broad basin of Illinois, Indiana, and Kentucky, the total number amounts to 18; and it is believed that 17 of these are of a size and quality suitable for mining. Only 2 or 3 such are believed to exist in the shallow and much-denuded basin of Michigan. Still farther W., the coal-fields of Iowa and Missouri contain, it is believed, only 2 or 3 beds thick enough to be profitable, while the total number of seams of all sizes is probably not more than 12 or 13.

Fossils.—The organic remains of the American coal strata belong to the same forms of vegetation which are typical of the coal-rocks of other countries. Many of the species, however, are local or peculiar. The strata of marine origin contain corals, shells, and remains of fishes; while others formed at the sea-level show the imprints of shore reptiles and molluscs.

European Equivalency.—It is obvious, from the very general accordance between the fossils of the American and the European coal strata, that the former were produced during the age of the upper or main coal-measures of the European carboniferous series.

UPPER COAL-MEASURES; SUPPOSED PERMIAN FORMATION.

West of the Coal-bearing rocks of Iowa, Missouri, and Arkansas, there ranges a belt of overlying deposits through the E. borders of Kansas, from near the mouth of the Platte River to the Canadian, which by some American geologists are regarded as representing the Permian division of the Palæozoic system of Europe. They repose conformably upon the Coal-measures, from which they are not separated by any stratigraphical or physical break. The group consists of a reddish-brown shale, alternating with beds of fossiliferous magnesian limestone. The organic remains, chiefly mollusca, belong in part to species abounding in the Coal-measures beneath, in part to other species here for the first time recognised, which Mr Meek, an able American palæontologist, has discovered to be of Permian genera; but these newly-introduced forms are not specifically identical with their European analogues, and they are sparsely represented, whereas the familiar carboniferous species among which they are dispersed are comparatively very populous. In the absence of any higher organisms decisive of a Permian age and in view of the above facts, showing an intimate relation, physical and palæontological, between these strata and the Coal-measures, it seems inexpedient to give them a separate recognition, such as an independent formation would be entitled to. The deposit may be styled, provisionally at least, the Upper or Newer Carboniferous formation. Its exact age is probably that of the interval or break which separates the European Coal-measures from the Permian deposits which rest unconformably upon them, or it may even overlap the beginning of the Permian period. It was nevertheless essentially a prolongation of the Carboniferous age of North America.

MESOZOIC FORMATIONS, OR MIDDLE SECONDARY STRATA.

Older Mesozoic.—It is remarkable that while the middle latitudes of North America contain very extensive districts of Palæozoic strata, and others almost as wide of the Newer Mesozoic or Cretaceous, and extensive regions of Tertiary or Cainozoic deposits, the Continent embraces an extremely small extent of the Older Mesozoic or Triassic and Jurassic formations. Along the Atlantic Slope these strata exist in narrow detached belts of comparatively restricted length, in situations which indicate that they were accumulated in local estuaries and small basins, and not upon the general oceanic border of the land as it then existed.

Two independent formations or groups of strata of very nearly the same geological age comprise all the older Mesozoic deposits of the Atlantic Slope hitherto ascertained. Possibly the oldest and certainly the most extensive of these is a Red Shale and Sandstone group, distributed in a series of detached basins from Prince Edward Island in the Gulf of St Lawrence to the Atlantic Slope of North Carolina. The other, a Coal formation of very limited area, occurs in three or four small and narrow basins in Eastern Virginia and North Carolina, and South Carolina, immediately W. of the West margin of the Atlantic Tertiary deposits.

Other tracts of Mesozoic strata exist, but farther in the interior of the Continent. One of these, of Jurassic age, occurs in Kansas; another of similar date encircles the Black Hills.

Mesozoic Red Sandstone.—Notwithstanding their insulated position with respect to each other, the several masses of Middle Secondary red sandstone exhibit a remarkable general agreement as regards their composition. Argillaceous red sandstone, red shale sometimes slightly calcareous, grey carbonaceous shales in small amount, and coarse silicious and other conglomerates, are the prevailing sedimentary rocks. Very generally, the whole deposit, especially that belt which extends continuously from the Hudson to the James River in Virginia, consists of three members, the lowest being a conglomerate formed of pebbles of the adjacent older strata, imbedded in a cement of red shale; the middle, an extensive alternation of red shale and argillaceous red sandstone; and the uppermost, often absent, and always of moderate thickness, another conglomerate similar in composition and in origin to the lowest.

That portion of the formation which occupies the S. half of the valley of the Connecticut River consists chiefly of argillaceous sandstone, with beds of red silicious conglomerate, and some partial layers of grey carbonaceous shale, but, on the whole, is much less shaly or argillaceous than the belt which traverses the middle States.

Those patches of the deposit which cover Prince Edward Island and the shores of Cobequid Bay in Nova Scotia, differ chiefly from the others in containing more calcareous cement in the soft red sandstones. The principal strata are coarse red sandstone, coarse heterogeneous conglomerates in the lower part, and soft calcareous red shales.

Geographical Distribution.—Commencing at the N.E., the first tract of Triassic or Jurassic red sandstone is that which skirts the N. shore of Chaleurs Bay in New Brunswick from the neighbourhood of Gaspé Bay S.W.

The next area is Prince Edward Island, almost the whole of which consists of a red sandstone, which some geologists refer to this formation. A third tract is the deposit already referred to as lining the shore of Cobequid Bay, or E. head of Minas Basin in Nova Scotia. This reaches only as far E. as Truro.

In the United States we meet with the next belt in the valley of the Connecticut, where the rock covers an area nearly 155 miles long, by from 7 to 10 miles wide, extending from near the N. line of Massachusetts S. to Long Island Sound.

The largest belt of all, or that of the Middle and Southern States, stretches from the W. bank of the Hudson River, where it is upon the level of the ocean, inland in a S.W. direction along the S.E. side of the South Mountain and Blue Ridge, gradually contracting in breadth, and ascending in level through the States of New Jersey, Pennsylvania, Maryland, and Virginia, to near the centre of the latter, where it terminates.

Another narrow strip of the same rocks runs from a little N. of the Roanoke River S.W. almost to the Yadkin in North Carolina; and between the main belt and this one there occurs a small patch on the James River, in a position which indicates that originally they were all three connected. Some miles to the E. of this principal belt there is another still smaller patch on Willis River, a tributary of the James, which, with one or two other still more trivial outlying masses, implies that there has been an extensive denudation of the original shallow deposit.

The most Southern tract hitherto brought to light lies to the S.E. and S. of the Roanoke belt, and extends from the Tar River, North Carolina, S.W. to a point 8 or 10 miles within the State of South Carolina. This belt passes a few miles to the W. of the city of Raleigh.

Organic Remains and Geological Age.—None of the deposits of the Middle Secondary or Mesozoic red sandstone formation of the Atlantic border abound in fossils, but the vestiges of organic life which they do contain are remarkable. These consist of plants, chiefly terrestrial, of two or three shells, and simple crustaceans, of several fishes, chiefly species of the genus *Catopteris*, of two or three *Thecodontoid Saurians*, and of the footprints of some twelve or fifteen species of quadrupedal animals believed to be reptiles, and of the tracks of between thirty and forty varieties of birds.

The red rocks of Prince Edward Island pertain probably both to the coal period and to that of the other red sandstones farther S., or the earliest Jurassic; some of these strata on the S. side of the island imbed what seem to be carboniferous plants, while others, on the N. side, have yielded a fossil reptile, the *Bathygnathus borealis*, the affinities of which point to a Middle Secondary epoch. No fossils have been discovered as yet in the Nova Scotian Mesozoic basin; but as it evidently lies unconformably in a trough of the carboniferous and other Palæozoic rocks, formed at the close of the coal period, we have the same evidence for its post-carboniferous age which was formerly accepted before the discovery of any fossils in the red sandstone of New Jersey and Pennsylvania, as a sufficient proof of the Middle Secondary date of that deposit. But besides this stratigraphical fact, there are many circumstances of close identity to connect this formation with those of the great Mesozoic estuaries of Connecticut and the Atlantic Slope. Chief among these is a close correspondence in the nature of the sedimentary materials, washings into shallow bays of the soils of the adjacent older rocks; and, secondly, a remarkable analogy in all the phenomena of the trappean rocks which contain native copper and its ores, and which penetrate alike these several formations. These trappean outbursts, closely linked in time with the strata which they penetrate, are so unlike in lithological constitution, in the minerals which they enclose, and in the constant presence of copper, especially in the native state, that we are compelled to regard them as the products of one period—the eruptions, indeed, of one crisis in the disturbances of the Atlantic front of the continent.

The vegetable fossils in the Connecticut sandstone, consisting chiefly of *Cycadites*, *Lycopodites*, a fern, *Clathoptenis meniscoides*, and a few equisetaceæ, display such alliances with those of the Jurassic coal-rocks of Eastern Virginia as to place the early Jurassic or late Triassic age of the deposit beyond a question.

The fossil fishes of the Connecticut Valley, once referred to the genus *Palæoniscus*, but since to a separate genus by Redfield and Sir P. Edgerton, have less heterocercal tails than that Palæozoic family, and plainly indicate a Middle Secondary age. These fossils, occurring both in the Connecticut and the New Jersey deposits, serve to identify these two formations in time, while the occurrence of other species very nearly of the same type in the Liassic coal-rocks of Eastern Virginia supplies a further link to associate these latter with the several different red-sandstone formations which we are describing. Redfield has called one genus Catopteris; the name Ischypterus has been proposed for another by Sir Philip Edgerton. But the most interesting of all the organic remains in the Connecticut red sandstone are the quadruped and biped footprints above referred to. The former, it is believed, were left by different species of lizards, turtles, and frog-like or Batrachian reptiles; the latter by various species of wading-birds, some of them of very colossal size. Coprolites, or specimens of the dung of these creatures, have also been occasionally met with. The tracks occur at intervals throughout a distance of more than 80 miles from Turner's Falls in Massachusetts southward, and are repeated on successive surfaces through a thickness of more than 1000 feet of strata, measuring this by the usual rule of the dip. This, as will presently appear, does not, however, necessarily prove a subsidence of the bed of the red sandstone estuary through so great a space. No actual remains of birds, recognised as such, have hitherto been brought to light; though a few obscure bones, believed to be reptilian, have, it is said, been discovered. As the bird-tracks here spoken of are the earliest vestiges of this high class of creatures yet met with in any country, an especial interest attaches to the determination of the true age of the rocks, of so remote an antiquity, which contain them.

Of the fossils of the Middle Secondary belt of the Middle and Southern States, one of the most significant is a small crustacean form, a *Posidonia* very similar to the *P. minuta* of the European Trias, but believed to be a species of Estherea—not a shell, but a crustacean. This occurs associated with countless multitudes of two minute species of *cypris*, another small crustacean. They are met with abundantly in the thinly-laminated carbonaceous shales of the formation in the interior of Virginia, and as far to the N.E. as the Schuylkill River in Pennsylvania. Being indicative of fresh waters, their presence is expressive of an ancient river flowing into a tidal estuary, debouching where the Hudson now opens towards the sea. Coprolites, probably reptilian, occur with them near the Schuylkill. Still farther to the N.E., but towards the upper or N.W. margin of the formation, near Morristown, and near Pompton, New Jersey, the remains of fishes and a few bird-tracks have been found, identifying, as already stated, this deposit with that of the Connecticut Valley. Besides these, the actual bones and teeth of a saurian reptile (*Clepsisaurus Pennsylvaniensis*) have been recovered from the upper beds of these red sandstones in Lehigh County, Pennsylvania.

In the Eastern Mesozoic belt of North Carolina, conjectured by Professor Emmons to contain deposits of both the Permian and Triassic age, the lower or supposed Permian group has afforded to that observer several thecodont saurians, and an interesting *mammalian* relic, the *Dromatherium Sylvestre* of Emmons. It is supposed, from its dentition, to have belonged to an insectivorous marsupial mammal. As hitherto no mammalian remains have anywhere been met with in deposits older than the Trias, the occurrence of this fossil in the Mesozoic coal strata of North Carolina militates strongly against the hypothesis of their Permian age, and, as Professor Emmons admits, indicates rather an Oolitic or Jurassic date.

Dip of the Red Sandstone, and Physical Conditions attending its Origin.—Some of the features of bedding of the Middle Secondary red sandstones are sufficiently remarkable to claim special mention here. In Prince Edward Island, and in the Nova Scotia basin, the stratigraphical conditions are not peculiar, the rocks in the first-named district being disposed in low and broad undulations, but with a prevailing dip to the N.E., and those in the latter having the form of a regular trough, one side or outcrop reposing with a N.W. dip on the Palæozoic rocks of the S. side of the Bay of Fundy and basin of Minas; the other side with a S.E. dip, skirting the S. base of the Cobequid Mountains, and fringing the N. shore of the same waters. But in the deposit of the Connecticut Valley, and that of the Middle and Southern States, the stratification is decidedly abnormal. Throughout the former there prevails only one direction of the dip, which is a little to the South of East, the average inclination being about 20°, though in some places it is as low as 7° or 10°, and in other places as steep as 40° and 50°. What renders this prevalence of one dip the more remarkable is the absence of any external marks of great faults or dislocations, or of any repetition of the same strata on a section transverse to the strike, the whole formation appearing to be one unbroken sequence of deposits. Over a large part of the tract the beds seem, indeed, to hold the very attitudes or inclinations under which they were formed, though in certain localities, especially towards the W. margin, and adjacent to the larger outbursts of trap-rock, they appear to have been uplifted, or laterally squeezed into steeper inclinations than originally belonged to them.

Throughout the great S. belt, from the Hudson to Virginia, a similar phenomenon of the dip presents itself under circumstances still more striking. Without exception the strata dip in only one direction, but they descend towards the N. and N.W., and not, as in the Connecticut Valley, towards the E. In each instance they dip from one shore towards the opposite, across the entire breadth of the basin or estuary which originally received them. In this longer tract the prevailing slope is 15° or 20°, and it nowhere exceeds about 30°. Everything in the constitution of these strata in both belts—their materials, the direction of their dip, and their oblique bedding—indicate that they were deposited slopingly from one side only of their respective estuaries; and we may see, in the positions of the respective water-sheds which fed them, the features of the physical geography which caused this mode of origin. In the case of the Connecticut estuary, we have merely to suppose that its greatest depth, or its channel, was near its E. shore, and that it was fed by lateral rivers descending E. from the water-shed of metamorphic strata which even now divides the plain of the Connecticut from that of the Hudson River. In the other instance we find, in the existing physical and geological structure of the two borders of this greater estuary, an equally ready explanation of the monoclinal dip and the origin of the materials. The bold features of the mountain-chain which formed the N.W. shore of this great bay and river imply that its deepest channel lay close upon that side; and in the talcose and other metamorphic rocks of the region bordering the estuary on the S.E., which even at this day are remarkable for the red soils they produce, we see the source from whence the materials were derived. The original obliquity of the deposition of the red shales and sandstones is not a matter of hypothesis, but a necessary inference from observed facts of superposition; for in some places, several miles to the N. of the S. border of the belt in Pennsylvania, where—measured by the ordinary trigonometrical rule, which assumes that the strata were originally horizontal, and were afterwards uplifted—the thickness of the deposit should be many thousand feet, we discover it to be actually extremely shallow, denudation having cut entirely through it, and exposed the older system of rocks which constitute its floor.

Interpreting, then, from the facts presented, the physical conditions which attended the beginning, progress, and close of these Middle Secondary deposits, we are entitled to assert that their period was ushered in by a sudden agitation of the region, resulting in an abrupt depression of the tidal portions of each tract below the general ocean-level, or, in other words, in the creation of broad and shallow river-valleys running longitudinally with the mountains, and opening to the sea. Into these newly-created depressions the suddenly-displaced drainage of the bordering tracts would introduce a load of fragmentary matter for the production of those conglomerates which almost everywhere constitute the lower strata of the formation. After the first convulsions were over, a permanent drainage, in the one case from the W., in the other from the S.E. and S., would supply the softer and finer materials of the great body of the deposit. The oblique deposition of these materials would result from their lateral introduction and the scouring action of a strong tidal or river current in the channel, sweeping out all sedimentary matter from the middle and far side of the estuary, and permitting only that to collect which was piled forward, layer upon layer, by muddy tributary streams frequently swollen by rains.

If, in connection with these views of the physical geography of the period, we people the borders of each estuary with the wading-birds and water-frequenting reptiles whose vestiges are impressed upon the once soft strata, and admit the natural assumption that the tracts in which they delighted were the tidal portions of these estuaries, we may readily conceive how the footprints of these animals were buried up and preserved. At each recession of the tide they would go down to feed upon the last newly-deposited silts of the sloping shore, and retiring would leave their footmarks, and then each returning or flood tide, backing the turbid waters descending from the hills, would throw down a fresh layer of sediment to fill these imprints, and preserve them unaltered for an indefinite time.

To account for the very heterogeneous conglomerates which constitute the uppermost or final stratum in so many localities, it is merely necessary to consider what would take place at the first coming on of that series of volcanic actions which produced the great dykes and outflows of trappean lava that occur so extensively in all these Middle Secondary belts. These conglomerates consist almost exclusively of the fragments, imperfectly rounded, of the older rocks of the immediately adjoining hills, imbedded in a paste of the red shaly matter of the waters of the estuary; and it is a significant fact that they include no pebbles of the trappean rocks. The eruption of the trap rocks was therefore posterior to the formation of the conglomerates. Let us, then, suppose that just prior to the actual eruption of the igneous rocks, these Middle Secondary tracts were violently convulsed and partially or even entirely uplifted by vehement earthquakes, and we have at once a sufficient cause for the formation of the conglomerates and the drainage of the basins. The waters of those estuaries containing these terminal breccias must have been lashed violently against the base of the steep bordering hills. In their agitation they would tear off, partially round, and strew the fragmentary materials within their reach, imbedding these in the paste of sand and mud with which they were already charged. The draining-off of the estuary waters towards the side of the ancient channel would naturally produce that oblique dip of the conglomerates under which they seem to have been formed, and by which they abut against the rocks of whose fragments they consist. Further and still more energetic convulsions, with uprising of the land, would complete the desiccation of those tracts which became permanently dry, and result in that extensive rupturing of the crust which gave birth to the dykes and the plateaus of trap-rock that now so extensively intersect these deposits. In certain cases the entire length of each Middle Secondary belt seems not to have been uplifted to the sea-level before the commencement of the trappean eruptions; and those tracts which remained thus submerged are seen to contain, interstratified, as it were, with the later sedimentary deposits, those sandy volcanic tuffs or subaqueous sedimentary forms of trappean matter which constitute the link between the exclusively aqueous and igneous masses. These aqueo-igneous rocks or trap shales abound more in the even now not entirely uplifted basin of Nova Scotia; and they occur to some extent in the lower or more oceanic parts of the other two great estuary tracts—that of the Connecticut River, and that of the Middle States.

Trap-Rocks.—The igneous rocks of these Middle Secondary belts of the Atlantic seaboard constitute one of the remarkable features in the geology of the country. With very few exceptions, they are restricted to the limits of the Red Sandstone deposits, there being obviously some law of connection between their geographical distribution and that of the rocks which they invade. For the most part they occur in great dykes and ridges, ranging longitudinally with the strike of the strata they intersect, or approximately parallel with the borders of the Middle Secondary basin. They are of all dimensions, from ridges and even plateaus many miles in length and several hundred feet in altitude, to short and narrow dykes of the length of a few hundred feet and the width of a few feet or inches. Some of them are approximately straight, but by far the greater number show a curved or crescent shape; and some of them are even hooked at their ends until their points range at right angles to their main portions. With a few exceptions the ends or horns of these crescent-shaped dykes and ridges point in the direction of the dip of the red sandstone strata which they intersect; and this law of their direction is not confined to the great Middle Secondary deposit of the Middle States, but prevails quite as conspicuously in that of the valley of the Connecticut. What makes this the more striking is, that as the strata in these two estuary-deposits dip towards nearly contrary quarters—in the former towards the N.W., in the latter towards the E.—the points of the trappean ridges in the two instances observe corresponding differences of direction. This remarkable relation of the form of the dykes to the dip of the strata enclosing them, has its probable solution in the fact that the trappean matter was extruded partly up the previously established slopes of the obliquely deposited red sandstone, and partly perpendicularly through the transverse breaks in the strata occasioned by the stretching of the crust, and the lifting, as on a hinge, of the outcrop part of the strata borne up by the rising trap.

These rocks consist for the most part of coarsely-crystallised greenstone trap and dykes of more compact basalt. Sometimes the rock is a true dolorite; amygdaloids, or vesicular traps and toadstone, are not unfrequent; and the trap shale or sedimentary aqueo-plutonic variety is also, as already stated, met with.

Of the minerals associated with the trap, the most distinctive are metallic copper and its ores, especially the red oxide of copper, green carbonate, and grey sulphuret; but these do not occur in regular lodes. Specular iron-ore, in small tabular crystals, is also common, and magnetic iron-ore. All these are most apt to occur next the outer walls of the dykes, or in the fissures of the sedimentary rocks immediately contiguous. Many attempts have been made to mine the copper at a profit, but hitherto invariably without success. Other characteristic minerals are—agates, stilbite, laumonite, chabasite, analcime, phrenite, epidote, and occasionally datholite, &c.

Metalliferous Veins.—In two or three dictricts true metalliferous lodes occur within the limits of the middle Secondary red sandstones. And in one locality—that of Montgomery and Chester counties, Pennsylvania—some of these veins have been experimentally mined, and with partial success. These veins are not associated with dykes of trap-rock, but are independent metalliferous injections, consisting of some of the ores of lead, zinc, and copper, involved in various gangue-stones, as quartz, felspar, oxide of iron, &c. The chief ores are sulphuret and phosphate of lead, carbonate and sulphate of copper, and the sulphuret and carbonate of zinc. The Wheatly lode, the most promising of this group, penetrates both the gneissic rocks and the red sandstones. It has already furnished nearly thirty mineral species; among these, some rare crystalline combinations or salts of the metals above named.

Jurassic Coal-Formation.—The Jurassic coal-formation, apparently identical in age, or nearly so, with the Jurassic or Middle Secondary red sandstone, occupies a much more restricted area than that other rock on the Atlantic slope. It is limited, indeed, to a series of small basins strung at intervals along the E. border of the great zone of metamorphic strata, a little West of the Western boundary of the tide-water tertiary plain, from the Potomac to near the Wateree River, in South Carolina. One strip stretches from the W. bank of the Potomac, some miles S. of Washington, in a narrow interrupted outcrop, as far as the James or Powhattan River, obscured for the most part, except where it is intersected by the Chesapeake rivers, by the overlapping lower beds of the Eocene and Miocene tertiaries. This long narrow zone consists chiefly of a soft pebbly imperfectly-cohering rock, a whitish-grey argillaceous sandstone, in which the cementing material of the sand is frequently a white kaolin. Though it contains numerous fragments of an oolitic vegetation, it appears to possess no regular seams of coal. Its position and composition indicate it to have been formed on a line of coast rather than in an estuary.

The next patch, a genuine coal-basin, occurs on a line a little west of the above described, and seems to have been originally more inland. It extends from a few miles N. of the James River to the S. side of the Appamattox River, a length of about 25 miles, with a mean width of 8 or 10 miles, the centre of the trough lying about 12 miles W. of the city of Richmond.

The materials of which this coal-basin consists are principally coarse grey micaceous sandstone, with comparatively little true shale or slate, and they seem to have been derived from the subjacent granitoid gneiss, upon which they immediately repose, in a wide deep trough. These Coal-measures have been penetrated on their E. margin, by mining, to a depth of nearly 900 feet, and a section across the basin shows that they probably have a total thickness in the centre of 1500 or 2000 feet. Only the very lowest portion of the formation is productive in coal: the two, and sometimes three, distinct known seams being all comprised within the lowest, 150 feet. One of these beds, the very lowest, is in some places of enormous size, being as much as 30 feet or even 40 feet thick. It is very variable, however, being in other spots not more than 4 or 5 feet, and appears to have been formed in hollows on an irregular floor of the older rocks, for the bottom of the seam is in some places within a few feet or even inches of gneiss. The coal is a highly bituminous fusible gas-making variety of the species called cherry coal, of a low specific gravity, and a brown streak or powder. The mines are wet and deep, and are not prosecuted with much activity, the total yield of the basin in 1854 being about 150,000 tons.

Fossil Vegetable and Animal Remains.—These coal-bearing strata contain several interesting species of extinct plants, some or all of which have evidently contributed to form the beds of peat out of which the coal-seams were derived; but none of them pertain to the vegetable forms found in the ancient carboniferous strata, or true Coal-measures. Nothing like the old Stigmariæ, Sigillariæ, or Lepidodendra, nor any species of the numerous herbaceous and tree ferns of the older coal have been seen. The distinctive forms are—*Z. tenuistriatus*, *Zamites obtusifolius*, and *Equisetum columnare*, *Lycopodites Williamsonis*, with a noble fern, *Tæniopteris magnifolia*, and *Pecopteris Whitbyensis.* Several of these forms appear to be identical with the well-known fossils of the lower oolitic sandstones of Yorkshire. It is probable that the carbonaceous matter of the coal was largely derived from the fleshy cellular stems of the gigantic Zamias.

Of the animal remains, the most significant relics yet discovered are a few teeth, which seem to have belonged to some saurian, and numerous specimens of two or three genera of very slightly heterocercal fishes, one of which is the *Catopterus Macrarus.* True mollusca are rare; but a shell-like form, the *Posidonia* or *Posidonomia*, once before spoken of, and recently suspected to belong to the crustacean genus *Estheria*, is occasionally found, and is one of the interesting fossil links which connect this oolitic coal-formation with the adjacent Jurassic red sandstones.

Like the red-sandstone basins, this coal-field seems to have been invaded at the date of its elevation by great crust-disturbances, lifting it from the water, faulting its rocks, and injecting it with dykes of trap. Some of these trappean injections appear not to have reached the surface, for they lose themselves between the strata; and in one remarkable case, the igneous rock, traversing or rather resting on one of the coal-seams, has converted it by slow heat and pressure into a natural coke of a dull lustre and great compactness. It is not a true anthracite, but a real coke; and it is doubtful if anthracite on the large scale has ever been produced from bituminous coal through the contact or proximity of igneous rocks merely. The coal-field of Eastern Virginia is excessively fiery, and many disastrous explosions have arisen in the mines from the copiousness of the fire-damp.

The coal-field of Eastern Virginia would appear to have been, at the date of its formation, a fresh-water swamp at the head of a bay penetrating the land from the N., and it is probable that the non-coal-bearing sandstones of the same age in the belts adjoining were deposited on the Western coast of this bay, or the main shore of the continent just outside of it.*

Oolitic Basin, North Carolina.—The third, principal, and by far the largest tract of the Jurassic coal-formation of the Atlantic slope occurs in North Carolina, extending from the Tar River, in a somewhat irregular belt, South-westward, a distance of 150 miles, to Lynche's Creek, or possibly the Wateree River, in the North-eastern corner of South Carolina. Of the geology of this belt less is at present known than of the Virginian belts. The rocks are chiefly argillaceous sandstones; and on the Deep River of North Carolina they contain one or two thin seams of bituminous coal. The principal, and apparently only valuable coal-bed, has nowhere, it is believed, a thickness of more than 4 feet; but it has been detected at intervals along an outcrop of 12 miles, and possibly, therefore, it may one day become of commercial importance. It occurs near the Eastern side of the formation, dipping, with all the rocks yet examined, gently to the Westward; but its opposite dip has never been discovered, and it is not yet ascertained that the strata themselves have the trough-like form, though the occurrence of a continuous seam of coal, which can only have originated when at least its own part of the formation was horizontal, is evidence of a more or less extensive uplifting or basining movement of the crust.

Fossils.—The few organic remains hitherto procured from this Carolina coal-field are in part identical with forms found either in the Virginian Jurassic coal strata, or in the Virginian Middle Secondary red sandstone, of nearly coincident Jurassic date. They are chiefly two or three coal plants, and the characteristic animal remains, *Posidonia* and *Cypris.* With these are the mammalian animal and the Thecodont saurians already mentioned, and remains of fishes.

Besides these Jurassic deposits of the Atlantic slope, there occur other tracts of strata of the oolitic age farther in the interior of the continent. The largest belt there known, outcrops, according to Professor Swallow, the State Geologist of Missouri, between the E. margin of the cretaceous strata and the W. border of the upper carboniferous group, suspected to be Permian, in the E. part of Kansas, running in a slender but expanding zone from a little South of the Nebraska River to the Arkansas River, where the cretaceous formation hides it. But the most satisfactory evidence of the existence of this system of strata in the central tracts of the continent is, according to Dr Hayden, the intrepid explorer of the Neobrara, in the Black Hills of the Rocky Mountains. The formation there constitutes an elliptical zone from 5 to 15 miles broad, encircling the older rocks which enclose the principal axis of elevation of these hills. Dr Hayden states, that " although it is not yet known to occupy a large geographical area, we have indications that it will be found to be extensively developed on the E. slope of the Rocky Mountains;" and he adds, " that he does not doubt that it exists towards the head-waters of the Yellow Stone around Panther and Big Horn mountains." None of the organic remains, it should be mentioned, though the species are numerous, are known to be positively identical with any of the Jurassic fossils of Europe, but so

* For fuller details on this subject, consult Reports and Essays of Professor W. B. Rogers.

many are closely allied to European Jurassic forms, that Mr Meek and Dr Hayden, who have studied them, do not hesitate to pronounce them of that age.

NEWER MESOZOIC.

Cretaceous Deposits.—One of the most widely-expanded of all the groups of strata in the United States is the cretaceous. Unlike the corresponding series in Europe, it embraces no formation of genuine chalk, though in the S.W. and far West it includes important strata of limestone. Along the Atlantic seaboard, and as far as the Mississippi, the chief materials are beds of sand and sandy clay, with thin layers of argillaceous limestone or calcareous shale; but the arenaceous character generally predominates. A characteristic constituent, especially in the N.E. portion of the Atlantic belt, is green sand or green earth in an arenaceous or granular form—this material existing in thick deposits 20 or 30 feet deep in the lower part of the formation in New Jersey and Delaware. In these States the whole series comprises five separate beds, which, in the ascending order, are:—

I. A group of sands and clays, some of which are extremely pure and white, affording excellent potter's clay.

II. A mixed alternating group of beds of dark-blue sandy clay, with beds of nearly pure greensand, uncemented or arenaceous, which, being endowed with highly fertilising qualities, is ordinarily called the greensand marl.

III. A thin bed, seldom more than a few feet thick, of a porous yellowish or straw-coloured limestone, frequently silicious, and always containing scattered specks of greensand.

IV. A very ferruginous, coarse, yellowish sand, occasionally containing a small amount of a green mineral. This deposit, generally, does not cohere, but near the Rariton Bay some of its layers possess the cohesion of a soft sandstone.

V. A coarse brown ferruginous sandstone, sometimes passing into a conglomerate, forming the fifth and apparently uppermost member of the group. This likewise contains the greensand in minute granules.

The total thickness of the series here described cannot be less than a thousand feet, for it occupies in New Jersey an outcrop several miles in width, with few or no perceptible undulations. Throughout its S. development, in Georgia, Alabama, Mississippi, and Arkansas, the cretaceous series preserves its general arenaceous type, though it is more calcareous than in New Jersey, some of the calcareo-argillaceous beds resembling the European Lias. Advancing W. through Texas and New Mexico, certain members at least of the formation have a more essential marine or deep-sea type, consisting in larger proportion of pure limestones. And this composition would seem to belong to them also farther North, where they spread through the high planes E. of the Rocky Mountains, and lap round the S. spurs of that great chain. Still farther to the N., or along the Missouri and its upper tributaries, where the formation is very widely exposed, the series consists in like manner of limestones, clays, and sands; but it would appear that the latter are relatively more prevalent than farther S. An interesting constituent of the formation is the sulphate of lime or gypsum, which belongs to it more or less throughout its whole wide distribution. It is insignificant in amount in New Jersey and the Atlantic Southern States, but is more abundant in the States north of the Gulf of Mexico. In Texas and in New Mexico this valuable material exists consolidated in beds of great thickness and prodigious expansion, one stratum ranging continuously from the S. tributaries of the Arkansas S.W. to the Rio Picos, and probably to the Rio Grande. Wide beds of gypsum are likewise known W. of the S. spurs of the Rocky Mountains.

Geographical Distribution.—The cretaceous formation would appear to constitute, throughout the middle latitudes of North America, a far wider area than any other group of strata, for it extends continuously from the very shore of the Atlantic in New Jersey, in lat. 41° N., S.W. to Mexico, W. beyond the Rocky Mountains, and N.W. to the sources of the Missouri, covering as much as 40° of longitude, and in the central tracts of the continent more than 30° of latitude. In this amazing geographical distribution, it rivals the great cretaceous deposits of Europe and Northern Africa, compared with which it forms a much more continuous area. Along the seaboard of the Southern Atlantic States it is partially concealed by a superficial covering of the tertiary strata; but from Georgia to New Mexico and the Upper Missouri it spreads in one unbroken tract, suggesting its deposition in a great continental or mediterranean sea. Commencing at the coast in New Jersey, the cretaceous series ranges thence in a contracting belt nearly to the Chesapeake Bay, where, encroached upon by the tertiary, it disappears. But we have indications of its passing under the tertiary plain of Maryland and Virginia, from the frequent occurrence of its characteristic constituent, the greensand, in both the Eocene and Miocene strata of those States. Farther South, the cretaceous formation emerges to the day in a succession of narrow exposures along the seaboard of North and South Carolina, where denuding action, sweeping away the tertiary, has laid it naked in the valleys of all the principal rivers from the Neuse to the great Pedee inclusive. Disappearing again below the tertiary, it emerges a second time in Georgia, on the Savannah and Ogeechee rivers. The great continuous Southern belt commences in Georgia near the Oconee River, south of Milledgeville, and quickly expanding to a width of 60 or 80 miles, extends W. from the Flint River of that State through Alabama, where it sweeps round the S. promontory of the Appalachain chain and the Palæozic formations, and stretches Northward, holding about the same breadth, through Mississippi and Western Tennesse as far as the W. corner of Kentucky. There it crosses the Mississippi, and bending abruptly S. it ranges in a S.W. course, gradually expanding in breadth into the State of Arkansas, where, deflected by the Washita Hills, it once more changes its direction and sweeps W. on the S. side of that axis of older rocks until it enters the broad plains of Texas, where this fringing zone now merges into the broad expanse of the central cretaceous basin of the continent, the wide general limits of which have been already indicated. This central basin, bounded on the E. by the Palæozoic formations of Minnesota, Iowa, Missouri, Arkansas, and Texas, and on the W. by the Rocky Mountains, has the shape and structure of a prodigious valley, between 300 and 400 miles broad, stretching from the Gulf of Mexico N. into the British territory. Between the Arkansas River and the N. line of the United States, its middle tracts are very extensively overspread with tertiary deposits of marine and fresh-water origin, to be presently defined.

According to Messrs Meek and Hayden, the cretaceous deposits of Nebraska are divisible into five groups.

1. A reddish and yellowish friable sandstone, alternating with dark and whitish clays. The organic remains are—layers of impure *lignite*, fossil *wood*, and impressions of *dicotoledonous leaves;* also *Solen, Pectunculus, Cyprina,* &c. Some doubt exists as to the cretaceous age of this member. Between Council Bluffs and the mouth of the Big Sioux River. Thickness, 100 feet.

2. A dark-grey laminated clay; its fossils are scales and other parts of *fishes*, small *Ammonites, Inoceramus prolematicus* (?) *Serpula, Ostrea congesta* (?), &c. &c. Along the Missouri, from near James's River to Big Sioux River. Thickness, 90 feet.

3. A triple group, consisting of a light yellowish-grey limestone below, with *Inoceramus prolematicus, Ostrea congesta,* and fish-scales; 30 feet thick; a grey calcareous marl in the middle, weathering yellow, with *fish* remains, and *Ostrea congesta,* 100 feet thick; a dark, smooth, unctuous clay above, containing much carbonaceous matter, with seams of sulphate of lime, and scattered sulphuret of iron, fish-scales, &c. Thickness, 20 feet. These three members are visible in the Bluffs of the Missouri below the Great Bend, and thence to the Big Sioux River.

The 2d and 3d groups are thought to be absent in New Jersey and Alabama.

4. A bluish and dark-grey plastic clay, containing *Nautilus Dekaye, Ammonites placenta, Baculites ovatus, B. compressus,* and many other marine mollusca, and also remains of *Mosasaurus,* occurs along the Missouri River below Fort Pierre; also at Sage and Bear creeks, and at the Great Bend, and near Milk and Muscle Shell rivers. Thickness, 350 feet.

5. Grey and yellow sandy clays and sandstones, containing *Belemnitella bulbosa, Nautilus Dekaye, Ammonites placenta, A. lobatas, Scaphites Conradi, Baculites ovatus,* and many other marine shells, found at Morean trading-post, and beneath the tertiary at Sage and Bear creeks. In the Fox Hills. Thickness, 130 feet.

Group No. 5, or the uppermost of Nebraska, is believed to represent the Fourth Group, or next to the uppermost of New Jersey; while the main marl-deposit, or next to the lowest group of New Jersey, is the equivalent of the Nebraska Bed No. 4.

Some uncertainty yet prevails respecting the N. limit of the cretaceous rocks in the central plains N. of the Missouri; nor can we trace at present with any precision the W. boundary of the formation where it finally outcrops against the older rocks of Mexico, or is lost to view under the newer tertiaries and volcanic accumulations of the desert plains of Utah and Oregon. The limits assigned show, however, the existing state of information derivable from a careful study of authentic documents and specimens.

Organic Remains and Equivalents.—The fossils of the North American cretaceous deposits pertain to species and genera which represent those of the cretaceous strata of Europe, more especially those which characterise the upper or chalk division of that series. Though the number of species common to the American and European basins is small compared with the whole number discovered, not exceeding probably about 10 per cent, yet 25 or 30 per cent of the known shells of the American group, now amounting to more than one hundred species, are representatives of European upper cretaceous forms; and this may be considered as exhibiting as close an identity in the fauna of that period as prevails between those of the different oceans of the present day.

No mammalian remains have ever hitherto come to light, unless a species referred to the family of Seals, and called *Sternorinchus*, found in the lower greensands of New Jersey, be really a specimen of that high class; but one or two relics of wading birds have been discovered in the greensand marl-pits of New Jersey. The remains of fossil reptilia are much more abundant. One of these belongs to the remarkable saurian genus *Mosasaurus*, others to two or three species of *Teleosaurus*, and as many to crocodiles, and one or two other saurian genera. More than one species of tortoise or Chelonian reptiles have been found. Fossil fishes are also met with, especially of the genera *Carcharodon, Lamna,* and *Galeus*. Of upwards of sixty molluscous forms from New Jersey, not more than five or six are actually identical with European species; among these are the *Gryphea costata, Pecten quinquecostatus,* and *Belemnites mucronatus;* but all of them have a great vertical range through the cretaceous rocks of both Europe and America, and are therefore not expressive of very exact equivalency. The thin yellow limestone of New Jersey has furnished several corals, sponges, and other forms which seem to relate it very closely to the upper chalk of Europe, or the limestone beds of Faxoe. More than ten European species have been discovered in the cretaceous strata of Texas out of less than one hundred forms. It is worthy of note that the organic remains from the W. side of the Rocky Mountains agree specifically with those of the cretaceous of the Atlantic States, as suites of specimens from the Rio Puerco, and other localities W. of the Rio del Norte, satisfactorily show.

Lignites and fossil plants, though generally in an obscure and fragmentary condition, are frequently found in the more littoral or lower strata of the cretaceous formation in New Jersey, and the States further S.; and on the Missouri, and especially on the Yellowstone, one of its great Rocky Mountain tributaries, large deposits of lignite have been met with, having the aspect and extended stratification of beds of coal. But it is now perfectly certain that some of these pertain to a lacustrine Tertiary formation, which is known to occur in wide tracts upon the cretaceous strata E. of the Rocky Mountains. As far as the lignites of New Jersey have been examined, they exhibit a vegetation closely agreeing with those of the cretaceous period of Europe.

Physical Geography of the Cretaceous Era.—An examination of the wide cretaceous deposits of the United States indicates a striking difference between the physical geography of this period and that now prevailing. It shows us, as a glance at the Geological Map of the country will prove, that, whatever may have been the area of dry land occupied by the ancient Palæozoic formations in the long interval which elapsed between the first elevation of those strata and the establishment of the boundaries of the cretaceous seas, the boundary or true shore of North America at the beginning of the Cretaceous deposits was that long undulating line which marks the inner or continental margin of the Atlantic and Gulf of Mexico plain, stretching from New Jersey along the foot of the Atlantic slope to the end of the Appalachians, thence N. to the mouth of the Ohio, then S.W. to the Red River, and N. from that to the Upper Missouri. Inside, or N. of this winding shore, lay the smaller North American continent while the cretaceous rocks were forming; and E., S., and W. of it spread the Atlantic Ocean, unbroken by masses of land as far as to where the Rocky Mountains and the chains farther to the W. lifted themselves in the form of a great oceanic archipelago, and to where the great Pacific chain bounded that sea, and either entirely or partially confined it from the ocean to the W. The cessation W. of the cretaceous deposits seems to imply that the now central plain of the continent was in the Cretaceous era occupied by a huge arm of the ocean, or great N. elongation of the present Gulf of Mexico, which washed the base of the western Cordillera, as far towards the North, or farther than the upper waters of the Missouri, just as the Mexican Gulf now washes it in the tropical latitudes. The gigantic scale of the actions which accumulated the cretaceous sediments over this vast inland sea, and those which uplifted it, and drained and denuded its sediments, may be conceived from the simple facts that these deposits possess in the interior of the continent the thickness of nearly one thousand feet, and that vast tracts of them now constitute the great plateaus of the country lifted from 2000 to 6000 feet above the level of the sea.

CAINOZOIC, OR TERTIARY FORMATIONS.

Applying the term Tertiary or Cainozoic to all those deposits which intervene between the Cretaceous series and the accumulations which are now in progress,—deposits entombing the relics of races more or less analogous to the forms which now people the globe, but not identical with them,—I shall proceed to describe the several subdivisions of the series in conformity with the classification which the phenomena require. The American Tertiary strata are separated by nature into four distinct groups, equivalent, approximately, to the Eocene, Miocene, Pliocene, and Pleistocene groups of Europe. These tertiary divisions of the two continents are co-ordinated with each other, through a sufficient number of identical organic remains, and through such a general analogy in their types, or correspondence in the *facies* of the fossils, as to justify the application, in the absence of a more philosophical nomenclature based on distinctions of time, of the same names to the corresponding divisions of the two series.

The Tertiary deposits of the United States—omitting for the present the latest member of them, or the Boulder-drift and the Pleistocene sediments associated with it—occupy, as will be seen by a glance at the Geological Map, three wide areas, the two oceanic slopes or borders of the continent, and a broad belt E. of the Rocky Mountains.

Atlantic Belt.—The Atlantic or E. belt commences at the N. in the islands of the S. coast of New England and New York. Entering the main land in the E. coast of New Jersey, it stretches thence, in a long zone, of an average width of about 100 miles, constituting the Atlantic tide-water plain, through all the seaboard States to Florida, nearly the whole surface of which it seems to cover. From Florida it ranges W. to the Mississippi, the valley of which it ascends for several hundred miles, beyond which it ranges, again contracting in breadth through Louisiana and S. Texas, until it crosses the Rio del Norte, and, trending S., skirts the W. coast of the Gulf of Mexico. It is a very well defined undulating zone, fringing the present continent in the form of a very level low plain, which scarcely anywhere rises to 100 feet above the level of the sea. This plain has a sandy surface, contains the tidal estuaries of all the Atlantic rivers between the Hudson and those of Mexico, and is intersected with innumerable sluggish creeks, and on its oceanic margin, with a network of low swamps and tidal meadows, particularly through the Southern and Gulf States. Within the territory of the United States alone, the length of this belt, including Florida, exceeds 2400 miles; and if we add the portion in Mexico, its length from Cape Cod to Vera Cruz is not less than 3000 miles. All the four divisions of the tertiary, excepting the drift and its accompaniments, are included in this long zone of marine deposits.

Pacific Slope.—The Pacific slope of the continent, from the Rocky Mountains to the sea, is extensively covered with tertiary deposits of both marine and volcanic origin, the whole being divided into two great zones by the Pacific range of mountains, or the Sierra Nevada and Cascade chains. The broadest and most irregular of these Western tertiary areas covers apparently the entire breadth of the W. desert table-land, including the Utah salt desert, and the volcanic desert of Oregon and Washington; occupying, in other words, nearly the whole space between the Wahsatch and Rocky Mountains on the E., and the Sierra Nevada and Cascade chains on the W., and stretching longitudinally northward a little west, from the Cordilleras of Mexico into British and Russian America. In its S. prolongation, this great tertiary tract declines from its average high level of more than 4000 feet to the sea-level, and even below it, at the Gulf of California; for, N. of that arm of the sea, a portion of the Colorado desert is depressed below the oceanic plain, in one place, to the amount of nearly 300 feet.

The other, or western Pacific belt of Tertiary, fringes the continent in a long and narrow strip, confined between the W. base of the great Pacific mountain-chain and the actual coast. This narrow zone is traceable from the S. end of the peninsula of California, N.W. or N., along the whole border of the continent, as far as Russian America, over a distance quite as great as the Eastern or Atlantic zone. These Western tertiary areas include the same four great divisions of the Cainozoic strata found on the Atlantic side of the continent; and, what is very interesting, they exhibit, in the organic remains, not only the general type or distinctive facies, significant of the period of their formation, but in each case the ordinary proportion of now existing species. This occurrence of the same succession of tertiary formations on the two great ocean-fronts of the continent, is indicative of the amazingly wide areas over which even the later crust-movements of the globe have extended. For there can be but little doubt that the disturbance which changed the Eocene and other waters on the Atlantic side, were contemporaneous with those which altered their sediments and their living races, on the opposite oceanic slope.

Central Tertiary Tracts.—Besides the two grand continuous oceanic areas of tertiary strata, the continent contains, in its more central districts, a number of wide tertiary deposits of more than one epoch. A glance at the Map will indicate the position of several of the more important of these along the W. side of the high plains E. of the Rocky Mountains. These, which for the most part are Miocene fresh-water basins, seem to belong to a great central or continental zone of tertiary deposits, which extends from the Arkansas River across the E. and W. water-shed of the continent, and Northward, in a long and narrow tract, parallel with the Rocky Mountains, to the valley of the Mackenzie River, and by it to the shores of the Arctic Sea. Other more or less insulated deposits of the tertiary strata occur on the opposite or W. side of the Rocky Mountains, between them and the Wahsatch chains. That on the upper waters of the Green River, between the S. pass and Fort Bridger, would appear, like others of the interior basins, to be of Eocene age. There are numerous and very extensive patches of tertiary strata capping the wide cretaceous deposits in Kansas, New Mexico, and Texas, of which we have at present some specific information.

Eocene Formations, Atlantic Slope.—No strata of Eocene age have been discovered in North America, to the E. of the meridian of the Chesapeake Bay, either in the Atlantic coast or in the interior. But from the Potomac River, S. and W., the beds occur in numerous localities, so scattered as to give the impression that the whole of the Atlantic tide-water tertiary plain, as far at least as Texas, is continuously underlaid by the formation. Throughout this zone, wherever Eocene beds appear, they present an extremely gentle inclination towards the Atlantic and Gulf of Mexico, not greater than belongs to the shelving bottom of those waters at the present time, for an equal distance from the coast. Their very slight seaward dip is not the result, therefore, of any uplifting action in the earth's crust, but a consequence of an original trivial obliquity of their planes of stratification; the whole Atlantic front of the continent, and probably the entire continent itself, having been lifted out of the sea at the successive tertiary epochs, either horizontally, or with extremely low crust-undulations.

Tracing the individual outcrops of the Eocene group upon this plain, the first which we encounter, going S., is a long narrow belt, extending from the Potomac, near Washington, across Virginia and North Carolina, to a point beyond the Cape Fear River. Throughout this line those strata lie, in almost horizontal position, against the older upturned gneissic rocks of the Atlantic slope, and in some places in Virginia against the nearly horizontal beds of the Jurassic coal-formation. They are overlaid by a parallel thin deposit of the Miocene tertiary strata, which, on the more upland tracts between the river-valleys, themselves also abut against the older formations, hiding the Eocene from view. The latter are therefore chiefly exposed in the ravines and river sections. All along the line of outcrop, the proper Atlantic slope meets the level Atlantic tertiary plain by an abrupt change in the surface, suggesting an ancient shore; and the line of junction is everywhere marked by a sudden change in the rivers, from the condition of running streams to that of tidal estuaries, each river usually having rapids of considerable extent before it falls into the tertiary plain.

This important physical feature, which prevails, indeed, from the Delaware, at Trenton, to North Carolina, has determined in a striking manner the sites of the principal cities of the whole seaboard of the Middle and Southern States. The upper limit of the tide in the Atlantic rivers being the limit of free navigation, it became the natural place for the transhipment of commodities. This circumstance, and the presence of the water-power of the streams, determined the selection of this boundary for the chief commercial towns in the first settlement of the country; and thus it is that Trenton, Havre de Grace, Philadelphia, Baltimore, Washington, Fredericksburg, Richmond, Petersburgh, Halifax, Raleigh, Colombia, Augusta, Maçon, Columbus, and Montgomery in Alabama, are all seated upon this great natural ancient shore.

Another belt of the Eocene deposits stretches from the Cape Fear River nearly to the Altamaha in Georgia, holding a more central position in the Atlantic plain between the sea and the upper country than the previously described outcrop, and being more interrupted by the overlapping of the newer strata on the water-sheds between the rivers. From the place occupied by this line of exposures, we are entitled to infer something like a very slight arching of the surface at the time of the uplifting and denuding of this part of the Atlantic plain.

Another still larger patch of the Eocene formation extends from near Milledgeville on the Oconee River in Georgia, W. in a narrow belt, across that State, and across Alabama, to the Alabama River, where it commences to expand rapidly, its S. border separating it from the Upper Tertiary formations, ranging nearly W. to the Mississippi at Grand-Gulf, and its N. one turning N., and running through the States of Mississippi and Tennessee, till it meets the Mississippi only a short distance below New Madrid. In the immediate valley of the Mississippi, the W. margin of this broad Eocene tract is formed by the overlapping of the newer alluvium of that mighty river. In Louisiana and Texas there are only two at present distinctly-known patches of the Eocene strata—one on the Nueces River, W. of Nacogdoches, the other on the Rio Brazos, South of Franklin. Nearly all the other portions of the extensive Tertiary plain of these States expose only the Pliocene and Pleistocene beds, and the wide modern alluviums of the existing rivers, though there can be but little doubt that the Eocene underlies the whole. No Eocene strata have hitherto been discovered in the interior of the continent.

We know too little as yet of the Tertiary rocks of the high central table-lands between the Rocky Mountains and the Sierra Nevada to pronounce upon the age of the widespread Tertiary strata which cover them, but certain considerations connected with the physical geography suggest that these desert plains must contain many fresh-water sediments, and make it probable that among them are some of Eocene age. To the W. of the great Californian chain, by far the larger portion of the Tertiary strata occupying the Pacific Slope appears to be of Miocene date; but some genuine Eocene rocks are known to exist there, though covering comparatively very limited tracts. The principal localities of these are in Southern California, N. of the Los Angelos Mountains, or on the verge of the Colorado Desert.

Description of Eocene Strata.—A considerable diversity of composition prevails in the North-American Eocene strata. Those of the Atlantic seaboard, exclusively marine in their origin, are very arenaceous in their more Northern development, but become more calcareous as we trace them S. and W. through the Southern States. In the Virginian outcrop the materials are chiefly argillo-micaceous sands and sandy blue clays, sometimes slightly calcareous and a little gypseous, and frequently possessing a minute quantity of the green granules so characteristic of the cretaceous formation scattered through them. Throughout this belt there is very little limestone.

The middle Atlantic belt, or that exposed upon the rivers of North Carolina, South Carolina, and Georgia, is a much more calcareous formation, consisting of ferruginous and silicious sands, lead-coloured sandy clays, and whitish and bluish friable limestones, with one or more beds of porous chert or burrstone, employed in some localities for millstones. All of these beds are more or less fossiliferous, and some of them excessively so.

The third and next great belt, or that which extends from the Ocmulgee River in Georgia to the Mississippi, may be described as a great triple formation. The upper member consists of two limestone strata, the higher composed largely of that singular foraminiferous fossil, the nummulite, or *Orbitoides*, whence it has been called the nummulitic limestone; and the lower, of a white porous limestone called commonly the rotten limestone, remarkable for containing the bones of a gigantic but slender whale-like creature, the *Zeuglodon cetoides*.

This division considerably exceeds 100 feet in thickness in some localities. The middle member is a ferruginous silicious sand and sandy marl, with a thickness of usually more than 100 feet. It abounds in the well-known Eocene shell, the *Cardita planicosta*, and contains the curious *Ostrea sellieformis*, a fossil which equally characterises the Eocene beds of Georgia and Virginia. The lowest member is a complex limestone and marly deposit of undetermined thickness, but exceeding considerably 100 feet. In this bed occur the above-named and many other shells of characteristic Eocene types. Such is the general aspect of the strata in Alabama and Mississippi.

In Texas the Eocene deposits are likewise both arenaceous and calcareous, the sands being some of them very ferruginous and red. Some of the limestone beds abound in fossils.

Of the Eocene deposits W. of the Rocky Mountains we possess too little information at present to describe their composition with accuracy, further than that some of them contain shales and marls, abounding in lignites and in lacustrine shells and other fresh-water remains.

Fossils and Geological Equivalents.—Throughout the Atlantic seaboard plain—intending this expression to include the Tertiary plain fringing the Gulf of Mexico—the Eocene strata possess certain characteristic fossils, particularly many species of shells which are common to all the districts. Some of these, and a few corals and fishes, are identical with European Eocene forms, while many others are only generically representative of European species. There can be little doubt, therefore, that the Eocene strata of the two continents are co-ordinate in age. Nevertheless, it is not a little remarkable that the two formations are connected by a very small proportion of strictly identical or common organisms. Thus, while more than four hundred species of marine shells, and many echinoderms and remains of fishes, have been procured from the very fossiliferous locality of Clayborne, Alabama, not more than eight or ten of these, or only two or three per cent, prove, upon comparison, to belong to known European types. Notwithstanding, this whole extensive group of organic remains has an unequivocally Eocene facies. Of the remains of fishes the most abundant are the teeth of several genera of sharks —*Carcharodon*, *Otodis*, *Lamna*, and others—belonging to races still higher in the scale. The Atlantic Eocene beds of North America contain several very interesting reptilian forms, among them some species of crocodiles, gavials, and turtles. No terrestrial mammalia, or land quadrupeds, have hitherto been discovered, nor from the marine origin of the beds are such likely to be readily found; but cetacean or oceanic mammalia, as already intimated, do frequently occur, as the zeuglodon of the rotten limestone of Alabama shows. This creature was a kind of slender whale, with yoke-shaped teeth not unlike those of the seal; its vertebræ, as thick as those of the largest whale, were twice as long, and the entire animal had a length, as shown by some specimens, of 70 or 80 feet.

Physical Geography of the Eocene Era.—It is obvious, from the relations of the Eocene and other later Tertiaries to the cretaceous strata upon which they repose, that, however extensively these latter were laid dry at the epoch of the drainage of the great basin in which they were formed, those parts of that basin now overlaid by the Tertiaries must have remained under water, or, if lifted, must have been immediately depressed again to the limit of that great Tertiary shore-line already traced as the inner boundary of the Atlantic plain. Throughout this plain the Eocene strata was quietly deposited in what was evidently a very shallow sea, their materials being derived from the sediments of the rivers descending the Atlantic Slope, and the Great Gulf Slope or S. part of the interior continental table-land. It is worthy of note that opposite the Atlantic Slope and Appalachian Mountains, where so large a proportion of the rocks are of a composition to furnish only sandy and clayey sediments, the Eocene deposits of the Atlantic plain are chiefly arenaceous and argillaceous in their composition, and that farther West, where there is a wide expanse of limestones occupying the great hydrographic basin of the Mississippi and the plains and mountains to the W. of it, the Eocene deposits fringing the Gulf of Mexico are greatly more calcareous and less arenaceous in character. We know at present too little of the geology of the borders of the scattered Eocene basins of the interior of the continent to speculate with profit respecting the physical geography of those regions in that morning of the great Tertiary day, but we may safely conjecture that the draining dry of the great inland Tertiary lakes must have been accompanied by no inconsiderable elevation of the regions bordering the Rocky Mountains, probably by a general bulging of the whole central water-shed of the continent. So long as the zone of country E. of the Rocky Mountains which includes these basins was occupied by the great lakes, the present Missouri River, draining as it does one uniform broad slope towards the E., could have no existence; but there is nothing in the geology of the interior of the continent which forbids the supposition that its present outlines may have been established at the epochs of the movements which terminated the Eocene and the Miocene formations.

MIOCENE STRATA OF THE UNITED STATES.

Geographical Distribution.—The Miocene strata of the United States appear to be far more extensively developed than the Eocene, forming not only the principal Tertiary deposits of the two oceanic belts, but the chief formation of the wide Tertiary plains E. of the Rocky Mountains. Possibly there are strata of this epoch in the broad desert table-lands between the Rocky Mountains and the great Pacific Chain, but none have been hitherto made known on sufficient evidence. In the progress of research it will very probably appear that wide tracts of the Atlantic plain in the Southern States, including Texas, are underlaid by Miocene strata exposed at intervals in the river-valleys; and the same remark may be applied to the Eocene. In like manner, it is very probable that Miocene strata occur at intervals along both coasts of the peninsula of Lower California.

Miocene on the Atlantic.—Restricting our attention, in the first place, to the well-ascertained Miocene areas of the Atlantic border, we find that they are all embraced in that part of the tide-water plain which extends from Martha's Vineyard, on the coast of New England, to the neighbourhood of the Cape Fear River in North Carolina, and in other detached patches farther South, as far as Georgia. Martha's Vineyard consists almost entirely of this formation, and Long Island appears to be, in part at least, underlaid by it. The principal area, however, is on the mainland, where it appears first in two or three very shallow patches on the E. and S. coasts of New Jersey, and then in a wide continuous sheet, covering nearly the whole breadth of the Atlantic plain from the Delaware Bay to the Neuse River, abutting on its W. margin against the older metamorphic rocks, at the base of the Atlantic Slope, and fringed on its E. by a thin capping of Pliocene deposits, stretching from the Chesapeake Bay to Pamlico Sound. Over all this tract the Miocene beds are abundantly exposed in the banks of the rivers and creeks, where they are now becoming extensively sought for, their calcareous shell-marls being applicable to the purposes of agriculture.

Description.—The Atlantic Miocene deposits consist, for the most part, of yellow and brown ferruginous sands, sandy blue clays, and calcareous clays and sands, imbedding extensive layers of uncemented fossil-shells, and other extinct organisms. As a mass, the formation contains fewer cemented beds than the Eocene of the more southern States, not having any true limestones or silicious burrstones. It resembles more closely, in general composition, the underlying Eocene of its own district, even in possessing a certain proportion of the green-sand characteristic of the cretaceous group which underlies them both.

Pacific Belt.—Though we are much less accurately acquainted at present with the distribution of the Miocene strata on the Pacific slope of the continent, we are enabled, by assembling the observations of different explorers, to represent at least one great belt as covering a large portion of the long narrow seaboard belt which intervenes between the W. base of the Sierra Nevada and Cascade Mountain, and the coast. It is believed that the chief part of the Tertiaries of this diversified zone belong to the Miocene period, but it is very probable that future researches will disclose not only Eocene, but Pliocene and Pleistocene deposits also. As already intimated, this margin of the continent differs essentially from the Atlantic Tertiary plain in its physical features, which are those of a broken and hilly tract sloping rather steeply towards the sea, traversed transversely by rushing rivers, undulated by chains of ridges and even mountains, and in some quarters dotted with volcanic hills. As might be expected from such a topography, the Tertiary beds are seldom in a horizontal position, but are uptilted and dislocated, and disposed in great undulations, the axes of the waves conforming in their directions to the general trend of the coast and the older mountains. The Coast Mountains, so called, and the Monte Diavolo range, consist largely of the Miocene strata, thus undulating. These seem to repose, in many places, immediately upon the crystalline stratified rocks; in other localities they rest directly upon ancient Tertiary trachytes, and other effusions of extinct volcanoes.

Description of the Strata.—As we might anticipate, from the more disturbed and volcanic character of the immediate Pacific Slope, as compared with the Atlantic plain, the Tertiary strata of California and Oregon are in a greatly more indurated or rocky condition than those of the E. coast. They consist largely of sandstones, conglomerates, and shales, with occasional beds of chert, but very rarely of limestone. Some of the sandstones are fossiliferous, the organic remains which they contain being sufficiently well preserved to establish their Miocene age. Extensive beds of infusorial earth belong to one portion of these upper Tertiary strata, and occur at intervals for more than 400 miles along the coast belt. A very interesting bed of infusorial earth, consisting chiefly of various forms of fossil Diatomaceæ and Desmidiæ, occurs near the base of the Miocene formation, above its contact with the Eocene, in the State of Virginia. This has been traced, at intervals, from the Potomac to the Meherrin rivers, on the S. borders of Virginia, a distance of more than 150 miles. In some places its thickness is from 20 to 30 feet, and it is made up almost exclusively of the silicious cases of these microscopic organisms.

Miocene Strata of the Central and Western Parts of the Continent.—In several places E. of the Rocky Mountains, broad patches of Miocene deposits cover the cretaceous strata in the high half-sterile steppes of the great interior plains. How far S. these shallow Tertiary basins extend we are at present unable to say; but there are some of them in Kansas, and probably even in Northern Texas, as we know there are to the W. of the Rocky Mountains, in New Mexico and Utah; but going N. we encounter a larger basin on the upper waters of the Nebraska or Platte River, extending from E. of Fort Kearney to Fort Laramie, or almost 300 miles. This vast Tertiary basin spreads S. nearly to the Arkansas River, and N.W. beyond the South Fork of the Shayenne, or nearly to the foot of the Black Hills, occupying the country of the Niobrara and White Earth rivers. It contains the celebrated *Mauvaises Terres*, or Bad Lands, a desert region of arid table-lands gashed into innumerable ravines insulating vertical precipices, and detached, flat-topped, turreted columns, the whole cut by deep denudation into an extraordinary labyrinth, 30 or 40 miles in diameter. In the Bad Lands the deposits are exclusively of fresh-water origin, as will be shown presently in speaking of their organic remains. The lignites and leaves of deciduous and coniferous trees, and some few molluscous fossils, all go to prove that at least some of these strata were accumulated in fresh-water lakes. Indeed, on both sides of the Rocky Mountains we have proofs of physical conditions in the early Tertiary times not unlike those which prevailed in the Eocene ages in France and other Tertiary countries of Europe, where lakes and estuaries entombed the remains of terrestrial and fresh-water animals and plants; and volcanic disturbances shortly afterwards arose to uplift and alter or entirely drain them.

Fossils and Equivalents of the Miocene.—The Miocene tertiaries of the Atlantic plain consist of about two hundred well-ascertained species, comprising corals, molluscs, certain crustaceans, several fishes, chiefly of the shark tribe, a few reptiles, and one or two cetaceans or marine mammalia. Of the shells and corals not more than twenty per cent can be recognised as belonging to races now alive; nor is it probable that future researches will materially modify this proportion. Very few of the extinct species are common to the strata of America and Europe, and out of one hundred and forty-seven of the American fossils, including both extinct and recent forms, reviewed by Sir Charles Lyell, only thirteen were found to be likewise European. Several of the most abundant of these Miocene remains are recent species now restricted to the Western or American side of the Atlantic. The Miocene shark's teeth appear, some of them, identical with those of the middle tertiary strata of Touraine. The nearest European equivalents of the Atlantic Miocene beds would seem to be the English crag and the faluns of Touraine.

Nebraska Basin.—The fresh-water Miocene strata of the Bad Lands of the Niobrara and White rivers abound in admirably well-preserved remains of an extraordinary extinct fauna. Professor Leidy of Philadelphia, who has described them, has shown that they contain three species of OREODON, a genus of ruminant quadrupeds intermediate between the existing ruminants and the fossil ANOPLOTHERIUM; two species of AGRIOCHŒRUS, ungulated ruminants of the same intermediate type; one species of POEBROTHERIUM, a ruminant allied to the living musks; three species of LEPTAUCHENIA, and one of PROTOMERYX, also ruminants. Of *Multungula*, or many-toed quadrupeds, he has detected, in the remains brought in by Dr Hayden and others, eight species belonging to the genera CHŒROPOTAMUS, ENTELODON, TITANOTHERIUM, PALÆOCHÆRUS, LEPTOCHÆRUS, and RHINOCEROS; besides three species of ANCHITHERIUM, a solidungulate genus, allied to the living horse and the extinct *Palæotherium;* also five genera of RODENTIA, among them a porcupine; together with seven species of CARNIVORA, consisting of *Hyænodon*, three species; *Amphicyon*, two—*Deinictis* and *Machairodus.* In addition to these, there occur an interesting Chelonian reptile, the *Testudo Nebracensis*, and four fresh-water shells, one land-shell, and a small fresh-water crustacean, the *Cypris Leidyi.*

Another extensive basin of Miocene age, known as the Great Lignite Basin, extends on both sides of the Missouri River, from about longitude 103° W. to the valley of the Yellow Stone, which descends to the mouth of the Big Horn. Outlying patches of this area occur W. of the Black Hills on the Powder River, and around the sources of the Big Horn. This formation consists of beds of clay, sand, sandstone, and lignite, and contains many fresh-water and land shells, with a few marine or estuary species; it also imbeds the remains of plants, saurians, turtles, &c. The beds of lignite, or Tertiary brown coal, are of unusual thickness and persistency.

Miocene Fresh-water Basin of the Niobrara and White Rivers.—According to Dr Hayden, the intrepid explorer of this region, the Miocene formation embraces five groups of strata. The lowest seen on Old Woman's Creek, and along the valley of the South Fork of the Shayenne, on Sage and Bear creeks, and in the valley of White River, consists of light-grey fine calcareous sand, plastic and ash-coloured clays underlaid by ferruginous sand and gravel; it is called the Titanotherium bed, from its containing the bones of a colossal quadruped of that name allied to Paleotherium. This deposit is nearly 100 feet thick.

The next group ascending, called the Turtle and Oreodon Bed, seen also on Old Woman's Creek, on the head of the South Fork of the Shayenne, on Sage and Bear creeks and White River, is a flesh-coloured argillo-calcareous grit, underlaid by sandy clay; it contains a profusion of mammalian and chelonian fossils, and is from 80 to 100 feet thick.

The third bed met with in the same localities consists of fine yellow calcareous sand, passing downward into an alternation of dark-brown clay and a light-grey calcareous grit; it imbeds layers of calcareous concretions, and a few organic remains.

The fourth group seen on the Niobrara and Platte and White rivers, and well developed near Fort Laramie, is a dull reddish-brown grit, or argillo-silicious stratum, with many layers of silico-calcareous concretions, passing into a fine-grained sandstone. It contains comparatively few fossils, and is from 350 to 400 feet thick.

The fifth and uppermost Miocene group, best developed around the upper portion of the Niobrara River, and in the region of Fort Laramie, is a coarse-grained sandstone, sometimes compact, sometimes incoherent. It contains great masses of conglomerate and layers of tabular limestone, slightly fossiliferous; it imbeds a few mammalian fossils, but these are in a fragmentary condition.

Notwithstanding the large number of species of molluscous and other remains found in both the Eocene and Miocene Atlantic tertiaries, it is worthy of note that very few of them, indeed not more than two or three per cent, are possessed in common by the two formations, showing a very remarkable extermination of the inhabitants of the ancient tertiary coast. This fact respecting the almost total revolution in the inhabitants of the tertiary waters, at the change from the Eocene to the Miocene deposits, is itself significant of a widespread alteration in the physical conditions of the region. This was no doubt a change in the level of the bed of the sea, amounting, probably, to its temporary desiccation, re-immersion, and almost certainly to a modification of its currents, its temperature, and the nature of its sediments, though the Eocene beds were neither permanently uplifted nor indurated, but left in their original horizontality beneath the ocean-level, as a floor for the reception of the parallel Miocene strata. There can be but little doubt that the changes here mentioned all came about, fitting the waters for the abode of new species, and even many new genera. How much actual time may have elapsed between the cessation of the Eocene and the beginning of the Miocene sediments, for the extirpation of the one group of living races and the creation and diffusion of the succeeding, we have no data for estimating, but that some interval elapsed is sufficiently obvious.

On the Pacific side of the continent the phenomena are somewhat different, the levels appearing to have been more disturbed than on the Atlantic border at the close of the Eocene period. But we know at present too little critically of the tertiary geology of California and Oregon to interpret safely what the revolutions exactly were at the several tertiary epochs. The effusion of volcanic materials early in the tertiary ages must have complicated greatly the tertiary physical geography of that side of the continent.

Pliocene and Pleistocene Strata.—Applying the terms Pliocene and Pleistocene to those tertiary deposits which were produced in the periods between the times of the Miocene formations and the recent or existing order of things, this designation will include several late tertiary tracts, not only on the Atlantic plain and on the Pacific slope, but in the interior of the continent in Nebraska. Very probably these deposits are not all of one age, but it is impossible, in the present stage of research, to place them under an exact chronology. It seems most probable that many of the so-called Post-pliocene fossiliferous beds of the Atlantic seaboard are contemporaneous with the superficial strata farther North which belong to the Pleistocene series. It will suffice for our present purpose to describe them as we know them.

Pliocene and Pleistocene Beds of Virginia and North Carolina.—The formation of Pleistocene age with which we are best acquainted is a thin deposit of shelly sands skirting the coasts of the Chesapeake Bay from the St Mary's River southward, and covering a broader belt of country on the Atlantic coast of Virginia and North Carolina as far as Pamlico Sound. These beds are characterised by shells, nearly all the species of which are identical with forms now occurring somewhere on the Atlantic coast, one or two of the most common species living now only in the warmer waters of the Gulf of Mexico. Mixed with these shells are the bones and teeth of several genera of extinct land quadrupeds: the fossil elephant or mammoth, the mastodon giganteum, and a species of horse somewhat larger than that now living. Still farther S. along the seaboard occur other modern tertiary deposits differing somewhat from these in composition, but apparently equivalent to them in age. They are characterised by the presence of fossil shells, and other marine and estuary remains, belonging to species now inhabiting the adjacent coast, associated with the relics of many interesting extinct quadrupeds.

Another Pleistocene deposit skirts the shores of Mobile Bay and the adjacent coast of the Gulf of Mexico. This contains some beds abounding in fossil shells identical with species now living in the Gulf. It is very probable, indeed almost certain, that there exist similar uplifted recent tertiary beds in many other places, both along the Atlantic coast and that of the Gulf of Mexico, but they have been too imperfectly examined to admit of being here described. Strata of Pliocene age, of lacustrine or fresh-water origin, exist in the interior of the continent. Recent researches render it probable that some of the more superficial tertiary strata of the W. coast of the continent, especially in California, appertain to this period; indeed, at several localities on the coast of that State, raised beds occur, abounding in marine shells nearly identical in species with those now existing in the Pacific, but associated with mammalian remains that imply an elevation at either the Pliocene or Pleistocene periods.

Pliocene Strata of Nebraska.—An upper tertiary formation, referred by Meek and Hayden to the Pliocene era, is somewhat extensively developed on the Niobrara River, spreading Westward from the mouth of Turtle River. It occurs in the valley of the Platte, also in the Bijou and Medicine hills, covers a large area on Loup Fork, and is thinly spread in the valley of White River. The deposit consists of brown incoherent sand, imbedding remains of mastodon, elephant, &c.; loose sand and gravel; a yellowish-white grit; a greenish-grey sand, containing a greater part of the organic remains of the formation; a dark-yellow sandy marl; and a yellowish-grey calcareous grit, with many layers of concretionary limestone, containing fresh-water and land shells closely allied and perhaps identical with living species. The thickness of the whole deposit is estimated to be between 300 and 400 feet.

The organic remains hitherto procured from the Nebraska Pliocene strata belong to the new Ruminant genera, *Merycodus*, *Megalomeryx*, *Procamelus*, three species; *Merychyus*, three species; and a deer, *Cervus Warreni*; to the many-toed genera, a species of rhinoceros, a mastodon, and an elephant; to the solid-footed races, six species, two of them to *Hipparion* or *Hippotherium*; two to *Merrichippus*, another horse-like genus; and two to the genus *Equus*, or true horse. Besides these, Professor Leidy has discovered among the remains a porcupine and a beaver, together with seven carnivorous species—namely, *Laptarchus primus*, *Felis intrepidus*, *Ælurodon ferox*, *Canis Sævus*, *Canis temerarius*, *Canis vafer*, and *Canis Haydeni*, besides a chelonian or turtle, *Testudo niobrœnsis*.

Californian Pleistocene Beds.—California contains several interesting pleistocene deposits, and it is probable that there are others farther N. on the Pacific Slope in Oregon. The recent researches of Mr Blake and Dr Trask have shown that several of the lower tracts on the W. side of the Sierra Nevada are of this age. The longest Pleistocene belt fills nearly the entire length of the valley of Middle California, or that of the Sacramento and San Joachim rivers, including the basins of the Tulare lakes. This plain or trough of pleistocene is the main auriferous region or gold basin of California; but the tertiary alluvium is not confined to the bed of the valley, it penetrates the lateral ravines at the base, and even ascends the longer ravines high upon the flanks, of the Sierra Nevada. To the west of this main belt occur two or three other parallel strips of upraised post-pliocene. One of these fills a part of the Nassa valley, another lesser one occurs in the Santa Clara valley, and a third runs from the Bay of Monterey up the valley of the San Antonio. Perhaps the most interesting of all the post-pliocene tracts belonging to the Pacific Slope is that which extends N. from the head of the Gulf of California into the Colorado Desert. This is a low plain or valley, having a well-defined sea-margin or ancient coast-line for its boundary, and consists of a fine silt or clay, the deposit evidently of the waters brought into the Gulf of California by the Colorado River. The remarkable feature connected with this valley-deposit is, that a large portion of its surface is at and below the existing level of the ocean—a region, in other words, of continental depression. Barometric measurements show that some parts of the ancient gulf-margin referred to now stand 80 or 90 feet beneath the mean level of the sea; Mr Blake and other observers testify that at their barometric stations the plain visibly sinks from both sides towards the centre at an inclination quite visible to the eye: so that they infer that the middle parts may be even between 200 and 300 feet lower than the surface of the sea. A very slight swell of the plain a little North of the mouth of the Colorado seems to have insulated this depressed area from the waters of the gulf; indeed, it is very probable that the same movement of the earth's crust, doubtless some earthquake convulsion which lifted the plain in this neighbourhood, depressed the district farther N. The whole phenomenon is thus easily explained on the supposition that the Gulf of California extended in the Pleistocene period to the head of this low plain, and that an earthquake movement of the whole region lifted slightly the surface from its previous level with a low swell or undulation transverse to the ancient gulf near the mouth of the Rio Colorado. The excessively dry character of the prevailing winds of this region will account for the absence of a lake in this depressed part of the Colorado Desert. The presence of much sea-salt in the soil, amounting in some localities to a white efflorescence upon the surface, like a permanent hoar-frost, shows not only how the ancient gulf-waters may have been evaporated by the parched atmosphere, but how those of any lake which may at first have existed there fed by the back-water of the Colorado in its times of freshets, may also have been drunk up. The Tulare lakes of the Joachim Valley offer at this time a condition of things somewhat parallel to that which is here assumed, for throughout the long dry season of California these are little else than broad level meadows, from whence the waters have been exhaled by the drying action of the climate, and only in the wet season are their wide marginal tracts covered with a thin sheet of transient rain-water.

The Pleistocene strata of Nebraska consist of yellow silicious marl, underlaid by clays and fine grits, in all from 300 to 500 feet thick. The *organic remains* are some extinct quadrupeds, mingled with species now existing; also a few species of Mollusca, of chiefly living types.

Fossils of the Atlantic Pleistocene Strata.—The Pleistocene beds on the Potomac River in St Mary's County, Maryland, contain, associated with several species now living in the Chesapeake Bay, an estuary shell, the *Gnathodon cuneatus*, now restricted to the warmer waters of the Gulf of Mexico; and the similar recent tertiary deposits on the Neuse River, Carolina, show a mingling of the gnathodon with shells of the Southern Atlantic coast. The more N. locality has produced no bones or teeth of extinct land animals, but from the Carolina formation have been procured those of the elephant, mastodon, and horse, as already mentioned. The modern tertiary beds between the Altamaha and Turtle rivers, Georgia, contain, along with shells of species now inhabiting the neighbouring waters, remains of the mastodon, elephant, horse, hippopotamus, bison, megatherium, and mylodon, these pachydermal and edentate genera pointing to an identity of period between the Georgian deposits and the superficial tertiaries of Patagonia, where Darwin and other naturalists found a similar association. Some of these species, the *Mastodon giganteum* and the *Elephas primogenius*, occur, as will be stated presently, in the upper deposits of the North American Pleistocene drift, showing most probably that all of these later tertiary formations were produced and uplifted about the epoch of the superficial boulder-deposit.

THE NORTHERN PLEISTOCENE, OR GREAT BOULDER-DRIFT.

Throughout the greater part of the continent of North America, from about the latitude of 40° Northward, the rocky floor of the country is covered to a greater or less depth with that well-characterised formation called the *Northern Boulder-Drift*. In many districts this is a complex group of deposits, consisting of three or more formations, denoting at least three distinct epochs, and at least three different conditions or changes in the physical geography. In the N.E. part of the United States, extending to the adjacent British Provinces, this triple division of the Northern Pleistocene Series is well characterised, and admits of the following brief description :—

The first or lowest deposit is a prevailing, indeed almost universal, stratum of boulder-drift, reposing immediately upon the rounded, scratched, and polished surface of the general rocky floor of the continent. This loose heterogeneous material is composed of gravel, sand, and clay, and boulders, more or less rounded, of all sizes, the whole rather promiscuously mingled, but generally stratified, the stratification being in oblique and often abutting planes of deposition, denoting turbulent and conflicting currents. This is the general character of the drift in all upland positions, and even in the river-valleys throughout New England and the Northern States. In some more restricted localities, immediately contiguous to the ocean, as around the harbours of New York and Boston, the drift has more the character of the European Boulder-clay, consisting of a mixture of sand and clay, destitute of lamination or stratification on the small scale, and imbedding boulders of various sizes irregularly scattered through it. The boulders and pebbles in both the stratified and unstratified drift are themselves smoothed and striated, and blunted and rounded on their edges, showing signs of having undergone a great amount of attrition. The materials composing this remarkable formation belong invariably to rocks lying N. or N.W. of their present positions, and in many districts are traceable to remote localities,—across broad plains, deep valleys, great sheets of water, and over chains of hills, and even across lofty mountains. The boulders have evidently not radiated from any centres of dispersion; they exhibit a progressive diminution of size as we trace the same kinds S. from their parent rocks, though solitary blocks of large dimensions occur within and upon the general mass of sand and gravel. But even these boulders show the same rapid diminution in size as we follow them S. In wide and level districts the larger boulders are frequently seen uniformly but sparsely scattered over broad tracts of country. In other quarters, where the surface is more diversified, they sometimes form long narrow belts, the borders of which are sometimes remarkably parallel. The direction which the drift matter has taken conforms generally to that of the scratches upon the rocks beneath; and in the hilly districts of New England, New York, New Jersey, and Pennsylvania, it is for the most part obliquely across the crests of the mountains. Lower on the slopes, and in the beds of the longitudinal valleys, it conforms partially to the courses of the great hollows in their surface, as if at these lower levels it had been deflected into the previously established lines of easiest drainage. One essential phenomenon is the occurrence of rocks, some of them of considerable size, high on the slopes and summits of mountain-ridges and table-lands, a thousand or fifteen hundred feet above the level of their parent rocks.

Southern Limit of the Drift.—The S. visible limit of the continuous drift stratum, in the British Provinces and in New England, is the sea-coast. From the estuary of the Hudson it trends inland, following an irregular undulating line W., across New Jersey and Northern Pennsylvania to Ohio, and the States farther West. On the mountains and table-lands its position is invariably farther N. than on the plains and in the valleys between them. And it projects long tails far to the S. of its general average boundary, through the great N. and S. valleys which open S. towards the Atlantic and Gulf slopes, through the Appalachians, and across the water-shed S. of the great lakes,—the gravel and boulder matter even extending hundreds of miles down the valleys of the Delaware, the Susquehanna, the Alleghany, and the Mississippi rivers. It seems to have been arrested in its progress S. by the high table-land of Northern Pennsylvania, only the lowest depressions in this plateau admitting it farther Southward with the slope of the continent.

Striated Rocky Floor of the Drift.—The rocky surface upon which the drift reposes is everywhere furrowed and smoothed, except upon the steep Southern or lee sides of the hills, where the outcropping strata retain an unworn or craggy aspect. The smoothed and striated region is nearly coextensive with the area covered by the drift, only the furrows grow faint, and even cease altogether, in many elevated districts, at a point some miles to the N. of the ultimate margin of the attenuated bed of drift or of scattered boulders. This worn condition

SPANISH HILL NEAR ATHENS, TIOGA Co PA

of the surface occurs at all altitudes, from the sea-level to the summits of the loftiest mountains in New England, New York, and Northern Pennsylvania. Only the culminating peak of Mount Washington, the highest point S. of the valley of the St Lawrence and great lakes, and 6228 feet above the ocean, appears to have escaped the abrading and polishing action, all the other hills of the same group, some of them more than 5000 feet high, having their very summits visibly worn. The scratches upon the rocky surface do not radiate from the high mountain-centres any more than do the materials which cover them; but they maintain, throughout New England, Pennsylvania, and the great plain West of the Appalachians, a very general average direction towards the S.S.E., or in the direction of the maximum slope of the continent. This course is most constant upon the open plains, high table-lands, and mountain-crests; but within the valleys, and at the feet of the ridges, a deflection is observable; and the new direction imparted is constantly such as a moving fluid or plastic mass would take in sweeping round or past the obstructing barriers. The striæ present a general parallelism in direction; but wherever the rocky surface is uneven, they exhibit a considerable deviation from one course, later grooves crossing earlier ones at various acute angles, some of which amount to 30°. The striæ are, moreover, not rigorously straight, but curve slightly to conform to inequalities in the shape and hardness of the resisting surfaces.

Pleistocene Fossiliferous Clays and Sands. — From the coast of Maine westward to the basin of Lake Ontario, and from the estuary of the Hudson northward to that of the St Lawrence, a deposit of blue clay and sand occupies the valleys of many of the rivers and lakes at all levels above the tide, and to a height of more than 400 feet in the valley of Lake Champlain, where its elevation is at a maximum. In the great valley occupied by Lake Champlain and the tidal portion of the Hudson, this stratum consists chiefly of a tenacious blue clay, with some beds of argillaceous sand towards its lower limit; and the same clayey character belongs to the formation which fills at a lower level the estuaries of the Connecticut, the Kennebeck, the Penobscot, and the St John rivers. In the valley and estuary of the St Lawrence the prevailing materials are sands and very sandy clays. Both the blue clay of Lake Champlain and the Atlantic rivers, and the more sandy beds of the St Lawrence, contain marine shells; in some localities, in great abundance, about twenty-three species having been identified. All of these, without exception, are forms now living either on the coast of Massachusetts or in the Gulf of St Lawrence, and are not therefore peculiarly sub-Arctic forms. The two most generally diffused species are the *Saxicava rugosa* and the *Tellina Greenlandica*, both of which are now abundant in Massachusetts Bay. It would appear that this stratum. having its maximum present elevation above the sea-level in the district of Lake Champlain, declines gradually in height both Southward and North-eastward. Its mean level in the plain of the St Lawrence, at Montreal, is only about 200 feet, though some of its materials, displaced and re-deposited, probably by the inundation which accompanied the uplifting and draining of the valley in which it was accumulated, are found lodged in small patches at considerably higher levels in the recesses of the bordering hills, particularly on the Montreal Mountain.

This marine Pleistocene formation has been appropriately named by Professor E. Desor the Lawrentian Clay.

Fresh-water Pleistocene of the Western States.—An extensive deposit occurs South of Lake Erie and Lake Michigan, and in the peninsula between them, which is probably nearly contemporaneous with the marine Lawrentian; for, like it, it rests generally upon the continental or general boulder-drift. It contains a few lacustrine shells, and fragments of leaves and wood, and seems to have been accumulated, like the Lawrentian formation, in the period of quiescence which intervened between the close of the great first drift-deposit and that later or last disturbance of the levels of the land which uplifted the Lawrentian formation, and at one and the same time drained the tidal valleys and straits in which it was collected in wide spaces around the present lakes. These fresh-water beds seem, in part at least, to be the products of swamps and lake margins. Covered as they are very generally by superficial sands, and even a sparse strewing of boulder gravel, they appear to belong to the middle Pleistocene era, or the period of repose which separated the convulsed epochs of the earlier general and the later local drifts.

Later Local Drift.—In the valleys of the Hudson and Lake Champlain, and elsewhere, the Pleistocene marine clay is covered to a shallow depth with a stratum of drift composed of coarse sand, gravel, and boulders, resting on its denuded and trenched surface. No one general direction or Northern source can be assigned to this upper deposit, its gravels and erratic blocks appearing rather to be derived from the more ancient general drift of the adjoining hills, re-dispersed by some aqueous movement upon the surface of the fossiliferous clays and sands. A similar superficial drift-like material, including in some districts erratic boulders of large dimensions, will be found to overlie very generally both the marine and the Western lacustrine middle Pleistocene deposits. A ready explanation of the origin of this newest Pleistocene deposit suggests itself when we consider the nature and energy of the crust-movements which lifted the Lawrentian clays and sands to a height, in one locality at least, of not less than 500 feet, and which drained wide tracts of the upper Lawrentian lakes. The mere agitation or pulsating movement of the crust would suffice, if unaccompanied by any permanent uplift of the land, we would think, by lashing the waters of the tidal estuaries in one quarter, and of the lakes in the other, to strew a portion of the older drift bordering all those basins in wide dispersion upon the top of the more tranquil sediments; but if such a pulsation of the crust were accompanied with successive paroxysmal liftings of wide tracts of the land, then the inundation would take the form of stupendous currents, the strewing power of which would be adequate to any amount of superficial transportation, even to the remote transportation of the largest erratics.

CONDITIONS OF THE PHYSICAL GEOGRAPHY ATTENDING THE PRODUCTION OF THE PALÆOZOIC STRATA OF THE UNITED STATES.

SOURCES OF THE SEDIMENTARY MATTER—STATE OF THE WATERS—CHANGES OF LEVEL OF THE SEA-BOTTOM—HORIZONS OF CONTINUITY AND DISCONTINUITY.

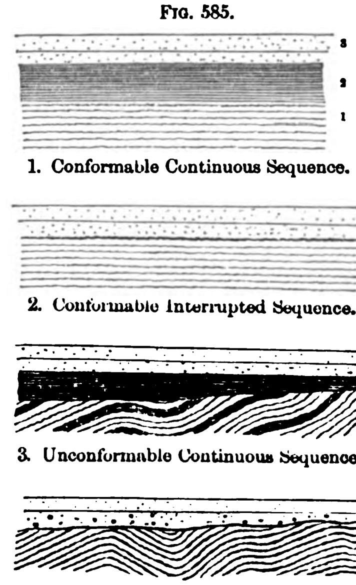
PRELIMINARY CONSIDERATIONS.

Before entering upon a discussion of the physical conditions which witnessed the deposition of the Palæozoic strata of Pennsylvania, and the Appalachian Basin generally, it will be expedient to recall attention to two or three deductions of modern geology, which may be accepted as criteria in our reasonings. As we are endeavouring, from a wide assemblage of facts relating to the composition, dimensions, and organic and other contents of the strata, and from their mutations, to deduce the conditions under which they were deposited, or gain some insight into their physical geography, the depth of the waters, their shore limits, the directions and relative force of their currents, and the elevations and shiftings of their successive bottoms, we must consider, in the outset, how we establish the preliminary inferences upon which we build our final conclusions.

First, as regards the evidence of the presence or absence of depositing waters, or of sedimentary action. Though a few speculative geologists, in their desire, independently of observation, to resort to alternate changes in the levels of the earth's crust to meet the emergencies of theory, are in the habit of contemplating submersions of the land beneath the sea, where there are yet no vestiges, organic or inorganic, of its presence at the epoch, we are warranted, I think, in stating, as an axiom of the science, that every current or over-resting sheet of water has left *some* permanent monument or trace of its presence or passage, and that wherever, between two strata or ancient surfaces, known to have been formed at an interval of time, nothing whatever of a sedimentary sort is interposed, we are to conclude that the vacuous space was dry land. It is not conceivable that the waters of the globe, known to be susceptible of holding their finer sediments in partial suspension for weeks, and months even, and of wafting them for hundreds, nay, even thousands of miles, and to have teemed, too, under every climate and condition, with millions of microscopic animal and vegetable organisms, could ever have rested long, or even have flowed transiently over any ancient surface now exposed to our view, without having left behind them some sediments as indelible records of their existence. It has been alleged that the deposits of one epoch may have been entirely removed by the erosive currents of a subsequent; but such complete obliteration is inconceivable, except for comparatively very narrow areas, for the same currents that could plough up and transport all the materials of the floor over which they moved, must have dropped those materials elsewhere on the confines of the eroded district, and under conditions, and bearing contents, capable of betraying in all cases the source from whence they were derived. It should be borne in mind that, as earthy sedimentary matter is to a large extent insoluble and indestructible by water, and all moving water is formative as well as destructive, or must deposit what it has lifted, it is always in the geologist's power to investigate the supposed removal of a stratum by an inductive study of the phænomena open to his observation. And until he can prove that there has been at least one formation completely removed from off a wide area of the earth's crust, over which it was deposited, he is not entitled, upon sound rules of scientific reasoning, to infer that it was ever present there. The recent discovery of minute organisms covering nearly the whole bed of the North Atlantic, and wide tracts in other seas, at profound depths, where previously no life nor vestiges of life were supposed to exist, but in their place only darkness, stillness, perfect rest, and an entire absence of the vital force, settles once for all this important fundamental question. If we are justified in attributing a watery origin to certain sheets of matter because they indicate deposition and strewing, and contain shells, scales, and bones, the obvious relics of creatures in affinity with the known aquatic races of the present day, we are equally warranted in rejecting the conception of a submersion of any district until we can there find some such evidences of the waters, or some independent proofs that the materials the waters must have contained and precipitated were once there, and were subsequently swept away.

One chief object of the present Chapter being to trace the several Palæozoic formations of Pennsylvania, as independent deposits or sheets of matter, through their various phases of composition and thickness across the State, and thence out into the great Appalachian basin of the continent, even to its distant shores, it is necessary that we should keep our attention, not only upon the strata themselves, but upon the horizons or ancient surfaces which divide them. Before attempting this, it will be expedient to settle a few points of definition in regard to the conditions under which contiguous strata are superposed.

FIG. 585.



1. Conformable Continuous Sequence.

2. Conformable Interrupted Sequence.

3. Unconformable Continuous Sequence.

4. Unconformable Interrupted Sequence.

Reviewing all the possible relations of superposition, it will be found that they arrange themselves under four categories. They are illustrated in the diagrams here annexed.

First, Deposits of successive dates may be superposed in regular parallel order, so continuously as to mark no pause in time, or interruption in the formative process; and even the transition from one formation to another may be so gradual, both in the substitution of a later sediment for a preceding, and of one set of organic remains for another, as to imply no positive cessation of time or action. Such a following of one formation by another, I propose to entitle a *conformable continuous sequence.*

Secondly, One stratum or set of strata may immediately overlie another with apparently perfect parallelism of their beds, and yet their plane of contact may represent a great interval of time, and a total change of the physical sedimentary conditions ; in other words, there may be an absence of strata, or even of whole formations, or entire series of formations, developed in other districts of the same or of other waters, and recording a long period of geological time. Where, from independent evidence of stratification and fossils, we are convinced that the contact is between deposits thus separated in age, though physically joined, and to all appearance directly sequent, we may entitle the relation a *conformable interrupted sequence.* This condition implies a cessation of sedimentary action through a longer or briefer period, and we know of no change but that of elevation above the water or into dry land compatible with it, at least for any length of time. This juxtaposition of rocks remote in age, where the lower were still level at the date of the deposition of the upper, proves not merely a lifting of the watery floor to the level of dry land, and its reimmersion, but a movement unattended by any narrow or steep undulations ; or in other words, it indicates merely a broad general bulging of the crust. Traced far, however such instances of parallelism will almost invariably be discovered to exhibit a change to unconformity, implying the universality of a law previously announced, that every displacement of the level of the earth's crust has been, and still is, somewhat undulatory.

Thirdly, There is a third condition of contact, where the upper group of beds reposes on the lower at a greater or less angle, their relative attitudes implying an uptilting or loss of levelness in the inferior before the superior were deposited, even though we are assured from their organic contents that they were strictly consecutive in time, or so nearly so that no independent formation, or group of organic beings, elsewhere occupied any part of the earth's surface within the interval. Such instances of superposition exhibit a physical break, but not a break in time. This relationship may be entitled an *unconformable continuous sequence* of the strata.

Fourthly, The remaining category under which two sets of strata may rest in contact is that where they exhibit not only an absence of parallelism, but an omission of one or more formations known in other districts to overlie the lower, and underlie the upper. This state of things implies not merely a disturbance of the inferior deposit, from the approximately horizontal position in which it was formed, but its elevation into dry land, with a lapse of time and a reimmersion of the mass without a regain of its original level attitude, all prior to the deposition of the formation resting over it. Such a condition, familiar to geologists as the commonest instance of unconformity, I propose to entitle an *unconformable interrupted sequence.*

I have presented the above definitions as essential to a clear understanding of the nature and relative magnitudes of the planes of discontinuity which separate the Appalachian strata, and, by interpretation, the crust-movements which preceded and followed the various formations which successively occupied the floor, or portions of the floor, of the Appalachian sea in Pennsylvania and elsewhere. It is only by holding these distinctions well in view, and by studying the corresponding breaks in the sequence of the organic remains imbedded in the strata, that we can hope philosophically to group, classify, and name our stratified rocks, and reconstruct in imagination the successive phases of the ancient physical geography of this quarter of the globe.

It should be observed, that we frequently meet with each of the four above-described conditions of contact of the strata, where the uppermost, though deposited horizontally, have undergone, together with those below them, great displacements from their primary level posture. However uptilted they may be, the two sets always retain, of course, their previously-established relative attitudes.

We may assume it also as an established law, upon which we may safely rely in our geological reasonings, that the relative coarseness or fineness of the sedimentary matter in a given stratum measures approximately the relative strength or feebleness of the watery currents that strewed them ; and furthermore, that the degree of thickness of a land-derived or mechanically-formed deposit, is a criterion of its relative proximity to the ancient shores from whence it was swept. Guided by the familiarly-known transporting functions of moving water, in which we witness every gradation of velocity, from speeds too swift for any deposition to motions too sluggish for the further floating of the suspended matter, we must infer that the greater number of sea-borne sediments, not merely sheets of gravel and sand, but the widest layers of clay, are in their component beds, and in their aggregate bulk, very thin, even to a feather-edge, at both their landward and seaward margins ;—their landward, from excess of velocity ; their seaward ones, from exhaustion of material. It is plain that, by carefully observing in any stratum all its gradations in respect to its aggregate thickness, the coarseness of its constituent fragments and particles, the nature of its organic remains as implying shallow or deep waters, and the quality of its materials as traceable to comminuted rocks of the dry land, or to chemical precipitates derivable only from water, the geologist—if the scale of the deposit is large—is enabled, by assembling his data, to ascertain, with considerable accuracy, the quarter whence the formation was derived, and the relative strength and depth of the transporting currents ; indeed, if he proceeds with caution, he may, by summoning to his aid the facts and deductions of physics on the one hand, and those of natural history on the other, gain not a little insight into the physical geography of the globe, at its best recorded successive epochs. This attempt at a restoration of the ancient geographies of the earth in the sense of the relations of its lands and waters, and the distribution of its living tribes, is one of the highest aims of geology, in the cautious inductive pursuit of which the science is gradually taking rank by the side of astronomy itself, for the sublimity of the field it opens, and its marvellous capacity of revealing the unknown. Humbly hoping to contribute some facts, and a few generalisations, as materials towards the construction of an Ancient Physical Geography for North America, I shall venture, in the following pages, to present the observations furnished by the Geological Survey of Pennsylvania, in connection with some derived from the best explorers who have been studying the other different districts of the ancient Palæozoic sea along its Northern, Western, and Southern shores, and throughout its middle tracts.

DEPOSITIONS AND DISTURBANCES OF THE PRIMAL PERIOD.

Commencing our description of the conditions of deposition and movements of the Palæozoic strata of Pennsylvania, and the Appalachian basin with the Primal series, the first feature which claims our attention is the prodigious thickness and great general uniformity of composition of certain members of this widely-extended deposit. Viewed broadly, it may be regarded as an enormous accumulation of a very ferruginous sandy clay, the lower and upper Primal slates imbedding comparatively thin sheets of coarser fragmentary matter ; a conglomerate at the base of or within the lower ; a white evenly-constituted sandstone at the base of the upper. The entire argillaceous mass has evidently been derived from a S.E. or S. source, and from a region in those directions as far away from the present N.W. outcrop of these strata in the South Mountain or Blue Ridge, as the lower portion of the Atlantic slope in Virginia, the Carolinas, and Georgia. Along their line of outcrop, at the edge of the great Appalachian valley, these Primal slates appear to cease towards the N. ere we reach the Delaware River, for we have but imperfect traces of them through New Jersey, New York, and the W. side of New England. In consonance with this fact, they thin away N. and N.W. probably near the same latitude, for they nowhere rise to the day in Canada, nor along the shores of Lake Superior, nor in Wisconsin and Minnesota ; but the Primal white sandstone, or great Arenaceous formation of the series, rests everywhere throughout this vastly-extended ancient coast-line, on an earlier metamorphic or Azoic system of rocks, and is in turn almost immediately overlaid by the sandy magnesian limestones of the Auroral series. How far to the S.W. the main body of the Primal series, the Primal slate, extends, I am at present unable to assert, but I believe it ranges in the Blue Ridge and Atlantic slope into Alabama. Some conception of its geographical and vertical dimensions may be gained by reflecting that it constitutes apparently a very large portion of the broad chain of the Blue Ridge and of the Atlantic slope through a breadth of about 40 or 50 miles from the Susquehanna to Georgia; and where the thickness of the whole series is susceptible of estimation, it cannot be less than 5000 feet, and it is probably much more.

So wide a deposit, derived evidently from the comminution of Gneissic or other older metamorphic rocks situated to the S.E. of its present outcrops, can only have proceeded from a very extensive degradation of a wide expanse of dry land, commencing in the lower portion of the Atlantic slope, and spreading where we have now the Tertiary sea-board plane, and even the waters of the Atlantic. It is obvious from the unconformable superposition of the Primal series upon the Gneissic system, that the deposition of the Primal was preceded by a wide movement of depression of its Gneissic floor, letting on the waters of the Appalachian sea, where we have now the upper half of the Southern Atlantic slope, but not permitting them to overflow the surface in those N.E. districts where the Primal white sandstone is the lowest Palæozoic formation resting against the Gneiss or the Azoic. This subsidence below the sea-level evidently began in the S.W., or S., as the deficiency of the lower Primal rocks in the N.E. plainly proves. The movement of the crust here spoken of must have left above the waters a large tract of continent, or at least a great chain of islands to the S.E. of the present Atlantic plane; and as so many of the subsequent formations of the Appalachian region point as clearly as the Primal to an E. and S.E. source for their land-derived materials, it is manifest that the supposed Eastern lands, with more or less of fluctuation in their limits, must have remained such even to the close of the Carboniferous period, or till the uplifting of the latest Coal-measures.

The coarse stratum of silicious conglomerate intercalated in the Primal lower slates, far below the horizon of the white sandstone, is manifestly a S. rock, for it does not reach N. to Pennsylvania, and seems to have its fullest development in Eastern Tennessee. It was produced, obviously, by some strong paroxysmal movement interrupting the quiet actions which were introducing and dispersing the sandy mud of the Primal lower slate, and pushing into the waters a column or broad sheet of angular fragmentary matter.

The conditions attending the deposition of the Primal white sandstone, or Potsdam sandstone, must have been very peculiar. If continuous as a single sheet of pure arenaceous rock, or even approximately so, as a series of thinning and thickening deposits embraced within nearly one horizon, or reposing on one clayey floor, it is one of the most remarkably persistent strata in the purity of its quartzose composition, and the constancy of its type, and its organic contents, which geological research has anywhere disclosed. From all the evidence now in our possession, it appears to underlie the entire Appalachian basin, ranging in one grand line of outcrop N.E. from Alabama to the St Lawrence, thence W. along the N. shore of the ancient sea to Minnesota, and rising in Missouri midway between these starting and terminating points. While it thus margins and probably spreads uninterruptedly under this wide area of more than 1000 miles diameter, it retains its simple condition of a nearly pure white sand, and is apparently nowhere more than a few hundred feet in thickness. That it was deposited in comparatively quiescent waters, and not from turbulent currents, is plainly evinced in the remarkable uniformity in the nature and size of its particles, in its freedom from heterogeneous conglomerates, and, indeed, from all pebbly masses, except some local beds of quartzose gravel, and strikingly in the universally perpendicular position of its long, slender, delicate, stem-like fossil, the *Scolithus linearis*, which seems to have been enclosed by the settling sand with as little horizontal bending motion of the stalks from any current, as when a field of standing corn is enclosed and bedded up in gently-falling snow. Whence could have arisen so very wide and uniform, and yet so gentle a dispersion or precipitation of this great floor of sand of nearly snowy whiteness? The regular bedding of the material, and its thin partings of almost impalpable clay, prove that the waters did possess some horizontal motion. Was this of the nature of a continuous systematic circulation like that now visible in the North Atlantic and some other seas? or was it intermittent without being paroxysmal, like the tide-wave currents stirring the beds of the broad shallow estuaries, such as those bordering the Gulf of Mexico at the present surface? Whence was derived so pure a sheet of unmixed quartzose sand? A mere *sorting* action of the waters operating upon mixed mineral sediments could scarcely have spread out this pure sand over such a breadth of floor, nor so very uniformly, but would have left large deposits of extraneous matter, and have intercalated many beds of gravel and clay. And to what source also are we to look for so prodigious a quantity of unmingled quartzose matter? May we not conjecture that this great sheet of white sand, unlike any sediment we can imagine to have come from the disintegration of the Gneissic or any other group of the older rocks, was supplied from the great dykes and veins of auriferous quartz, which, upon independent grounds of geological evidence, we are induced to infer, issued about this epoch in a melted condition through the rents and fissures of the crust over all the region of the Atlantic slope, and elsewhere around the Appalachian sea. It is but a conjecture, though in accordance, I think, with geologico-chemical facts, that outgushing bodies of this quartz, mingled with volcanic steam, and suddenly chilled and pelted upon by cold and heavy rains, may have been granulated into sand, as would occur with heated unannealed glass, and then washed in copious streams into the broad, shallow, and tide-moved sea, and there gradually dispersed and precipitated.

The waters of the Appalachian sea in the Primal ages would appear to have been as tranquil as those of other later periods. The clayey matter of the slates or shales denotes, by its finely-comminuted condition, the gentleness of the in-wafting currents; and the immense thickness of the deposits, the enormous time it occupied in collecting. The period was one of vast duration ;—an enormous age of quiet sedimentation, with almost no life in the wide turbid sea.

A somewhat abrupt disturbance of the levels of the surface must have attended the rather sudden cessation of the previous prolonged precipitation of the Primal upper slate, and this movement was evidently an unequal one—an elevation and a subsidence of the floor of the sea which contained the Primal mud. It resulted in a totally new condition of the waters. The introduction of the Primal clays from the S.E. was stopped for ever—not suspended, as during the precipitation of the white sandstone; and in their place there commenced an immensely-extended gradual deposition of the materials of the sandy magnesian limestones of the next or Auroral period. This cessation took place at the beginning of the Upper Clay period in the N.E., and at its close in the S.W. The transition cannot have been a violent one, for almost no pebbly beds marking an active rush of waters are discoverable at the passage from the one formation to the other, but the two groups alternate their deposits through a thickness in some places of many hundred feet, one or more beds of the limestone being interstratified with the slate before the great body of the limestone commences. As the lowest Auroral formation, in Auroral calcareous sandstone, is absent with the Primal upper slate E. of the Schuylkill, the hiatus of two formations produces a conformable interrupted sequence.

Palæontological Break.—Throughout the Appalachian chain the Primal series contains only three or four fossils, two *Lingulæ* and the *Scolithus* in the white sandstone, and a vaguely-defined plant, at present the oldest known relic of organic existence in America, or perhaps in the world. But in Wisconsin, near the N.W. shore of the Primal sea, the white sandstone imbeds on a succession of thin floors some seventeen more species, among them some curious trilobites. Two of the seventeen are forms common to the E. outcrop, so that the total number of species yet defined is only about eighteen. Now it is remarkable that not one of these is to be met with in any of the formations of later date, though these were produced under circumstances especially favourable to the existence of organic beings. It thus appears that the physical revolution which cut off the Primal deposits, and fitted the ocean for the reception of the Auroral, *completely exterminated the previously-existing races.*

Here, then, is one of the most decided palæontological breaks, or epochs of discontinuity in the organic world to be met with in the whole succession of our ancient Palæozoic formations.

DEPOSITIONS AND DISTURBANCES OF THE AURORAL PERIOD.

We have seen, from foregoing descriptions of the Auroral strata of Pennsylvania and other districts, that it consists largely of a sandy magnesian limestone, which terminates towards its base, from excess of sand, in a calcareous sandstone, and that it is only towards its upper limit that the rock passes to a nearly pure carbonate of line, or becomes at all crowded with fossils. We have also noticed that the whole mass is enormously thick at its S.E. outcrops, throughout the Appalachian chain, from Alabama to the St Lawrence, and that, though much thinner along the N. border of the basin, it is still largely developed, upon its N.W. and W. margin, in Wisconsin, Iowa, and Missouri.

As the chief deposit of the Auroral series, the magnesian limestone exhibits its greatest development along its most S.E. limit, having a thickness there of some 4000 feet or more; and as it declines in bulk N. and N.W., it is manifest that it had a S.E. or S. origin, or at least that the conditions for its production were in fullest energy in those quarters; and it is equally obvious that it must have existed, in those directions, far beyond its present boundary, since we cannot suppose the deposition to have been thickest just at its margin. We are compelled, on the contrary, to suppose that, as all marine deposits must, it commenced geographically with a thin or feather edge, and gradually deepened seaward. Indeed, judging alone from a comparison of its mass in different quarters, we are led to infer that its existing S.E. outcrop in the Appalachian chain occupies rather a mid-sea position in relation to the waters in which it was precipitated Very possibly, however, the Appalachian ocean of the Auroral period was, like most of the oceanic basins of the world at the present day, deepest towards one side; and that this broad channel, stretching N.E., and shoaling towards the N. and W., was the region of most copious deposition of the material.

The striking increase in the magnitude of the cherty member of the formation, as we trace it S.W. along the great Appalachian valley into Central Virginia, and indeed into East Tennessee, supports the view here taken of a S: or S.E. development of the whole mass.

Respecting the origin or source of the ingredients of this stupendous deposit, it is not easy, in the present state of our knowledge, to offer more than some plausible conjectures. Being in the main a triple mixture of carbonate of lime, carbonate of magnesia, and quartzose sand, with a little alumina, and carbonate or oxide of iron, we have, in the first place, to account for the two first-named ingredients. These constituents of many great formations, of all geological ages, are by some geologists regarded as derived almost exclusively from shells, corals, and the exuviæ of various minuter marine creatures, triturated into an impalpable calcareous sand or mud; but by those of another school they are attributed in large part to a chemical precipitate of the carbonates of lime and magnesia, from waters sufficiently charged with carbonic acid to hold these salts temporarily in solution. Neither of these hypotheses meets the primary difficulty of finding a source for the enormous amount of the carbonates, combined with but little foreign matter, which this and other great limestone formations exhibit, under circumstances that almost preclude our tracing them to a solution of any of the pre-existing formations or mineral masses of the crust. In no region of the ancient metamorphic and igneous rocks, encompassing the present limits of these old Appalachian formations, do we discover any large mass, aqueous or Plutonic, of either pure or magnesian limestone, whence, by solution or by washing, so pure a deposit, or one even one tenth or one hundredth part the thickness of this mile-deep formation, could be derived. In truth it is, if not absolutely, very nearly the most ancient calcareous stratum known upon the continent. To what more primordial source, then, are we to look for its ingredients? Scarcely to the minerals of the crystalline and semi-crystalline Gneissic and Azoic strata, or to the comparatively limited granitic and other Plutonic dykes. The predominant constituents of all these masses are silex and clay, the former nearly fifty per cent, the latter about seventeen per cent; whereas the calcium and magnesium, the metallic bases of the lime and magnesia, scarcely exceed five per cent each. There was evidently some other hitherto unexplained source whence the early Palæozoic waters of the globe received their long-continued, gradual, but, in the aggregate, most prodigious supplies of the carbonates of lime and magnesia. To trace them, as some do, to submarine volcanic emissions, is to contradict all analogy with the known nature of modern volcanic products and volcanic functions; indeed, we have the amplest geological evidence that the ancient igneous eruptions through the crust were accompanied with as small a proportion of these mineral substances, so indispensable to the solid skeletons of corals, shell-fish, and many other marine races, as the modern volcanic lavas.

Concerning the origin of the quartzose sand so abundantly dispersed through the carbonates of lime and magnesia in nearly all portions of this formation, but especially in its lower member, the Matinal calcareous sandstone, or calciferous sandstone of New York, there is less obscurity. We have already seen, that around the N.E., N., and W. borders of the Appalachian sea, the Primal white sandstone constitutes the uppermost deposit of the series, there having been an elevation of the sea-bed in those quarters which shut out the clays of the Primal upper slate accumulated farther S. It is highly probable that the same movement lifted out the Primal white sandstone in a similar manner, S.E. of the Southern Atlantic slope, and thus around almost the whole periphery of the basin there must have been a broad expanse of freshly-risen, scarcely-cemented white sand, exposed to be washed by the tropic-like rains of that period into the wide, shallow, but constantly-sinking receptacle, and there commingled with the carbonates of lime and magnesia as these were being precipitated.

AURORAL BLUE LIMESTONE, CHAZY AND BLACK-RIVER LIMESTONE OF NEW YORK.

The upper member of our Auroral series, consisting, as will have been seen, of a regularly-bedded, evenly-deposited pure blue limestone, interstratified in some districts with layers of shale or clay, and distributed not only throughout the Appalachian chain of Pennsylvania, but as far in different directions as Alabama, the St Lawrence, and Missouri, must likewise have been deposited under conditions of extraordinary geographical uniformity. It is nowhere a thick formation, and appears to be almost entirely absent from some districts of the Appalachian chain. Elsewhere it has a depth of 200 or 300 feet. The most interesting general facts connected with it, are its repleteness in organic remains, and its almost entire freedom from the quartzose sand which is so general a constituent of the formation next beneath it, with which it is likewise contrasted, in containing a far less proportion of the carbonate of magnesia. The two formations differ greatly in the abundance of the fossils which they entomb. Thus Professor James Hall, after a long study of the species derivable from these deposits in New York, describes, in his Palæontology of that State, but thirteen forms from the magnesian limestone; whereas he defines seventy-seven as belonging to the Chazy, Birds-Eye, and Black River groups, or the local members of our Auroral blue limestone; and, what is remarkable, only one is common to the two deposits. There was evidently a physical change in the Auroral waters, and probably in the circumjacent land, at the coming in of this formation, some new condition checking the production of the carbonate of magnesia, and stopping entirely the introduction of the silicious sand, but favouring the inflow of a moderate amount of clay. This change was unquestionably owing to, or connected with, a wide movement of the bed of the waters, as shown by the *calcareous conglomerates*, an elevation amounting in some quarters to an actual lifting out to the level of the atmosphere of their magnesian limestone floor, as the absence of the Auroral blue limestone, and the Matinal limestone, and Matinal black slate over large tracts, abundantly establishes. Everything connected with the stratification of the blue limestone proves that it was deposited in comparatively shallow waters, and the structure of its fossils, and their high abundance, go to confirm this inference. We can hardly attribute the great increase in the amount of life, towards the later part of the Auroral period, merely to a change in the mineral sediments, for we find in other quarters of the globe, and even in other parts of the American Palæozoic strata, very magnesian and sandy limestones, though most usually sandy ones, which are not magnesian, quite full of organic remains. We are constrained, therefore, to think that their comparative paucity in the Auroral magnesian limestone was due to some other condition of the waters—possibly turbidness or temperature, or both—which accompanied the precipitation of its materials.

DISTURBANCES OF THE CRUST AT THE END OF THE AURORAL PERIOD.

Comparing the physical conditions of the later part of the Auroral period with those of the earlier part of the Matinal, as indicated by the strata and their organic contents, we discern signs of an important change throughout wide spaces of the Appalachian sea, especially in Pennsylvania and towards the S.W. Indeed, almost everywhere there is an important alteration in the materials of the strata—the Matinal argillaceous limestone, Trenton limestone of New York, including a much-increased amount of clayey and carbonaceous matter in the limestone, and many layers of pure clay or shale between its calcareous beds. That state of the physicial geography, whatever it was, which subsequently and for a long time permitted the deposition of widespread sheets of clay, had already begun with the commencement of the Matinal period. That there was a shift in the levels of the surface over many districts around the margin of the Auroral basin, is manifested in the circumstance that the Matinal limestone there spreads beyond the limits of the Auroral blue limestone, and reposes directly on the Auroral magnesian rock, in a *conformable interrupted sequence*, a condition which could only arise from a previous elevation of the sea's bed at the end of the Magnesian Limestone age, and a subsequent re-emersion of the surface at the beginning of the Matinal period, for the reception of its fossiliferous limestone. Such must have been the state of things over those portions of the edge of the basin, now the Appalachian or Kittatinny Valley of Pennsylvania, where the Auroral blue limestone is wanting, and the Matinal or Trenton limestone lies in contact with the magnesian. Such also was the condition in parts of Wisconsin, Minnesota, and Missouri. The shift of level of the sea-bottom towards the end of the Auroral period must have commenced with a somewhat violent agitation of the crust, for such is evidently the inference to be drawn from the conglomerate beds of very large limestone pebbles, seen near the superior limit of the Auroral magnesian limestone in the Kittatinny Valley. It was plainly no movement of elevation, since the Auroral blue limestone, and quite generally the Matinal limestone also, are wanting from the column of formations. The break of succession in which this movement resulted was greatest apparently towards the S.E.

The waters of the Appalachian ocean in the Auroral period were probably deep in the earlier ages, and deepest in the region of the present Appalachian Mountains, where the superior thickness of the great magnesian limestone implies either this condition or a more rapid subsidence of the sea-bed, and a more copious introduction of material. But this more copious precipitation of an aqueous sediment itself denotes a greater depth or mass of water.

PALÆONTOLOGICAL BREAK BETWEEN THE AURORAL AND MATINAL SERIES.

This transition from the Auroral to the Matinal deposits was accompanied by an almost entire extinction of the numerous marine races which lived in the Auroral waters, and heralded the introduction of still more numerous groups of kindred species. Indeed, as I shall elsewhere show, there appeared, with the almost total change in the species, quite a number of new genera. According to the tables of Professor Hall, the number of species restricted to the Auroral blue limestone, as hitherto examined in New York, is about seventy-seven, whereas the number peculiar to the Matinal limestone (Trenton) is one hundred and eighty-eight, while there are but three other species common to the two formations. Here, then, there is a palæontological break or interruption to the stream of life, so far as respects the races—if not the generic types—which for magnitude is quite in consonance with the wide revolution above adverted to in the physical geography of the Appalachian ocean and its bordering lands. This palæontological break is indeed only surpassed, as respects its grandeur, by one or two others in the whole succession of the epochs of the destruction and repeopling of the Palæozoic waters. Towards what quarter we are to seek for the maximum disturbance of the crust which produced the transition from the Auroral to the Matinal worlds, it is difficult, with the data hitherto collected, to determine; but there exist strong indications that it was towards the N.E. angle of the Appalachian sea. In more than one locality in that direction—namely, in places on Lake Champlain and in Canada—the Matinal or Trenton limestone seems to rest unconformably upon upturned and dislocated Auroral and Primal rocks, a condition of discontinuity not met with anywhere to the W. or S.W.

DEPOSITIONS AND DISTURBANCES OF THE MATINAL PERIOD.

Three successive sedimentary conditions appear to have prevailed in the Appalachian basin during the long Matinal ages. First, a state favourable to the deposition of an alternation of rather pure carbonate of lime and blue mud or clay, and to the existence of multitudes of marine species, in myriads of individuals of all grades, from corals up to trilobites. Secondly, a condition depositing nothing but a dark-blue carbonaceous mud, inhabited by a few delicately-constructed molluscs and small trilobites. Thirdly, a wholly different order of things, precipitating, through a long period, an alternation of deposits of sandy clay and clayey sand, crowded, where the waters were more calcareous, with marine creatures of very similar types to those that had frequented the two preceding deposits. Upon the first of these it is hardly necessary to speculate, after what has been already said. The age of the Matinal (Trenton) limestone was, throughout the Appalachian basin, one of extreme general tranquillity of the crust, of moderate depth, and only slight turbidity in the waters, and of climatal and other relations evidently conducive to a redundant harvest of living forms. The carbonaceous matter diffused in the blacker layers of the Matinal limestone and its shales, is attributed by some geologists to the carbon constituent of innumerable organic beings, of a soft fleshy structure, that possessed no shells or stony parts, and could leave no other vestige of their ever having lived.

Matinal Black Slate.—The transition from the formation of this very fossiliferous limestone to that of the bluish-black carbonaceous Matinal slate, was, throughout most portions of the basin now accessible to study, somewhat abrupt; though, as we have seen, it was extremely gradual in one part of their S.E. outcrop, or in the N. section of the great valley of Virginia. There, there is such an intermingling of the materials, and even the fossils of the two strata, that a division of the blended mass is difficult, if not impossible. But throughout Pennsylvania, and in all the country N. and N.W. of it, wherever both formations appear, their line of separation is a somewhat crisp one. It is evident from this, that over most of the watery floor there occurred almost simultaneously some great physical change, banishing the conditions favourable for the deposition or secretion of carbonate of lime, and permitting the introduction and tranquil precipitation of a dark carbonaceous sandy clay, or fine gritty blue mud. With this change there arose an almost entire destruction of the more than one hundred and eighty-eight species inhabiting the limestone sea, only two of these, so far as is yet known, surviving to flourish in the succeeding period of the dark muddy sediment which has hitherto revealed only eight races, to replace the more than one hundred and eighty-six exterminated. The age producing this Matinal black slate was therefore one manifestly very inimical to organic life. The deposit does not show itself at all, we believe, in the N.W. and W. outcrops of the other Matinal groups.

Matinal Shales.—Respecting the physical conditions concerned in the washing into the Appalachian sea of the deep and widespread accumulation of argillaceous matter and fine sand, which form, by their consolidation, the remarkable formation of the Matinal shales, we have to notice, as chiefly suggestive, the following circumstances: the deposit is thickest and most arenaceous along the great Appalachian valley, or at its S.E. outcrops, and particularly, it would seem, towards the N.E., or in Pennsylvania, New Jersey, and New York; and there it encloses, towards its upper limit, thick beds of coarse grey pebbly sandstone, and even of conglomerate. Along the N. and W. borders of the basin, the mass is much thinner, and of finer composition. It is obvious, therefore, that the materials were swept in mainly, or at least in greatest abundance, from the N.E. This view receives corroboration from another fact, previously given, that from a Northern district in Virginia, south-westward, and likewise throughout all its W. and N.W. outcrops, the formation loses its exclusively shore character, and becomes greatly more marine in its type, intercalating among its shales numerous thin plates of very fossiliferous limestone, until, in South-western Virginia, the lower half of it, and in Ohio and Wisconsin the whole mass, is as much a limestone as a shale. Combining these and other facts, we are impelled to infer, that while the Matinal waters were gradually receiving widely-strewn sediments of clay from the E., their S. and W. portions were less turbid, and were precipitating, between each incursion of the mud, their deposits of the carbonate of lime in pulpy sheets, that were teeming with creatures inhabiting its bed and floating in its waves. The steady, gradual change of composition in this great stratum, from its E. to its W. outcrops, is as remarkable as the opposite fact of constancy of type maintained by the two other groups, the limestone and black slate of the Matinal series, or, still more signally, by the Primal white sandstone.

The Galena Limestone.—This lead-bearing limestone of Wisconsin and Illinois, superior in position to the Matinal argillaceous limestone, and inferior to the Matinal shales, is evidently nearly upon the horizon of the Matinal black slate; but whether it was produced in the same age with that deposit, or in that next before it, or, again, in that next after it, we are without the means, for the present at least, of ascertaining, since the black slate and it nowhere occur in the same districts, nor even approach each other by a wide geographical interval. It is obvious, however, that at some period between the close of the calcareous limestone deposit and the beginning of that of the Matinal shale, while a part, at least, of the matter of the black slate was collecting, this galena limestone was in progress, imbedding its peculiar organisms. It pertained to some then existing condition of the physical geography of the N.W. side of the Appalachian basin, favourable to the production of a copious amount of carbonate of lime, for the formation is of considerable thickness under its fullest development. The very marked transition between the Matinal argillaceous limestone and this lead-bearing rock, in regard to their organic remains, strongly intimates that some important physical change occurred in the interval. Not improbably there was a depression of the bed of the sea. The general condition of the Appalachian sea during the Matinal period would appear to have been, considerable depth in the earlier ages, while the Matinal limestone was in progress; then comparative shallowness at the forming of the Matinal black slate; and finally, oscillations during the reception of the Matinal shales and sandstones.

STUPENDOUS CRUST-MOVEMENT AND REVOLUTION IN THE EARTH'S INHABITANTS AT THE CLOSE OF THE MATINAL PERIOD.

The relations of the Matinal series to the overlying sedimentary strata throughout the hitherto explored portions of the Appalachian basin, plainly show that all this portion of the earth's crust experienced a prodigious movement at the close of the Matinal period. This agitation of the floor of the sea, which had just received the materials of the Matinal shales, appears to have been everywhere attended by an extensive displacement of its level, accompanied, in some districts, by undulation, amounting even to a close plication or corrugation of its sediments, and, in some districts, to a lifting up of wide areas above the general sea-level into dry land. The proofs of this revolution—the most momentous, as it affected the physical geography and the organic inhabitants of the ancient North-American waters—have been set forth by me in a communication to the British Association, on the Correlation of the North American and British Palæozoic Strata, read at a meeting of that body in Cheltenham in 1856,* and the reader is referred to that essay for a full discussion of the subject; but the present seems a fit occasion for presenting an outline of the chief facts adduced.

From Gaspé, on the Gulf of St Lawrence, S.W. to the River Hudson, wherever the Matinal rocks appear in contact with any of the superposed formations, the former are either highly inclined and folded, or give evidence of disturbance and partial metamorphism, while the overlying strata display much less displacement and alteration. Within this range of 800 miles, sometimes the Oneida conglomerate, or lowest member of the Levant series—sometimes the Niagara or Scalent series—rests directly on the upturned Matinal. In the one case, the middle Palæozoic rocks repose upon the older unconformably, without a lapsus of any of the formations; but in the other case, the unconformity is accompanied by a wide hiatus in the series of strata. The latter condition was discovered by me near the city of Hudson in 1837, and was referred to in my Second Annual Report on the Geology of Pennsylvania, as proving the magnitude of the disturbance which terminated the formation of the Matinal shale. The locality where the unconformity was detected is Becraft's Mount, where the Lower Helderberg or Pre-meridian rocks are seen in horizontal stratification in the hill; while the Hudson River slates around its base are steeply inclined and contorted, from a movement previous to the deposition of the shales and limestones upon them.

Another locality, near the Hudson Valley, is the end of the Shawangunk Mountain. In this vicinity we may find instances of a physical unconformity of the Levant rocks upon the Matinal, and instances of a similar unconformity of still higher strata upon the same.

The cut here presented (Fig. 586) is a picture, taken on the spot, of the mode of contact of the Pre-meridian or Lower Helderberg limestone and the Matinal strata, as seen by us in 1842 at Hasbruck's Quarry. Here the attitude of the strata is such as to imply—first, an uptilting of the Matinal rocks into a steep inclination; secondly, a submersion of the uplifted surface to receive the deposition of the Pre-meridian limestone horizontally upon the edges of the Matinal slate, after these latter had remained above the water long enough for three great formations—the Levant, Surgent, and Scalent—to have taken place elsewhere; and, thirdly, another elevation imparting a steep dip to the horizontally-formed Pre-meridian limestone. We have the authority of Sir William Logan, in his Annual Reports of the Geological Survey of Canada, for stating "that in the E. division of the Palæozoic basin—that is to say, the portion S.E. of the St Lawrence—there are evidences of a want of conformity between the Upper and Lower Silurian formations." While such is the general state of things throughout the Appalachian chain N.E. of the Hudson, there exist, not improbably, districts within or beyond this belt where the sequence of the Palæozoic formations is full, and was not disturbed by any important physical movement at the close of the Matinal period, or the epoch which separated the middle from the older Palæozoic ages. One such district would seem to be the Island of Anticosta, where, it is alleged by the Canadian geologists, the Lower and Middle Palæozoic rocks exhibit not only an absence of all sign of physical disturbance at their passage, but display a remarkable commingling of their organic remains, proving an equally striking absence of any great disturbance in the conditions of life. Notwithstanding this exceptional instance, it would appear, from the Reports of the Geological Survey of Canada, that the Middle Palæozoic formations (the Upper Silurian of Murchison) repose very extensively in discordant stratification upon the Matinal or Hudson River rocks of Quebec and Sillery. In some quarters, this break in the sequence of deposits consists in the omission of one, and, in others, of more than one, formation, implying an uprising into dry land, and subsequent re-immersion of the bed of the Palæozoic ocean. There is evidence that this uplifting of the sea-bed extended as far S. as the W. side of the Hudson, and nearly as far W. as Oneida Lake.

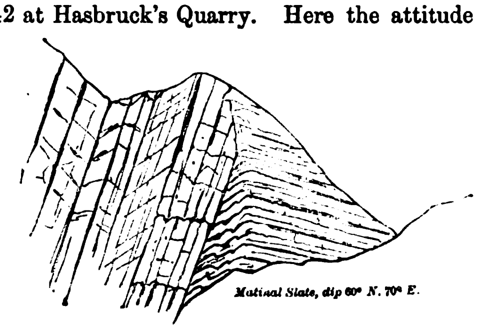


FIG. 586.—Hasbruck's Quarry, Rondout, showing unconformity of Pre-meridian upon Matinal strata.

This latter statement is confirmed by the fact that there is an omission of one or more of the formations at the base of the Middle Palæozoic series discernible throughout a winding line of outcrop, stretching from the Rondout River up the W. side of the Hudson River, and thence N.W. and W. by the base of the Helderberg Mountain, along the S. side of the valley of the Mohawk. From Rondout to Schoharie, the two lowest of the four Silurian formations are wholly wanting, causing the upper beds of the Scalent or Niagara group, and frequently even the lower layers of the Pre-meridian or Lower Helderberg group—the uppermost of all the Silurians—to lie in discordant contact upon the Matinal slates, or highest of the Cambrian equivalents. The undulations of the Matinal floor appear not to extend very far W. of the Hudson; for, as we ascend the Mohawk Valley, the higher series of rocks becomes parallel with the lower at their plane of contact. Only when we approach Oneida Lake does the conglomerate of the Levant series begin to take its intermediate place in the succession of strata, filling the gapbetween the two systems. But

* Report of Twenty-Sixth Meeting of British Association, held at Cheltenham.

even it displays, over a wide tract to the W. of its E. margin, traces of the violence of the crust-movements of the period; for it is largely composed of fragmentary particles of the Primal, Auroral, and Matinal rocks, uplifted and eroded by the commotions which gave birth to it.

Along the entire S.E. margin, or mountain front, of the Appalachian basin, between the Hudson and its S. border in Alabama, the close of the Matinal period exhibits indications of a great and violent change in the state of the waters, implying a commensurate degree of action in the ocean's floor and ancient shores. Although there is no hiatus in the series of formations, nor any want of parallelism between the upper and lower groups, yet there prevails so abrupt or sharp a plain of separation—such a striking change in the sedimentary materials—such proofs of the upper rock, the Levant conglomerate, having been formed out of the wreck of the Matinal and other lower strata—and such indications that the shore-line had undergone an extensive shift in its position, that the evidence of a violent movement of the crust, or change in the level of the sea-bed, is almost as conclusive for this half of the Appalachian zone as for the portion N.E. of the Hudson Valley.

Turning next to the N. outcrop of the Matinal deposits, with a view to the question, whether the disturbance which marked the close of the Matinal period, in the line of the Appalachian chain, extended along this border of the basin, we find that the sequence of the formations remains complete only for a short distance W. of Oneida County—namely, to the E. end of Lake Ontario—and that the break prevails again from Lake Ontario westward to the Missouri River, and generally throughout the wide plain W. of the Appalachian Mountains. Indeed, the whole of the Levant series is not present anywhere W. of Oneida County, but only the Medina sandstone or upper member. This rock, serving but partially to fill the gap, extends through New York to the head of Lake Ontario, and thence, thinning down to the Manitoulin Islands of Lake Huron, it vanishes. The blank thus left by it reaches from Lake Huron to the W. boundary of Iowa.

Tracing the next higher group, the Surgent or Clinton formation, along this border of the basin, from where it takes its station in the series at the foot of the Helderberg Mountain near Schoharie we follow it through New York, to the Niagara River, and through Canada to the Manitoulin Islands, and doubtfully beyond these to the E. end of Green Bay, where there is no longer any vestige of it. The whole deposit is very thin between the Niagara River and the Manitoulins. Though a few fossils of the formation occur among Scalent (Niagara) fossils in Wisconsin, no independent Surgent formation seems to exist there; on the contrary, there is an omission of two entire formations above the Matinal shales all the way from the peninsula, dividing lakes Michigan and Superior, to the neighbourhood of the Missouri River, where the cretaceous deposits of Nebraska overlap and conceal all the older Palæozoic rocks in their prolongation West.

Still directing our attention to the N. border of the basin, bounded by the Matinal outcrop, we observe that the Scalent or Niagara series—the third great Middle Palæozoic formation—assumes its place in the break we have been describing, somewhat farther W. than the Surgent deposit, but presents a much broader outcrop and a far greater development. This group, almost wanting in the Appalachian chain to the S.W. of the Hudson, and very thin in the E. part of New York, becomes, in the W. part of that State, a stratum of much magnitude; and it retains this expansion, and a commensurate richness in its organic remains, all the way to its W. limit, near the Missouri River. From the region of Lake Michigan, to its disappearance beneath the cretaceous strata of Nebraska, it was the first Silurian or Middle Palæozoic formation precipitated on the floor of the Appalachian sea, then established on the previously uplifted and re-submerged strata of the Matinal series.

Reviewing the phenomena presented by this N. outcrop of the earlier Middle Palæozoic strata, we find that they indicate, as among the most important revolutions of the physical geography of their periods, first, at the close of the Matinal age, a tremendous agitation of the bed of the Palæozoic sea, resulting in the upheaval and draining of its sediments throughout several wide districts, and a very general shoaling of the remaining portions. There next arose a local paroxysmal movement of depression in the Appalachian chain S.W. of the Hudson, accompanied by deposition of the Levant or Oneida conglomerate within its narrow area, but characterised elsewhere as a gradual and progressive sinking under of the upraised sea-bed, throughout wider and wider limits, during the later Levant (Medina) and the Surgent (Clinton) periods, until the waters, in the next or Scalent (Niagara) period, resumed almost their ancient extension over their recovered floor. During the first period of this re-subsidence the sea occupied only a long narrow trough, parallel with the Appalachian Mountains, spreading no more than 100 or 200 miles W. from the zone they subsequently occupied. In the next or later Levant (Medina) age, the waters had encroached W. as far as Lake Huron, but were extremely shallow; and in the succeeding or Surgent (Clinton) period, growing deeper, and supporting a greater multitude of inhabitants, they diffused themselves to a limit W. of what is now Lake Michigan. But it was only in the next long age—that of the Scalent (Niagara) formations—that this second-time-created Palæozoic sea recovered all its earlier wide dominion, and spread its waves from where the Appalachian Mountains afterwards uprose upon its borders, and cast it off as far as a distant Western shore, perhaps to be yet discovered, in the region of the Rocky Mountains.

The great crust-movement, denoted by the break in the stratification at the upper limit of the Matinal series, is proved to have extended to the interior of the Palæozoic basin. It is clearly shown in the geological phenomena of the wide anticlinal zone which ranges through Western Ohio, and Middle Kentucky, and Tennessee, approximately parallel with the Appalachian chain. In two districts within this broad flat wave of the strata, the Lower Palæozoic rocks are lifted to the day, and made visible by denudation. In one of these tracts, having Cincinnati for its centre, the Matinal beds, forming a large, elliptical, dome-shaped outcrop, are overlaid by the Scalent or Niagara group, containing, amid its own appropriate fossils, two or three species distinctive of the Surgent or Clinton, though no true Surgent sediments are recognisable. A similar omission of the lowest of the Middle Palæozoic formations occurs around the anticlinal area of Middle Tennessee, along the E. side of which there is neither Levant, Surgent, Scalent, nor Pre-meridian deposit—in other words, no true Silurian formation whatsoever intervening between the Matinal, or uppermost of the older Palæozoic or Cambrian formations, and the Cadent black-slate, the lowest W. representative of the European Devonian strata. But along the N. and W. margin of this tract there does occur a thin layer of Scalent (Niagara) limestone, containing one or two Clinton and Lower Helderberg fossils; and this is the only deposit of a middle Palæozoic age which appears in the wide break between the lower and upper masses along this W. anticlinal uplift of the formations.

The same inferences are deducible from the absence of the earlier Middle Palæozoic formations in this zone as have been already drawn from their non-existence along the Northern side of the basin; namely, that the sea-bottom was upraised into dry land over all this area at the close of the Matinal period, and not fully submerged again until the age of the Scalent or Niagara limestone had arrived.

A still more extensive area of elevation of the Matinal sea-bed is discernible to the W. of the zone just described, in a long chain of exposures of the older rocks, stretching from Lake Superior by the valley of the Mississippi through Southern Missouri and Northern Arkansas, and the Washita Hills, to the igneous axis of the Rio Colorado in Texas. In this long chain of partially independent axes of elevation, observing the same N.E. and S.W. trend which characterises the Appalachians, the undulations are fewer, more depressed, and less continuous than those of that mountain system. The largest areas of the older rocks within this zone are that of Northern and Middle Wisconsin, and that of Eastern Missouri, in both of which the undulations of the crust appear to observe a general N.E. and S.W. trend, or to be in parallelism with those of the Appalachian chain. Other flexures affect the carboniferous strata of the coal-fields E. and W. of the Mississippi; but those which are of a later origin appear to possess in the main a N.W. and S.E. direction, or to conform rather to the lines of elevations and undulations of the Rocky Mountains.

The same great break or interruption in the series of the sedimentary formations, at the upper limit of the Lower Palæozoic strata, is visible around these several Western areas of elevation. In some districts, only a few of the lowest formations of the Middle Palæozoic series are wanting. In other tracts there is no trace of any true Silurian rock, and even the lower members of the Upper Palæozoic series—that is to say, the equivalents of some of the European Devonian—are also absent. Thus a very common case of superposition is that of the Vergent or Chemung formation, resting with a gentle inclination upon equally gently-dipping beds of the Auroral or Matinal series; in Missouri, most generally on the Auroral limestones. In not a few sections in Missouri, there is an almost perfect parallelism between the upper and lower formations, notwithstanding the omisson of several important formations of the middle period.

According to the geological survey of Dr Owen, and the later researches conducted by Professor Swallow, there is a wide irregular tract of the older Palæozoic rocks—Matinal and Auroral—extending along the Missouri River from Moniteau County to St Charles County, and Northward from the Missouri to Salt River of the Upper Mississippi; and the late investigations under Professor Swallow show that this area of the older Palæozoics, or so-called lower Silurian rocks, embraces nearly all the counties of the State south of the Missouri River, excepting a Western belt occupied by the carboniferous limestone and Coal-measures. His map and sections prove, moreover, that all along the irregular N.W. border of this ancient area, the Vergent (Middle Devonian) strata repose with parallelism, but with interruption of sequence, upon either the Matinal or Auroral limestones. There is reason to believe that a similar structural condition prevails still farther to the S.W. In many localities the Vergent formation—called in Missouri the Choteau Limestone—is a thin and obscure stratum, and there the carboniferous limestone appears to overlie the limestones of the older Palæozoic series; but the true extent of the hiatus is that of all the middle and upper Palæozoic formations from the bottom of the Levant to the base of the Vergent.

From these statements it is obvious that, throughout at least a large area of this Western anticlinal zone, the sea-bottom was elevated into dry land at the end of the Matinal period, as it was so extensively in other quarters; but it appears to have remained thus uncovered for a longer interval, or during the lapse of a greater number of formations, than in the tracts farther E. In some districts of the Appalachian chain the uplifting of the Matinal sea-bed was followed immediately by its re-immersion; W. of the mountains, in the district of Lake Ontario, the re-entering of the waters for the deposition of new sediments did not begin till the latter part of the Levant period (Medina). Still farther W. of the chain, or beyond Lake Huron, and in the wide uplift of Ohio and Middle Tennessee, the re-immersion did not take place till the Scalent or Niagara age, and then only partially; and here, in the farthest exposed tract of all in the meridian of Missouri, the return of the waters was postponed until the period of the Vergent sediments, or the middle epoch of the Devonian ages. We may regard this Middle Palæozoic or Silurian sea as a wide mediterranean, covering those portions of the crust which are now occupied by the Northern, Middle, and North-western Atlantic States, gradually shifting its borders and encroaching Westward for the production of successive formations; but it was by no means coextensive with the broader ocean of the three earlier series of formations, the upheaval of whose extensive bed at the close of the Matinal ages conferred upon it its own more restricted shores.

PALÆONTOLOGICAL BREAK AT THE END OF THE MATINAL PERIOD.

By far the most complete interruption in the life of the Palæozoic waters, within the limits of the Appalachian sea, was that which occurred at the close of the Matinal period. It amounted apparently to the extinction of all the organised existences, both plants and animals, of which any relics have been preserved to us. Out of more than 400 species, now known as entombed in the lower Palæozoic rocks of the United States, not more than two or three—and of these there is a doubt—survived the convulsions which closed the Matinal period, and ushered in the conditions which witnessed the deposition of the Middle Palæozoic formations. Every one of the few specimens of the two or three dubious species alluded to were found in so worn and injured a state as to suggest that they had been washed out of the Matinal strata, and may not have lived in any later waters. With the exception of these, every fossil preserved in the deposits overlying the Matinal are specifically distinct from their predecessors, and, according to Mr Hall, those from the Middle Palæozoic rocks, or from the Medina, Clinton, Niagara, Coralline, and Onondaga salt groups of New York, numbered in 1853 nearly 350, to which we may add more than 200 additional species from the lower Helderberg or Pre-meridian series, making in all about 550 Silurian forms unlike any characteristic of the strata below the great break.

DEPOSITION AND DISTURBANCES OF THE LEVANT PERIOD.

The conditions under which the three members of the Levant series were deposited, were evidently peculiar for each. The Levant grey sandstone (Oneida conglomerate of New York), more or less pebbly in its lower beds, and growing less and less coarse as we trace it W. across the Appalachian chain, appears to have been deposited upon the newly-established bed of the ocean by the currents produced by the last of the train of agitations which had just previously terminated the Matinal deposits, and shifted the relations of the waters to the land. We have already inferred that the currents which strewed its materials moved from the E. and N.E. This formation, more than 500 feet thick in some parts of the Appalachian chain, dwindles to nothing under the great coal-basin W. of the mountains, indicating that the waters did not cover the great anticlinal zone of the older Palæozoic rocks of Ohio and Middle Tennessee.

The Levant red sandstone (Medina red shale of New York) fills an area lying somewhat W. of that of the grey sandstone under it. Its E. margin does not reach the border of the great Appalachian valley, where the other is in full force. Expanding to a thickness of 1000 feet before it dives under the great coal-field, it yet fails to reach the anticlinal of Ohio and Tennessee; and its true W. limit is therefore unknown, except along the N. border of the basin, where, as already hinted, it stretches almost as far W. as the Straits of Mackinac. The epoch of this deposit was obviously marked by much greater tranquillity in the waters than those of the strata above and beneath it. In Western New York, and other districts, where the conditions attending its deposition were comparatively quiet, its materials are chiefly those of a finely-comminuted red marl or calcareous red clay, and it contains a few organic remains; but in Pennsylvania, and throughout the Appalachian chain, it is a coarser and more sandy rock, and is almost wholly destitute of fossils. It is not easy to say from which quarter the supply of this sheet of sediment was derived, though the indications are that the source was the N.E.

The Levant white sandstone, also a part of the Medina group of New York, consisting of white sandstones and olive-coloured and reddish slates in complex alternation, though a conspicuous member of the series in the Appalachian Mountains, evidently ceases, like the others, under the great coal-field. Along the N. side of the basin it reaches W. beyond Lake Ontario, becoming, however, very thin. Its upper layers contain in New York, where its chief sandstone member is known as the Medina Sandstone, several characteristic fossils. Some of these, particularly the marine plants, characterise the rock throughout its whole range from Pennsylvania to the S. border of Tennessee. In the Appalachians, the dominant member of this group is a fine-grained yellowish-white sandstone, in some localities almost snowy white. Neither this rock, which belongs to the lower half of the formation, nor the slates and grey sandstones above it, appear to extend as far to the W. in the region of the lakes as the Levant red shale beneath it.

A striking feature of all these strata forming the Levant series, is their general poverty in organic remains. It would seem as if the ocean had not resumed, during their deposition, a state sufficiently favourable for living beings, after the excessive turmoil it had undergone at the close of the preceding Matinal period. Possibly the newly-established climatal conditions of the waters were unfavourable to life; possibly the Levant sea of the Appalachian region was too much insulated from the general ocean of the globe for the introduction by colonisation of the species already created and flourishing in other quarters; possibly time enough had not yet elapsed, after the almost total extinction which marine life had undergone, for the repeopling of this insulated sea.

The disturbances of the crust, and the consequent revolutions of the physical geography in the Levant period, though important, were manifestly of less magnitude than some of those of an earlier date; they were, however, sufficiently great to produce entire alterations in the nature of the sediments, and essential changes in the limits to which these sediments were wafted: we are entitled to infer, indeed, from the superior Westward distribution of the later over the earlier members of this series, that, as the deposition proceeded, the commotions of the crust resulted in a constantly-increasing extension of the Levant waters in that direction, or, in other words, a progressive subsidence of the previously-uplifted Matinal shores.

DEPOSITION AND DISTURBANCES OF THE SURGENT SERIES.

The physical circumstances attending the sedimentation of the very complicated group of deposits we have called the Surgent series, were manifestly very fluctuating. The seven formations or sub-groups of beds composing it were deposited in the region of the Appalachian chain during a long period of alternating conditions of the waters; the Surgent lower slate, Surgent upper slate, Surgent lower shale, and Surgent upper shale, being all precipitated from gently-moving water, which accumulated them towards the N.W. side of the mountain-zone; the Surgent red shale accumulating most to the S.E., and the two sandstones, the Surgent Iron-sandstone and Surgent Ore-sandstone, by swifter currents dispersing their materials widely, but laying them down more irregularly.

Though none of the deposits of the Surgent series reached the anticlinal uplift of Ohio and Middle Tennessee, they seem to have gained the meridian of Lake Huron, where probably the waters of the period possessed a wider Westward diffusion.

The statement already made, that the next later formation, the Scalent (Niagara) limestone, bordering the dome-shaped Matinal rocks in Southern Ohio, though not underlaid by any Levant sediments, contains two or three Levant fossils mingled with its own proper species, suggests as a probability that the Levant waters could not have been far distant at the beginning of the Scalent formation, though it must be confessed we are not in a position to argue critically from phenomena of this sort, until we know more than we do concerning the rate at which species extend or colonise themselves from one geographical habitat to another.

The Surgent period seems to have been one marked by no violent commotion within the Appalachian area. The series is, indeed, singularly destitute of deposits implying any violent action of the waters, being, with the exception of its two sandstones, composed almost entirely of finely-comminuted material, such as denote only very quiescent currents. It appears to have been ushered in most gently, for the transition from the antecedent Levant slates to the slates of this epoch is almost imperceptible. It will appear presently that the passage from the deposition of the Surgent rocks to that of the succeeding Scalent formation, was, if possible, even more gradual, being attended by simply a gradual change in the sedimentation, and a slow successive dying-out of certain forms of life, with a quiet introduction of new forms to replace them.

DEPOSITION AND DISTURBANCES OF THE SCALENT SERIES.

The Scalent (Niagara) deposits, consisting of variegated marls and grey marls surmounted by limestone, exhibit a more decidedly Western development than the two preceding groups. The variegated and grey marls, thick, but not very persistent, in Pennsylvania, follow the Appalachian chain far to the S.W. in Virginia, and their limestone (the water-lime of New York) is also very generally met with; but the Scalent limestone (Niagara) is hardly to be met with in the mountains S.W. of its N. outcrop in New York. On the other hand, the marl-groups cease ere we reach the uplift of the strata in Middle Tennessee, while both they and the Scalent limestone spread far to the W. in more Northern latitudes. It has been already stated that the limestone (Niagara) is imperfectly developed around the Matinal areas of Ohio and Middle Tennessee; indeed, it there appears to constitute the first independent formation deposited after the elevation of the older Palæozoic rocks. It appears to be present too, though thin, in some localities in contact with these older formations in Missouri. But along the N. border of the basin, this limestone, and the shale which accompanies it, stretches continuously, from the Helderberg Mountain in New York, the whole way past the Lawrentian lakes and across the Mississippi nearly to the Missouri, where it is overlapped and hid under the cretaceous basin of Nebraska. From these statements it is obvious that the waters of the later ages of the Scalent period, charged with their clayey sediments, wafted these in greatest abundance to the zone which afterwards became the Appalachian chain, not conveying them to the region of Middle Tennessee, whereas those of the earlier or limestone age precipitated their calcareous matter far more widely towards the W., and in greatest abundance towards the N., or rather the N.W.

The finely-comminuted condition of all the deposits of this series, and the great profusion of organic remains entombed in its once pulpy sediments of clay and carbonate of lime, and the wide uniform sheets into which these sediments were dispersed, all go to prove that the period was one of extremely quiet and uninterrupted aqueous and vital action. We have seen already that the passage strata between the base of this series and the top of the Surgent series subjacent to it, betoken an extremely gentle transition from the one formation to the other, there being, indeed, no sharp line of demarcation to separate either the mineral materials or the organic forms of the red marls of the Surgent group from the variegated and grey marls of the Scalent series before us. We shall hereafter witness a similar gentleness of gradation, implying a similar absence of disturbance at the upper limit of the series, or that which divides it from the overlying shales and limestone of the Pre-meridian or lower Helderberg group.

It is not easy to speculate as to the features of the physical geography, and the aqueous conditions which attended the precipitation of the Niagara or upper Scalent limestone. It is easy enough to account for the clayey sediments of the overlying saliferous shales, as we may readily conceive, from what has been sketched above, that the Appalachian sea of the period must have been bordered by very wide tracts of the yet imperfectly-consolidated clayey strata, those of the Primal and Matinal slates and shales converted into dry land at the period of crust-disturbance which preceded the Middle Palæozoic or Silurian formations. The repleteness of the waters in marine organisms, mollusca, corals, &c., adapted to the secretion of carbonate of lime, suggests that they must have been charged with an abundance of this substance; and we may imagine a ready source for it in the broad tracts of Auroral and Matinal limestone sediments raised into dry land at the close of the Matinal period, the atmospheric waters dissolving this mineral substance, and conveying it to the sea. Perhaps the view of the origin of the limestone most consistent with sound chemical and zoological science is this, that the shore or margin of the Appalachian sea of the time, and all its shoals and islands, were widely fringed with a growth of lime-secreting corals and broad beds or colonies of shell-fish; and that large quantities of carbonate of lime and other constituents of the limestone were poured in among these stone-producing animals, by streams flowing off from the wide upraised plains of the older Palæozoic limestone. It is difficult to conceive that the whole of this broad fossiliferous stratum, abounding though it does in stony corals, was a coral reef in the true sense of that term, for the stratum is too wide, being, in fact, coextensive with almost the entire Northern half of the Palæozoic basin W. of the Appalachian chain: the composition of the rock suggests, moreover, an influx of too much material from the land to be compatible with the simple reef hypothesis.

DEPOSITION AND DISTURBANCES OF THE PRE-MERIDIAN SERIES.

This latest or uppermost representative of the European Silurian rocks maintains itself throughout the Appalachian chain, with a thickness fluctuating from zero to 250 feet, ranging from New York to the Southern States; but it seems to extend to only a comparatively limited distance N.W. of the mountains. Its chief member, the Lower Helderberg limestone, does not reach Western New York, nor is it discernible in the anticlinal belt of Middle Tennessee, where it should appear if it had been deposited so far to the W. It was evidently formed in a basin occupying the existing site of the S. half of the Appalachian chain, having its S.E. margin near the Appalachian valley, towards which the deposit thins to nothing, and its W. limit E. of Lake Ontario and the upraised Matinal areas of Ohio and Middle Tennessee. This slender shallow arm or strait of the Silurian sea was evidently, especially towards the N., of narrower E. and W. dimensions than the area occupied by the waters in the preceding periods. It was bounded, no doubt, both S.E. and N.W., by the uplifted tracts of the older Palæozoic deposits; and we may imagine that the restriction which the basin underwent in the Pre-meridian period was due to a moderate elevation of the crust in the previously upraised anticlinal zone, traceable from the W. end of Lake Erie to Western Ohio, and Middle Kentucky and Tennessee. The coming in of this formation seems not to have been marked by any great paroxysmal movement, though the transition between its organic remains and those of the preceding deposits shows a great revolution in the conditions affecting marine life, this formation being very prolific in organic remains, not less than 200 species of which have been discovered in New York. The close of the formation betokens a very general disturbance of the waters, cutting off nearly all the living inhabitants, suspending the calcareous deposit, and strewing the shifted sea-bed with coarse silicious sand, to the production of a new formation. To this we next proceed.

DEPOSITION AND DISTURBANCES OF THE MERIDIAN SERIES.

This well-characterised sandstone, deemed by palæontologists to be the lowest or oldest representative of the European Devonian formations, is almost as much restricted as the Pre-meridian limestone upon which it reposes, to the Appalachian chain, and the zone immediately W. of it. It does not reach the anticlinal uplift of the strata W. of the great coal-field, but merely spreads itself in a very attenuated stratum as far along its N. outcrop as Western New York. To the S.W. it occurs in the mountains at least as far as Eastern Tennessee. Its greatest thickness is about 200 feet, but it fluctuates much in size; and among the E. outcrops of the strata in the Appalachians, it is sometimes wholly wanting. From these and other circumstances we may infer that this formation was deposited in nearly the same basin or trough of the waters as that which received the Pre-meridian limestone, after a disturbance had taken place, however, in the sea-bottom, and a corresponding change in their shores, especially their N. ones, and after an equally momentous change had arisen in the state of the waters themselves, which were previously quiescent and charged with calcareous matter, but had now become agitated with currents, and turbid with a profusion of floating sand.

The more than 200 species of creatures living in the Pre-meridian sea were all cut off by the changes which ushered in this deposit, and a few new organisms of peculiar type assumed their place. The uncongenial nature of the sediment, and probably the unsteady condition of the medium by which they lived, prevented these from being either numerous in species or populous in individuals. A still greater revolution in the physical geography than that which brought in this Meridian deposit, wholly subverted it, and gave place to a new condition of the sea, productive of a calcareous sediment of altogether wider dimensions.

DEPOSITION AND DISTURBANCES OF THE POST-MERIDIAN SERIES.

The Post-meridian deposits, called in New York the Upper Helderberg group, have a very restricted E. outcrop, their range along the Appalachians extending no farther than from the base of the Catskill Mountain to the Lehigh River; but they have a very extended N. one, stretching from the Hudson westward to Lake Erie, and thence N.W. to Lake Michigan; Southward to Middle Tennessee, and Westward through Northern Ohio, Indiana, and Illinois, and thence through Northern Iowa even to the Missouri River. Though thin towards the E., the formation acquires in the W. a maximum thickness of 350 feet. It encompasses the dome-shaped anticlinal area of the older Palæozoic rocks in Ohio and Kentucky, and just reaches the N. verge of that of Middle Tennessee. Farther W., its most Southern visible outcrops are in Eastern Missouri, where its maximum thickness does not exceed 75 feet.

This widely-distributed calcareous formation, distinguishable from both the underlying and overlying deposits by sixty or more known species of interesting fossils, appears to have been formed in a wide basin which had its S.E. shore under the great Appalachian coal-field, and its N. one nearly coincident with the Lawrentian lakes as far as the Straits of Mackinac. We may presume that its materials were derived from the same sources which furnished those of the great Scalent (Niagara) limestone, upon which, in the Western States, it very generally reposes. The branch of the Palæozoic sea, or wide marine trough in which this very fossiliferous limestone was collected, must have possessed very different limits and dissimilar configuration from those which were the receptacles of the two preceding deposits. Indeed, all the formations, from the Levant to the Meridian sediments inclusive, excepting the great Scalent (Niagara) limestone, were evidently accumulated in a sheet of water extending far, from N.E. to S.W., but comparatively narrow in an E. and W. direction; whereas this far broader formation was spread over a sea-bed, longest from E. to W., and of a N. and S. expansion equal to the length of the other.

A glance at the Geological Map of the United States enables one to discern, in this contrast between the boundaries of the Post-meridian limestone and those of the formations beneath it, the magnitude of the change in a distribution of land and water which must have occurred at the close of the Meridian period. It amounted probably to a submersion of the whole broad area which intervened between the anticlinal zone of Ohio and Middle Tennessee and the W. visible limits of the Palæozoic strata. So prodigious a revolution in the area of the waters, implies a very broad or diffused sinking of the lands upraised at the end of the Matinal and later epochs. The phenomena do not imply, however, that this subsidence of the crust was paroxysmal or very sudden; for though the base of the formation consists, especially Eastward, of argillaceous grits, indicative of some commotion in the yet shallow waters, the prevailing presence of a very pure limestone, with numerous organic remains of structures incompatible with a turbulent medium, intimates very plainly that the deposit took place during a protracted period of repose, ushered in by no convulsive heavings of the crust, but by a gentle and gradual depression of the surface. The termination of the deposit was effected, however, more abruptly, as will be better understood when we have passed in review the physical geography of the next succeeding or Cadent series.

Nearly 100 species of marine organic remains have been already recognised in this formation, and none of them are specifically identical with the forms recovered from the Meridian or yet older strata. Notwithstanding this insulation or exclusive character of its fossils, it is a curious fact that several of its forms resemble closely those of the upper Silurian rocks of Europe, especially the Ludlow strata of England. It would seem as if these Transatlantic species had somehow survived the convulsions which exterminated them in the European part of the Palæozoic ocean, in the end of the Ludlow or Silurian ages, to colonise the waters of the American branch of that sea in the later epoch of this Post-meridian period, which, by the aspect of all its other fossils, is of true Devonian and not Silurian date.

DEPOSITIONS AND DISTURBANCES OF THE CADENT SERIES.

The deposits of the Cadent series resemble none of the formations which preceded them, except the Matinal. Like these, they consist of fissile black carbonaceous slates, and of olive-coloured and bluish more or less sandy shales. They are also almost commensurate with that series in their geographical distribution, following the Appalachian chain from New York to East Tennessee, and extending from the Hudson River to an immense distance W. and N.W. through the continent. Towards the N.E. they appear to enclose the coal-field of New Brunswick. Judging from the composition and contents of the formation—which, it will be recollected, comprises three chief members, two bituminous black slates and an interposed shale—the circumstances under which these sediments were formed must have been peculiar. The Cadent older black slate, the lowest member of the series, reposing immediately upon the Post-meridian limestone, could hardly, from the nature of its materials and its fossils, have been a deep-sea or mid-sea deposit, but was apparently accumulated in very shallow water, over a vastly-expanded and very level plain. It contains, mingled with several species of decidedly marine mollusca, vestiges of a vegetation which appears to have been air-breathing or terrestrial; and it possesses, moreover, such an amount of bituminous matter, or, more truly, such a quantity of material yielding carburetted hydrogen gas, as to give us the impression that it was the accumulation of a very widely-spread sea-marsh or marine savannah. Early in the progress of this deposit, the surface upon which it was forming must have undergone a wide but gentle depression; for, intercalated low down in the black slate, there occurs a band of marine limestone and calcareous carbonate of iron, imbedding organic remains, which imply some depth of oceanic waters.

The second member of the series, the olive-coloured and blue shale, apparently owes its origin to a different physical geography. It seems to have been accumulated in deeper and less sluggish waters—to be the result, in fact, of wide-sweeping, steady currents, charged with argillaceous sediment, sometimes mingled with much sand, and replete with an exclusively marine life. Neither this middle member, nor the black slate supporting it, were spread very widely to the W. of the zone now occupied by the Appalachian chain.

The Cadent upper black slate, however, or a member of the series answering to this description, is very widely distributed, not only along the mountains, but as far W. as the E. verge of the great carboniferous basin of Indiana and Illinois. Indeed, upon the excellent authority of Sir John Richardson, a rock, identical with it or the Cadent lower black slate, occurs far in the interior of the continent, with an outcrop ranging in a N.W. direction through the British Territories, even to the Mackenzie River. Throughout the Appalachian chain and in Ohio, this upper black slate is almost the exact counterpart of the lower; indeed, so closely alike are they, even in their organic remains, that some doubt still exists as to which of them we should refer the black slate of the Western States. In Pennsylvania, this uppermost Cadent formation contains in some localities well-preserved remains of *Lepidodendron*, one of the well-known fossil plants deemed to be distinctive of the Palæozoic coal-measures, fragments of this vegetation abounding indeed between its laminæ. The deposit is, moreover, almost everywhere more or less bituminous, yielding petroleum on distillation, and emitting naturally not only this fluid, but much carburetted hydrogen or coal-gas. Notwithstanding the presence of a few marine or aquatic organisms, this feature seems to justify the hypothesis we have above ventured upon, in explanation of the similarly-constituted lower black slate of the same series. I deem it highly probable that the whole deposit was once the muddy floor of a broad sea-meadow or morass, occupied at times by the ocean tides, and sustaining, at least in its drier localities, an air-breathing or terrestrial vegetation, foreshadowing in its aspect and structure that of the coal-producing savannahs of the long-subsequent carboniferous ages.

It is evident, from this brief sketch of the conditions of deposition of the Cadent strata, that an entire revolution must have taken place in the physical geography of the Palæozoic sea at the close of the Pre-meridian period. It is not difficult to perceive that this change was connected with an extensive shallowing of the waters, and with an oscillation of the bed of the sea which twice brought it, at least over very wide tracts, almost into the condition of dry land. In this tendency to a shoaling up, or to a broad-diffused rising of the bed and shores of the Appalachian ocean, in the later Palæozoic times, we witness the beginning of that interesting train of oscillations of level which terminated in the great coal-formation, where the proofs of such a fluctuation are so conspicuous. As we proceed in our sketch of what is most significant among the phenomena of the later formations, we shall discover more and more abundant relics of terrestrial vegetable life, and constantly-accumulating evidences of this frequently-recurring oscillation with exposure to the atmosphere, of the ancient Devonian and Carboniferous shores, until we enter the coal strata themselves, where every coal-bed is a monument of a plane at the sea-level, supporting its rank vegetation partly in the water, partly in the air.

DEPOSITIONS AND DISTURBANCES OF THE VERGENT SERIES.

The state of things prevailing at the deposition of the Vergent series (Chemung group) would appear to be very different from those productive of the Cadent black slates, but somewhat analogous to the conditions which gave birth to the Cadent shales. In the Appalachian chain the formation comprises two members: a lower mass, composed of flagstones parted by blue shale, and abounding in the marine vegetation called Fucoides; and an upper mass, consisting of grey and olive-coloured shales and grey sandstones, replete in the shaly beds with marine mollusca, especially brachiopods. Under these types this series ranges from New York along the Appalachian chain to Tennessee, and W. through the S. side of New York to Lake Erie, and thence S.W., skirting the great Appalachian coal-field to the Tennessee River in Northern Alabama. From Middle Tennessee, where it encompasses the older formations in a narrow tortuous outcrop, it sweeps N. through Kentucky, and thence N.W. along the E. margin of the second great coal-field to Northern Illinois, where it thins out near the Desplaines River east of La Salle. The formation reappears on the W. side of the Illinois coal-field, and ranges in a slender irregular outcrop in a S.W. direction centrally across the State of Missouri, which it leaves at its S.W. corner to enter the Indian territory. At this its most Western outcrop the rock wears a very different type from that which it possesses anywhere E. of the Illinois coal-field. The lowest member is a lithographic limestone about 60 feet thick; the middle. a blue shale and buff-coloured argillo-calcareous sandstone, containing but few fossils, except Fucoides or sea-weeds, and usually about 75 feet thick; and the highest member, a limestone, magnesian in its upper division, and 70 feet thick when at a maximum. Lithologically, the middle member is the only one which corresponds to the E. type of the deposit, and it is probable that the limestones which enclose it are independent sub-formations not elsewhere represented.

Taking a wide view of the Vergent series, one of the features which first arrests our attention is the amazing declension in thickness which the whole mass undergoes as it spreads from the Appalachian chain to Northern Illinois and Missouri, declining with a regular gradation from a diameter of nearly 5000 feet to one of 200 feet W. of the Mississippi, and thinning to nothing S.W. of Lake Michigan. This gradual declension of size is attended with a gradual reduction in the coarseness of the whole mass, and in the magnitude and frequency of the arenaceous beds—all circumstances which go to indicate that the E. and S.E. was the quarter whence the materials were derived. A confirmation of this view is to be found in the less littoral or more purely marine character of all divisions of the mass in its extreme W. outcrop in Missouri. One of the most surprising features of the formation is the aspect which it almost everywhere presents of shallowness in the depositing waters. One intimation of this is the constant abundance of certain types of marine vegetation, such as could hardly flourish in a deep sea; another is the occasional presence of relics of a terrestrial flora, especially of *Lepidodendron*. But the most significant signs of all are the frequent occurrence of ripple-marks, and the *glazed* surfaces and lines of trickle, which imply extreme shallowness in the water, and occasional exposure of the forming sediments to the atmosphere.

It is obvious that the waters which received this formation, though not deep, were very widely distributed, spreading Westward even beyond the limits which they occupied in the preceding period, during the deposition of the Cadent sediments. I think we are entitled, from all the phenomena of the Vergent series, to conjecture that its sea-basin experienced, throughout at least its Eastern half, a gradual progressive subsidence of its bed, without any important paroxysmal oscillations during the accumulation of its sediments, and that the materials for these were swept in, under remarkably uniform conditions, during a great lapse of time. The beginning of the Vergent formation was not signalised by any vehement crust-disturbance, nor do we witness indications of any violent derangement of the floor of the sea at the close of the period, though in the W. portion of the area we behold a break in the succession of the strata, or a conformable interrupted sequence, of much importance, implying a quiet lifting-up of the sea-bed into dry land at this epoch. The proofs of this will appear under the next head.

DEPOSITIONS AND DISTURBANCES OF THE PONENT SERIES.

The Ponent series (Catskill Group of New York), the uppermost Red Shale and Sandstone formation, except the Umbral series, or middle member of the Carboniferous formations, would appear to be an exclusively Eastern or Appalachian deposit. It seems to attain its greatest bulk in Pennsylvania, where its thickness exceeds 5000 feet. It gradually declines in size toward the S.W., and even thins away in Eastern Tennessee. In a transverse direction it abates much more rapidly, growing thin under the Alleghany Mountain, and fining off to nothing before it reaches the Alleghany River. It must originally have spread itself far E. across the Appalachian chain, for it presents its fullest thickness at the more Eastern outcrops left after very extensive denudation. Its attenuated W. or N.W. margin is everywhere under the great Appalachian coal-field. Like the Levant, and some of the earlier formations of the Middle Palæozoic series, this thick but comparatively restricted deposit seems to have been formed in a branch or trough of the sea, nearly coincident with the zone now occupied by the Appalachian Mountains, and part of the great coal-field W. of them, and, as in some of the prior instances, the land-derived materials were probably swept into this slender basin longitudinally, entering it from the N.E., and partially from the E. That these materials were dispersed to so limited a distance W. seems best explained by supposing that newly-uplifted tracts of land, composed of the lately-deposited Vergent series, lay in that direction, for it is hard to understand, if the waters still spread to the W., as in the Vergent period, why these Ponent sediments, quite as impalpable and buoyant as those of the Vergent shales, floated so short a distance; nor can we comprehend why, if they ceased from expenditure of material, the waters assumed to extend farther West did not precipitate something of a more purely marine character, to remain as a monument of their presence there. We are constrained, therefore, to imagine a very wide and diffused elevation of the crust, changing the level of the sea's bed at the end of the Vergent period, lifting it into dry land W. of the present mountains, but probably depressing it into a comparatively deep slender trough along its S.E. border. The argument for this hypothesis becomes strengthened when we review, as we shall presently, the phenomena of relative distribution of the Vergent and lower carboniferous strata in the Western States.

DEPOSITIONS AND DISTURBANCES OF THE VESPERTINE SERIES.

We come now to the consideration of the conditions under which the first or oldest of the true Carboniferous formations was produced. This Vespertine series betrays, in everything connected with it, a littoral or semi-terrestrial origin. Consisting of grey and yellow sandstones alternating with coarse silicious conglomerates and with dark-blue slates and shales, and containing beds of black carbonaceous slate, and even here and there a thin impure seam of coal; possessing, moreover, no decidedly marine organic remains, but numerous relics of the terrestrial vegetation, significant of the subsequent coal period,—it is essentially a mass of barren or unproductive Coal-measures, and must be viewed as having been formed under very nearly the physical conditions which attended that important formation. The most material difference in their composition is the absence from the Vespertine series of numerous and widely-extended sheets of coal, a feature which implies, that during its accumulation there were not those repeatedly-recurring intervals of almost absolute repose of the crust, with constancy of sea-level requisite for the growth of the coal-producing meadows, but, on the contrary, that the period was one of more incessant agitation. Possibly, too, the Vespertine strata were formed too much under water, and not, like the Coal-measures, sufficiently near the common limit of air and water to admit sheets of vegetable carbon to be stored up within them. Certainly the physical geography of the period, so far as it is indicated in the respective boundaries of the two formations, was wholly unlike that of the age of the coal. The geographical limits of the Coal-measures, as elsewhere shown, were very broad, the W. verge of the formation lying in Nebraska, Kansas, and Central Texas. Those of the Vespertine strata are much more restricted, being confined to the Appalachian chain on the S.E., and on the N.W. to the Appalachian coal-field, even the N.W. border of which they fail to reach where this basin is broadest in North-western Pennsylvania and Ohio. The area occupied by the whole formation is a long, comparatively narrow zone of country, commencing in N.E. Pennsylvania, and stretching S.W. to North Alabama. Throughout this zone the deposit displays its thickest outcrops along its most Eastern exposures in the mountains, and its actual maximum on the borders of the Schuylkill anthracite coal-field. From this line of its greatest development the mass steadily declines in thickness, and grows less coarse and heterogeneous in composition as it spreads towards the N.W. and W., until it dwindles away entirely before it reaches the place where it should outcrop on the W. edge of the great coal-field in Ohio. Unlike the Ponent stratum underneath it, it does reach the Alleghany River in Western Pennsylvania, though under a very attenuated thickness.

From these facts it would appear that the Vespertine sediments were received in a sheet of waters somewhat coincident in position and limits with that which was previously the receptacle of the underlying materials of the Ponent series, a view corroborative of that already presented, that the close of the Vergent period was an epoch of elevation of a very broad area of the ocean's bed into dry land, in the region now lying to the W. and N.W. of the great Appalachian coal-field.

The materials of the Vespertine rocks, their lessening gradation in size going W., the direction of their bedding, and sundry other phenomena, all concur to suggest that the deposit was chiefly derived by currents and paroxysmal movements of the waters from the E. and N.E., from shores much convulsed by repeated agitations of the crust, but not amounting to undulations productive of permanent flexures.

DEPOSITIONS AND DISTURBANCES OF THE UMBRAL SERIES.

An extensive and marked change arose in the physical geography of the Palæozoic sea at the close of the Vespertine period. Judging from the composition of the Umbral or Middle Carboniferous strata, and the features of their geographical distribution, we must infer that these were deposited under circumstances very dissimilar from those which saw the accumulation of either the Vespertine sediments which preceded them, or the Coal-measures which usurped their place in the ages following. We have mentioned in our description of the Umbral deposits, that in the Appalachian chain the series consists, in its fullest development, which is in Virginia, of buff and red shales below, of a thick limestone in the middle, and of blue, olive, and red marly shales, with red and brown sandstone above; and that in Pennsylvania the whole mass is composed of red shale and argillaceous red sandstone under a maximum thickness, where it surrounds the S. anthracite coal-field of 3000 feet. This great red-shale deposit of Pennsylvania was, it is obvious, collected in a portion of the wide oceanic basin of the period, much more copiously invaded by the washings of adjacent lands than were the districts lying to the S.W. and W. Everything connected with the red shale and sandstone betokens, indeed, an origin contiguous to agitated coasts swept by turbid currents. The total absence of organic remains is an intimation that the sea was too foul with poisonous sediments to permit the presence of the usual marine animals; and the abundance of ripple-marks, sun-cracks, and the specks attributed to rain, and called rain-spots, confirm the impression of the nearness of the land, by giving proof that the layers, while yet freshly deposited, were frequently laid naked to the atmosphere. That they were thus exposed in some localities is, indeed, actually demonstrated by our finding many layers of the rock covered with that polish and those marks of trickling water which never arise in deposits continuously submerged, but are produced solely where an impressible slimy material is left naked by a gentle recession of the precipitating waters. But the crowning proof of all is the occasional occurrence of quadrupedal footprints on these water-marked surfaces, clearly referable to reptilian animals of a batrachian type.

The gradual introduction of a limestone formation in the centre of this shale deposit in the S.W. part of the mountain-chain in Pennsylvania, and its steady enlargement as far at least as the Greenbrier River in Virginia, where its thickness exceeds 1000 feet, is an intimation that a change occurred towards the middle of the period, deepening the bed of the sea for the reception of purely marine matter and of organic inhabitants, and cleansing it of the clayey sediments derived from its E. or N.E. shores.

Crossing the Palæozoic area W. to the W. outcrop of the Appalachian coal-field, we are surprised to find nearly all traces of the red shale, both that underlying and that resting upon the limestone, entirely gone from the series; and upon tracking the deposits from North-eastern Pennsylvania in the same direction W., where no limestone whatever enters the red shale, we perceive that this latter material undergoes a rapid and progressive attenuation, until it vanishes altogether before we reach the waters of the Alleghany River. It would thus appear that the land-derived or argillaceous and sandy beds of the Umbral formation are essentially an E. deposit, and that it was only towards the S.W. that the sea of that epoch precipitated any carbonate of lime; but the area of the Umbral ocean which collected this deposit was a very broad one, for the limestone not only ranges as a continuous stratum from Cambria County, Pennsylvania, to the S. end of the great coal-field in Central Alabama, but it skirts the W. border of that coal-field in Eastern

Kentucky and Middle Tennessee, encloses all but the N. side of the great coal-field of Western Kentucky, Indiana, and Illinois, and even entirely encompasses and underlies the enormous coal-basin which ranges from Central Iowa through Missouri to Western Arkansas. This carboniferous limestone is indeed, to all appearance, the most widely-diffused formation as yet identified by its fossils in North America; for passing under the broad cretaceous basin which fills the plains of Nebraska, Kansas, and Western Texas, E. of the Rocky Mountains, it reappears in that chain, and in the valley of the Rio del Norte, and, plunging under again and again, regains the surface under full development in the Wahsatch Mountains of Utah, and yet farther W. in the Humboldt Chain of the Great Desert. Until its far W. localities are better known, it is impossible to define, even approximately, the limits of this prodigiously broad calcareous sea-bottom; but there is reason to believe that it reaches Vancouver's Island, and that it is the limestone of some of the valleys of the Pacific slope.

The uniform and tranquil physical conditions of the period, implied by the wide diffusion and uniform nature of the deposit, and the character of its organic remains, mark an age which was a fit prelude to the period of the coal-formation which immediately followed, a period in which the geographical scale of action in this quarter of the globe was almost as grand, but which was marked by a uniformity of surface, and of physical and vital conditions wholly different in their nature. I shall present in another place an analysis of the circumstances attendant upon the production of the coal strata.

As the beginning of the Umbral period was marked by a striking change in the state of the precipitating waters, so would seem to have been its close. This latter was evidently attended by a very broad and equal lifting of wide portions of the sea-bed, overspread with its sheet of limestone, and with such commotion in the region of the Appalachian chain, and of the coal-fields W. of it, as far as that of Missouri inclusive, as to strew the uprisen floor with a very broad sheet or sheets of land-derived sandy and pebbly matter, the foundation of the first soil on which the swamps and jungles of the lowest coal-seams of the productive Coal-measures grew. But surpassing this wide-rising of the earth's crust was the sinking of it, which seems to have taken place at the first letting-on of the Umbral waters in which the Carboniferous limestone was to be collected. We have seen that, throughout the Ponent and Vespertine periods, and, we may add, the period of the first half of the Umbral red shale, there could have been no sea W. of the present W. margin of the Appalachian coal-field, as none of these rocks, nor any marine equivalents of them, are discernible at or beyond that boundary. The area of subsidence, therefore, for the reception of the limestone, was almost coextensive with the breadth of the continent. That the ocean came over the dry land, which had remained as such since its upheaval at the close of the Vergent period, gently, and not with paroxysmal violence, is recorded in the universal absence of any widely water-strewn materials between the limestone and the Vergent floor upon which it rests.

As yet we know too little of the strata in and beyond the Rocky Mountains, to speculate respecting the events of the Palæozoic ages on that side of the continent. We must postpone the attempt until further researches accumulate additional data.

The design of the remaining part of the present chapter is to exhibit in a condensed shape some of the most characteristic phenomena of the great coal-formation of the Appalachian region of the United States, to develop the laws which regulate the distribution and order of succession of the strata, and to discuss the theory of their origin.

OF THE LIMITS OF THE APPALACHIAN COAL STRATA.

The extensive Appalachian coal-formation embraces all the detached basins, both anthracitic and semi-bituminous, of the mountain-chain of Pennsylvania, Maryland, and Virginia, and also the vast bituminous trough lying to the N.W. in Pennsylvania, Ohio, Virginia, Kentucky, Tennessee, and Alabama. I shall endeavour presently to show that all these coal-fields, extending from the N.E. counties of Pennsylvania to the N. part of Alabama, and from the great Appalachian valley Westward into the interior of Ohio and Kentucky, include only a portion of the original formation, immense tracts having been destroyed by denudation. A comparison of the coal strata of contiguous basins has convinced me that they are only detached parts of a once-continuous deposit; and the physical structure of the whole region most satisfactorily confirms this idea, by showing that they all repose conformably on the same rocks; the more or less insulated troughs in which they occur, merely being separated by anticlinal tracts of greater or less breadth, from which denuding action has removed the other portions of the formation. This distribution of the coal in a series of parallel and closely-connected synclinal depressions, is a direct result of the system of vast flexures, into which the whole of the Appalachian rocks have been bent, by the undulatory movements that accompanied the final elevation of the strata, and terminated the era of the coal.

Many of the general phenomena about to be described, seem to belong, in an equal degree, to the wide coal-basins of equivalent age, which lie remote from the Appalachian chain, far to the N.W.; namely, that of the State of Michigan, and that which occupies a part of Indiana, Illinois, and Missouri. I shall confine my views for the present, however, to the formation as it is developed in the mountain-basins, and in the great trough or plain which lies immediately to the N.W. of the chain. This last, most Western, or chief Appalachian basin, terminates on the N.E., near Towanda, in Bradford County, Pennsylvania, while its S. point is near Huntsville, in Alabama. The S.E. margin coincides nearly with the main escarpment of the Alleghany Mountain, as far S. as the county of Hardy, in Virginia, beyond which it lies farther to the N.W., following as it ranges through that State, and through Tennessee, the great line of escarpment locally named Laurel Hill, Rich Mountain, Little Gauly Mountain, Great Flat Top, and Cumberland Mountain, ending with the termination of the last in Northern Alabama.

The opposite or N.W. outcrop, commencing likewise at Towanda, extends nearly W. through the N. counties of Pennsylvania to the Alleghany River, at Warren. It here begins to curve gently S., passing through Crawford and Mercer counties, and enters Ohio north of Sharon. Beyond this its general course is about W.S.W. to Akron, where it deflects to the S., so as to pass about 25 miles W. of Zanesville, after which it crosses the Ohio River a few miles above the mouth of the Scioto. Southward from this point the W. line of the coal traverses Kentucky in a S.S.W. direction, passing the Kentucky River near the centre of Estil County, and the Tennessee line a little East of Rock Creek. Ranging through Tennessee, its course is rather irregular, first running S. to Montgomery, thence N.W. to Morgan, and thence by a winding line S. to Sparta, beyond which it stretches S.W. to the termination of the Cumberland Mountain, N.E. of Huntsville.

This enormous tract of the coal-formation is unbroken, except in two quarters : first, near its N.E. termination, and along its N. border in Pennsylvania, where, by the influence of denudation, and a few low anticlinal arches, many small patches of the strata lie insulated from the general mass ; and, secondly, along its S.E. side in Pennsylvania, Maryland, and Virginia, where a few bold axes of elevation have thrown the coal-rocks into a series of long, parallel, and nearly united troughs. Considering all of these outlying portions of the formation as subordinate and intimately-connected parts of one great bituminous coal-field, the S.E. boundary of which is the escarpment of the Alleghany and Cumberland mountains, the dimensions of the great basin will be nearly as follows : its length, from N.E. to S.W., is rather more than 720 miles, and its greatest breadth about 180 miles. Upon a moderate estimate, its superficial area amounts to 70,000 square miles.

Though the deep anthracite basins abound in curious structural features, and contain thick seams of coal, they chiefly interest us at present by the geographical position which they occupy. More than 40 miles distant from the general denuded margin of the main or W. coal-field, they nevertheless present, in the character of their strata, and of the rocks upon which they repose, unequivocal evidence that they and the bituminous basins were once united. In this identification we are presented with an amazing picture of the former extent of our carboniferous deposits. The existing S.E. limit of the coal, in these insulated basins, lies, in Pennsylvania, only a short distance to the N.W. of the great Appalachian valley, and a survey of all the circumstances involved in the question of the ancient physical geography of the formation, convinces me that it extended, both in that State and Virginia, at least as far to the S.E. as the great valley. To enter here into all the facts and reasonings upon which this inference is founded, would lead me aside from the main purpose of the present chapter ; but I may mention, as one argument, that a group of coal strata, somewhat lower in the formation than the main series, does reach, at intervals, as far E. as the margin of the great valley, in a number of localities between the Potomac River and the Tennessee line. Restricting our attention at present, however, to those districts where the main coal series is developed, we meet with the most ample proofs that all the strata in the insulated basins are precisely on the same geological horizon as those of the great basin W. of the mountains. These coal-rocks all repose conformably on the same easily-recognised formation, the great coal-conglomerate, with the upper beds of which the lower seams are very generally interstratified. This fact, but more especially the circumstance that I have traced many of the principal coal-seams and beds of fossiliferous limestone from basin to basin, fully demonstrates that all these detached troughs, however insulated and remote from the main mass at present, were, at the period of their deposition, united in one continuous formation, which, previously to its elevation and waste by denuding currents, extended from near the E. side of the Appalachian chain to a W. margin at least as distant as the centres of the States of Ohio, Kentucky, and Tennessee.

Here then we have a coal-formation which, before its original limits were reduced, measured, at a reasonable calculation, 900 miles in length, and in some places more than 200 miles in breadth. I would ask, is it conceivable that any lake, bay, or estuary, could have been the receptacle of a deposit so extended, or that any river or rivers could have possessed a delta so vast ? The ancient Appalachian ocean grew deeper, as I shall show, towards the W. or N.W. ; and inasmuch as rivers push their deltal deposits seawards, and not laterally, and as the carboniferous sediments here to be described are traceable coastwise, as respects this ancient sea, for a length of 900 miles, it is inconceivable how any local fluviatile currents could have assembled them.

NATURE OF THE COAL STRATA.

Assuming it as susceptible of demonstration, that the various coal-basins, bituminous and anthracitic, of Pennsylvania, Ohio, Maryland, Virginia, Kentucky, and Tennessee, were originally united, we may consider the whole as one great formation, in which some highly-interesting gradations in the type and composition of the beds may be traced. To call attention to these phenomena of variation is indeed my main object at this time, since by them only can we arrive at a true theory of the conditions under which the whole were formed. A comprehensive classification of the strata shows the following principal varieties :—

1. Rocks of mechanical origin, of every grade of coarseness, from the smoothest fire-clay to exceedingly rough silicious conglomerates, the whole including within these extremes a wide variety of shales, marls, argillaceous sandstones, and quartzose grits.

2. Limestones, both pure and magnesian, in strata of all thicknesses, from thin bands and narrow layers of detached nodules, to beds measuring from 50 to 100 feet depth. Some of the limestones contain a considerable amount of argillaceous and silicious matter, and many of the thicker deposits consist of alternating layers of limestone and soft shale. Though a few of these calcareous strata are remarkably destitute of fossils, they are rarely found to be altogether deficient in organic remains, when widely and diligently searched; and some of them quite abound in them. It is especially deserving of note, that the genera are such as invariably indicate oceanic habits. This fact is of the more importance, since some of the limestones occur in immediate contact with beds of coal, and with shales and other strata containing the remains of terrestrial vegetation.

Besides the strata of limestone, we meet with other chemically-formed deposits, in the form of numerous seams of carbonate of iron, and a few considerable beds of regularly-stratified chert. The nodular variety of the iron ore is usually imbedded in shale, and lies oftenest adjacent to the coal, while the ore in bands occurs more frequently in contact with the limestone.

3. Coal, in nearly all its known varieties, including every description, from the dryest and most compact anthracites to the most fusible and bituminous kinds of common coal.

Such are the three great classes of strata comprised within the Appalachian coal region of the United States. If we direct our attention to the manner of their distribution, we shall behold some striking and instructive phenomena, susceptible of reduction to regular and harmonious laws of gradation.

Comparing, in the first place, the rocks of mechanical origin as they occur in different districts, we almost invariably find them coarsest and most massive towards the S.E., and more and more fine-grained and less arenaceous as we pursue them across the successive parallel basins N.W. Thus in the anthracite coal-fields, which are the most South-eastern of all, the coal is interstratified with a vast thickness of rough and ponderous grits, and coarse silicious conglomerates, but is associated with comparatively very little soft clay-slate or shale. In this region the coal-slates themselves are more than ordinarily arenaceous, and bear a smaller proportion to the sandstones than in the basins more to the W. At the same time that the coal-rocks, viewed in the aggregate, acquire a finer texture in going W., the individual strata undergo a corresponding reduction in thickness, while many of them entirely thin away. I may cite, as a striking instance of these changes, the great coal-conglomerate itself, which forms the general base of the main or upper Coal-measures. This massive rock is chiefly composed of large quartzose pebbles imbedded in coarse sand. Adjacent to its most S.E. outcrop in Pennsylvania—that is to say, in Sharp Mountain, where it constitutes the boundary of the first or Pottsville basin—it has a thickness of nearly 1500 feet; but in the mountains which embrace the Wyoming coal-field, about 30 miles to the N.W., the thickness of the formation is only about 500 feet; while still farther across the chain, where it becomes the general floor of the Coal-measures under the bituminous form, in the basins N.W. of the Alleghany Mountain, its entire thickness seldom exceeds 80 or 100 feet. Tracing it across the great Western coal-field, until we encounter its last outcrop in Western Pennsylvania, Ohio, and Kentucky, this wonderfully-expanded rock dwindles to a thin bed of sandstone, sprinkled with a few pebbles, its whole thickness amounting generally to only 20 or 30 feet. There is a corresponding and quite as striking a diminution in its constituent fragments, the pebbles in the most S.E. belts of the formation being often as large as a hen's egg, while in the N.W. their diameter is reduced to that of a pea.

A similar gradation obtains in the thickness and coarseness of nearly all the interstratified sandstones and other mechanical members of the formation. I conceive that this interesting fact, fully established by the surveys of Pennsylvania and Virginia, shows beyond all question that the S.E. was the quarter whence the coarser materials of the coal-rocks were derived. But there are not wanting other proofs that the ancient land lay in that direction; these will be presently detailed in describing the gradations witnessed in the limestones and beds of coal. The above general law of distribution relates, it should be observed, only to the coarser mechanical aggregates, since there are some apparent exceptions to its generality among the finer-grained slates and shales. Though the texture of these continues to grow finer as we advance W., some of the strata, when individually traced, seem to increase for a certain distance in thickness. This curious circumstance, which belongs indeed to many of the more argillaceous members of our Appalachian formations, so far from invalidating the above inferences respecting the W. transportation of the sediments, comes beautifully to confirm them, since it is evident, that until a current, holding in suspension a quantity of sedimentary matter, declines in velocity to a certain point, it cannot let fall any considerable amount of the smaller particles. After it has reached a given degree of retardation, the finer materials will subside, and in an increasing quantity, up to a certain point, at which the loss of velocity in the current is compensated by the exhaustion of material, when a gradual and final thinning of the deposit will take place.

If we examine, in the next place, the gradations of thickness visible in the limestones and other marine deposits, they will be found to lead to precisely similar inferences respecting the position of the ancient land. Viewed either together or individually, the limestones of the Coal-measures of Pennsylvania, Virginia, and Ohio, display a remarkably uniform augmentation as we trace them W. Thus, throughout all the S.E. basins, comprising the whole of the anthracite coal-fields of Pennsylvania, and the Broad-Top Mountain in the same State, the formation exhibits a total absence of limestone, and a corresponding deficiency of calcareous matter in the shales and the iron ores. Advancing, however, a distance of 25 or 50 miles N.W. to the general S.E. margin of the great bituminous region, where we enter on the first of the chain of partially-insulated troughs adjacent to the escarpment of the Alleghany Mountain, we no longer encounter a total poverty of limestone, though we still meet with a striking deficiency. As an evidence of this, let us take one of the basins of the Alleghany Mountain—that, for example, which lies near the head of the Potomac River. The minute researches there made in connection with the geological surveys of Virginia and Pennsylvania, have shown that the total thickness of the limestones, counting all the thin bands and layers of nodules, does not probably exceed 10 feet. This statement is confirmed by a pamphlet on the same coal-field, describing the land of the George's Creek Company, by Messrs Alexander and Tyson. In their very full section of the strata, we do not see a single band of limestone introduced.

Turning to the Moshanon basin, in Centre County, which is also a marginal trough of the great W. coal-field, the entire quantity of limestone appears to be about 7 or 8 feet. If, however, we pass W. from this S.E. line, and cross the great coal-fieldby any section between the Susquehanna in Pennsylvania and the Little Kenawha in Virginia, we witness a regularly progressive expansion of the calcareous rocks. In the following tabular statement, which refers chiefly to the Southern counties of Pennsylvania, this gradation is rendered strikingly obvious :—

TABLE FIRST,

Showing the gradual Increase in the aggregate Thickness of the Limestone, as we cross the Southern Coal-field of Pennsylvania, westward.

Broad-Top basin, half-way across the Appalachian chain,	*none.*
Potomac basin, near the main escarpment of the Alleghany Mountain,	about 10 feet.
Eastern basin of Somerset County, W. of the escarpment, and about 12 miles W. of the Potomac basin,	12 „
Ligonier basin, 20 miles W. of the last,	30 „
Second Western basin on the Youghiogheny River, 15 miles W. of the last,	about 40 „
Great basin of the Monongahela and Ohio rivers, at Brownsville, probably	60 „
Same basin at Wheeling,	about 200 „

The above aggregates admit the more accurately of comparison, since most of them refer to the same portion of the formation—that, namely, which is included between the great conglomerate and the top of the main limestone, above the Pittsburg Coal-seam.

TABLE SECOND,

Showing the Gradation in the Thickness of the large Limestone Stratum overlying the Pittsburg Coal-seam.

Cumberland basin, not more than	2 feet.
Eastern Somerset basin, not determined, but	thin.
Ligonier basin,—average about	7 feet.
Monongahela and Ohio basin, at Brownsville,	41 „
Same basin at Wheeling,	54 „

In the upper coal group, or that part of the series which commences with the Pittsburg Seam, the total thickness of pure limestone, excluding numerous thin bands associated with some of the layers of shale, is not less than 150 feet.* Some of the limestone strata of the Coal-measures possess, as will be seen from the second of these tables, a remarkably wide distribution, ranging without interruption from the vicinity of the Alleghany Mountain to the country W. of the Alleghany River. Having ascertained the positions of a number of these fossiliferous beds, I am now engaged in investigating their organic remains. The examinations already made show that these all belong to *marine* genera, and that the different beds are characterised by their peculiar species. Many of these beds of limestone have been traced continuously from Northern Pennsylvania to the Kenawha, and from the E. outcrop, near the Alleghany Mountain, to their W. boundary in Ohio. The marine character of their genera—*Terebratula, Goniatites, Bellerophon, Encrinus,* &c.—sufficiently proves that these rocks were originally deposited beneath the waters of an ocean, while, at the same time, the increasing purity of the limestones and the multiplication and expansion of the beds Westward, clearly show that the ancient ocean augmented regularly in depth in that direction. This conclusion, it will be observed, agrees strictly with the results before deduced from the general gradation, visible in the sandstones and other mechanically-formed rocks, which proves that the ancient land was situated towards the E. or S.E. If we examine the relations of the two classes of the coal strata to each other, the land-derived and sea-derived rocks, we perceive that the latter, or the limestones, thicken, going West, at the expense of the former. Frequently two beds approach, and either entirely coalesce, or remain divided by only a thin marly shale, formed from the residual finely-subdivided matter wafted out by the currents, which, farther E., or nearer the land, deposited the coarser and thicker sandstones and arenaceous slates. While this gradation shows itself, new beds of calcareous rock interpolate them-

* See "Report of Geological Survey of Virginia for 1840."

selves in new positions in the series, and many of the sandstones thin away and cease altogether, so that the whole formation becomes, by both these changes, more and more oceanic in its type. But the most important result of this mode of tracing the strata is the evidence we have of the frequent alternation of a tranquil and disturbed condition of the waters. Such an intermission of movement and repose will be more fully proved when I come to describe the phenomena connected with the coal-seams. It may be sufficient here to refer to what I have above stated respecting the oceanic and shore rocks, and to appeal to the argument that the coarser or more irregularly strewn the materials of a stratum are, the more violent must have been the current which transported them. With these considerations before us, we cannot fail to perceive in the Appalachian coal strata the monuments of many alternate periods of movement and total or comparative rest. If it be conceded that each of the purer beds of limestone, remarkable for the extreme fineness of their texture and the absence of foreign sedimentary matter, is the index of a longer or a shorter interval of tranquillity in the waters, we shall discern (omitting for the present all similar inferences to be derived from the coal-seams) a much greater number of such separate periods than a mere enumeration of the individual beds would indicate, unless we count the interstratified shales and marls. These last-mentioned strata, generally assuming, as we go E., a thicker and coarser type, furnish as unequivocal a record of disturbances as if the spaces they occupy between the beds of limestone were filled by the coarsest mechanical aggregates.

One of the most interestinggeneral questions connected with the land and sea produced strata relates to the physical geography of the ancient coast near to which they were deposited, and the inquiry at once suggests itself, whether the receptacle of these various sediments was an extensive estuary receiving the silts of some gigantic river or rivers, or a vast expanse of shallow sea, bounded by a long line of coast, upon which the successive deposits were formed by a very different agency from any we can ascribe to ordinary fluviatile or littoral currents.

OF THE PHENOMENA CONNECTED WITH THE COAL-SEAMS.

Great extent of certain individual coal-beds.—Passing, in the next place, to an examination of the most interesting portion of the coal strata, the coal-seams themselves, we discover in the facts connected with their range and distribution, in the structure of the coal, and in the nature of the beds in immediate contact with the seams, several general laws, tending to afford us a still better insight into the physical conditions which accompanied the production of these strata.

Of the facts connected with the range of the individual coal-seams, that of their prodigious extent is itself one of the most surprising and instructive. As a general rule, this wide expansion characterises all the beds of both the bituminous and anthracitic basins. It is true that many seams possess a comparatively local range,but not a few of those which, on first examination, appear of circumscribed extent, cover in reality a very wide area, the error respecting them being caused by fluctuations of thickness, or by their occasionally thinning out and reappearing. Among those which manifest great permanency as to thickness, the vast range of some of the larger ones is truly extraordinary. Let us trace, for example, the great bed which occurs so finely exposed at Pittsburg, and along nearly the whole length of the Monongahela River, and which I have called the Pittsburg Seam. The high position which this bed occupies in the formation, and the nearly horizontal attitude of all the strata, combine to expose it very extensively to observation, while its great size and the excellence of the coal have caused it to be generally mined. After identifying and tracing it from basin to basin in Pennsylvania, I have been furnished with much information, in relation to its limits and features in Virginia and Ohio, by my brother and Mr Briggs. Guided by the data thus collected, I have been enabled to determine its area and boundaries with very considerable accuracy. The limits of this bed, as at present known, are nearly as follows: That portion, by far the largest part, which is contained in the great Western basin, has its N. termination in Indiana County, in Pennsylvania, and its S.W. on the Ohio River below Guyandotte. The general S.E. outcrop ranges along the W. foot of Chestnut Ridge, or West Laurel Hill, from Indiana County to Tygart's River, in Virginia. It here alters its strike from S.S.W. to a direction more nearly S., passing a little W. of and parallel to Buchanan's River, until it nearly gains the head-waters of the Monongahela. From this point its course is more winding, but the general direction is a little W. of S.W. to the Great Kenawha, which it crosses between Charlestown and the Pocatalico Creek. From the Kenawha it ranges nearly W. to the Ohio River, between Guyandotte and Burlington, where, crossing that great stream into the State of Ohio, it sweeps rapidly North. Its outcrop, now following the W. margin of the basin, preserves a general N.N.E. direction as far as McConnellsville, on the Muskingum. Beyond this point it stretches in a N.E. course until it recrosses the Ohio River a little above Steubenville, where it soon reaches the W. line of Pennsylvania, in Beaver County. Here the edge of the seam turns E., and crosses the Ohio River once more, a few miles below Pittsburg and the Alleghany River, some miles N.E. of that town. E. of this point it pursues a more devious line, the meanderings of which are caused by three parallel anticlinal axes, crossing the Kiskiminetas and Conemaugh rivers. Being thrown into a very irregular and curving outcrop by these elevations, it finally joins the S.E. margin at the N.E. extremity of the basin in Indiana County, the point from which we set out. The longest diameter of the great elliptical area here delineated is very nearly 225 miles, and its maximum breadth about 100 miles. The superficial extent of the whole coal-seam, as nearly as I can estimate it, is about 14,000 square miles.

But the limits here described, though wide, fall very far within those which the bed anciently occupied. To the S.E. of the large basin of the Ohio River there are several other insulated parallel troughs, which also contain the Pittsburg Seam. Of these, the farthest from the main coal-field is that at the head of the Potomac River, at a distance of about 43 miles in a straight line. The E. margin of the Pittsburg Bed is here, however, nearly 50 miles E.S.E. of the E. edge of the same seam in the main or W. basin, and it has a corresponding expansion E. in other districts. That this coal-bed preserves an unbroken range for many miles to the N.E. of the termination of the principal basin in Indiana County, appears highly probable, from a comparison of the Coal-measures at certain localities in that quarter. I shall not, however, assume the known length of the tract actually occupied by it as exceeding the above-mentioned 225 miles, throughout which it is uninterruptedly traceable. If we now take into account the 50 additional miles of breadth which the bed once possessed, its former area must have been at least 34,000 square miles, a superficial extent greater than that of Scotland or Ireland.

Though the above is perhaps the greatest extent of surface which it is in our power positively to assign to this bed of coal, the proofs of a prodigious denudation of the strata, throughout the districts bordering its present outcrop, are so irresistible that I consider the dimensions here given as bearing actually but a small proportion to the real ancient limits of the stratum. But restricting our attention for the present to those limits which it did undoubtedly once occupy, it is still by far the most extensive coal-bed yet explored in any country; and the mere fact of its great extent must exert an influence on our views concerning the conditions under which the whole coal-formation originated.

The general uniformity in the thickness of this superb bed, throughout so vast a region, and at the same time the regular and gentle gradation which it experiences in size when we trace it from one outcrop to the other, are features not less remarkable than its enormous length and breadth. In the most South-eastern basins, where it is most developed, its total thickness is from 12 to 14 feet; while in the basins between Chestnut Ridge and the Monongahela River, it usually measures from 10 to 12 feet. Still farther to the W., between the Monongahela River at Brownsville, and the Ohio at Wheeling, it declines from about 10 to 8 feet, and beyond this, in the State of Ohio, it seldom exceeds 5 or 6 feet. Following it longitudinally, or in the direction of the great elliptical basin, it displays quite as remarkable a persistency in its dimensions, the reduction in its size being, if anything, still more gradual from N.E. to S.W. Thus, at Pittsburg, it measures altogether about 8 feet; at the mouth of Big Grave Creek, rather more than 5; on the Great Kenawha, about 5; and from this point to Guyandotte, where it terminates, 3 feet; and, finally, hardly 2 feet. Tracing it along a parallel line from N.E. to S.W., but nearer its S.E. outcrop, we detect the same very gradual abatement in its thickness. While we are thus furnished with conclusive evidence, from the fact that its rate of increase is most rapid towards the S.E., that the ancient land with which the stratum was connected must have been situated in that direction, we see that the N.E. part of the coast was the quarter where its materials were supplied in the greatest abundance. To this conclusion I am disposed to appeal, in support of the conjecture already ventured, that this great bed of the main or W. coal-field is but a remnant of a still more expanded stratum, which attained its maximum size in the enormous seam of which all the anthracite basins present us insulated patches. The singular constancy in the thickness of this Pittsburg Bed, no less than its prodigious range, are circumstances that seem strongly adverse to the theory which ascribes the formation of such deposits to any species of *drifting* action. But a more thorough discussion of this question will be attempted presently.

OF THE INTIMATE MECHANICAL STRUCTURE OF THE COAL.

An examination of the structure of the coal itself, apart from the fact of the great range and uniformity in the thickness of the beds, renders it apparent that no irregular dispersion of the vegetable matter by any conceivable mode of drifting, either into estuaries or the open sea, could produce the phenomena which they exhibit. The mechanical arrangement of the layers in every coal-seam, as seen when viewed edgewise, indicates plainly that it is a compound stratum as much as any other sedimentary deposit, each bed being made up of innumerable very thin laminæ of glossy coal, alternating with equally minute plates of impure coal, containing a small admixture of finely-divided earthy matter. These subdivisions, differing in their lustre and fracture, are frequently of excessive thinness, the less brilliant leaves sometimes not exceeding the thickness of a sheet of paper. In many of the purer coal-beds, both anthracitic and bituminous, these thin partings between the more lustrous layers consist of little laminæ of pure fibrous charcoal, in which we may discover the peculiar texture of the leaves, fronds, and even the bark of the plants which supplied a part of the vegetable matter of the bed. If traced out to their edges, all these ultimate divisions of a mass of coal will be found to extend over a surprisingly large surface when we consider their minute thickness. Pursuing any given brilliant layer, whose thickness may not exceed the fourth part of an inch, we may observe it to extend over a superficial space which is wholly incompatible with the idea that it can have been derived from the flattened trunk or limb of any arborescent plant, however compressible. When a very large block of coal is thus minutely and carefully dissected, it very seldom, if ever, gives the slightest evidence of having been produced from the more solid parts of trees, though it may abound in fragments of their fronds and deciduous extremities. The laminæ of brilliant carbonaceous matter almost invariably thin away to a fine edge before they terminate, a fact which of itself seems to prove that the material was in a soft or pulpy state at the time of its accumulation, and this supposition receives countenance from the homogeneous texture and conchoidal fracture of every such layer.

Granting the correctness of this inference, which is not in conflict with the beautiful microscopic determinations by Hutton respecting the traces of vegetable structure in certain portions of coal, the argument seems almost conclusive that the vegetable matter grew where it was deposited. It is difficult to understand why the coal should not consist principally of the larger parts of trees—such as their trunks, limbs, and roots—if any species of drifting operation brought together the materials of the bed, by conveying seawards the growth of ancient forests. The leaves and other fragile parts would soon become detached on the voyage, and these, together with the smaller plants, would subside and get imbedded long before the trunks and lighter woody parts could grow sufficiently waterlogged to sink. It is obvious that a stratum formed by the successive deposition of huge irregular stems and branches, would exhibit, no matter what might be the subsequent pressure, a very different structure from that thin and uniform lamination which distinguishes all beds of coal. These considerations, derived from the mechanical features of every seam of coal, receive strong confirmation from the microscopic researches of Mr Hutton. Though that observer found more or less of the cellular vegetable structure in each of the three varieties of Newcastle coal, he discovered a complete obliteration of the characteristic cells in those finest lustrous portions of the caking coal, where the crystalline structure, as he terms it, is best developed. Besides the above-mentioned features, all the coal-beds which I have ever examined, or seen minutely described, possess another peculiarity in their mechanical constitution, on a less minute scale, which is equally incompatible with the notion of transportation by currents. I refer here to the subordinate divisions of the coal-beds, some of which are strata of pure coal, some of earthy coal, and some of common shale, all constituting together the compound mass which we call a coal-seam, but each maintaining its particular position and character as a distinct deposit over an area which is truly astonishing. Those persons who are conversant with large mining districts are aware of the many instances of remarkable persistency in these subdivisions in the coal-beds, since it is frequently by their means that the miners recognise a known coal-seam in cases of difficulty. Thus the largest bed of the anthracite fields of Pennsylvania contains almost everywhere a particular band of unusually pure coal, not far from the bottom, generally from 3 to 4 feet in thickness. A still more striking example occurs in the great Pittsburg Bed already spoken of. If we dissect this compound mass, and trace the several divisions, we become impressed with the wonderful distances to which some of them extend. Not to enter here into a minute discussion of all the features of this widely-distributed seam, it will suffice to state that it consists principally of three members which are readily recognised. The lowest is a thick bed of uncommonly pure coal, the middle a layer of soft shale or fire-clay, about 1 foot in thickness, and the uppermost, or roof coal, is itself a compound seam, 2 or 3 feet thick, of alternating layers of coal and fire-clay. Now it is a highly-instructive fact, that this general triple subdivision prevails throughout nearly the whole range of the seam from its E. to its W. outcrops, and from the Conemaugh in Pennsylvania into Western Virginia, for a distance of more than 200 miles, from N.E. to S.W. But besides this fact, each subordinate portion preserves its own distinctive features, the upper member being everywhere remarkable for its alternation of thin bands of coal and shale. Can any evidence be more conclusive as to the uniformity of the conditions under which every part of this coal-bed was produced? There must, indeed, have prevailed an almost perfect uniformity in the state of the surface throughout the vast area which it occupies, as respects even the formation of the thinnest of these subdivisions. Such remarkable sameness of action throughout the same geological horizon, appears absolutely incompatible with any mode of drifting of the vegetable matter. Only one particular process of accumulation appears to explain the occurrence, in such cases, of these thin and uniform sheets of material, of which the thickness is often less than a foot, while their superficial area is many hundred square miles. I cannot conceive any state of the surface adopted to account for these appearances, but that in which the margin of the sea was occupied by vast marine savannahs of some peat-creating plant, growing half-immersed on a perfectly horizontal plain, and this fringed and interspersed with forests of trees, shedding their leaves upon the marsh. Such are the only circumstances under which it is likely that these regularly parallel, thin, and widely-extended sheets of carbonaceous matter, could have been accumulated.

Independently of the above argument, based on the breadth and uniform distribution of the layers in the coal there is another, drawn from the striking deficiency of earthy sedimentary particles. In many of the purest layers, the total proportion by weight of foreign mineral substance in the coal, is less than two per cent, sometimes barely one per cent, while the ratio by bulk is consequently less than one half of this. So extremely insignificant a quantity is what we should expect, on the hypothesis of a tranquil accumulation in wide sea-meadows, extending far out from the edge of the ancient shore, where no turbid currents could get access. It is as inconsistent, on the other hand, with the notion of a drifting of the vegetable matter itself, which, according to any conceivable mode of transportation, would be accompanied by a large amount of earthy matter, such as abounds in all deltal deposits, and even mingles with the wood in the raft of the Atchafalaya. That so nearly the whole of the suspended mineral matter, even to the fine particles of impalpable clay, should have subsided, in almost every instance, before the first portions of the floating vegetation sank, contradicts all observation respecting similar actions now occurring. The introduction of any argillaceous matter into the transparent waters of the great peat-morasses, must have happened in the manner of an exceedingly quiet and diffused silting in, or more properly a slow intermingling, of very slightly turbid water with that of the limpid sea. The above arguments from the uniformity in the distribution of the vegetable matter of the coal-seams, and from the absence of earthy matters in the coal, have been already employed by Mr Beaumont as objections to the drift theory, in a communication read to the Geological Society of London, February 26th, 1840.*

OF THE CHARACTER OF THE STRATA IN IMMEDIATE CONTACT WITH THE COAL-SEAMS.

Turning from the structure of the coal itself to the character of the strata usually in immediate contact with it, we discover certain prevailing relations, from which, by a careful study, much light is to be derived, both as to the statical conditions and the order of the physical events which attended the production of the whole coal-formation. There is an interesting and characteristic difference, in point of composition and structure, between the beds bounding the upper and lower surfaces of every coal-seam. This, though of great significance in its bearings on the theory of the formation of coal, has never been distinctly examined with that view.

Of the Material underlying the Coal-beds.—The deposit upon which each seam of coal immediately rests, and which I shall call the floor, is, with a few rare exceptions, wholly distinct in its composition from the roof, or that which reposes directly upon the bed. To Sir William Logan we are indebted for having ascertained the highly important fact, that the floor of every coal-seam in South Wales is composed of a peculiar variety of more or less sandy clay, distinguished by its containing the *Stigmaria ficoides*. "Portions of the stem of the *Stigmaria* are found in other parts of the Coal-measures, but it is only in the under clay that the fibrous processes are attached to the stem, or associated with it."† Since the publication of his *Observations on the Stigmaria Beds of South Wales*, the same gentleman has extended his researches to the United States, and has found our own coal-seams in Pennsylvania to be similarly accompanied.‡ Sir Charles Lyell has also shown that this peculiar stratum underlies the bituminous coal-beds at Blossburg, in Pennsylvania. I visited, with that eminent geologist, the anthracite beds of the Pottsville and the Beaver Meadow basins in Pennsylvania, where we found the Stigmaria bed, in the same position, below those seams. Still more recently, I have ascertained, from my own notes on the geological survey of Pennsylvania, and from those of my brother in relation to Virginia, that this deposit accompanies nearly every coal-bed in the great bituminous coal-region W. of the Alleghany Mountain. I shall take occasion presently, however, to point out some peculiar exceptions to its general prevalence. The theoretical importance of this generalisation concerning the Stigmaria, and the fire-clay enclosing it, appears to have been discerned by Sir William Logan, but he has not offered any explanation of the fact;—the following passage from the published abstract of his paper conveys his views: "When it is considered that, over so considerable an area as the coal-field of South Wales, not a seam has been discovered without an under-clay abounding in Stigmaria, it is impossible to avoid the inference, that there is some essential and necessary connection between the existence of the Stigmaria and the production of the coal. To account for their unfailing combination by drift seems unsatisfactory; but whatever may be the mutual dependence of the phenomena, it affords reasonable grounds to suppose that the *Stigmaria ficoides* is the plant to which we may mainly ascribe the vast stores of fossil fuel." I am not aware that either Logan or any other geological writer has attempted to account for the great frequency of this stratum immediately underneath the coal, or that any hypothesis has been advanced to explain the general prevalence in it of the Stigmaria, and the absence of all those other species of plants which abound among the layers of the coal itself, and in the roof and other overlying rocks. One main object of the following theory of the origin of the Coal-measures is to attempt the solution of these curious facts. §

* BEAUMONT, "Proceedings of the Geological Society," No. 69. † LOGAN, *Ibid.* ‡ *Ibid.*, for April 1842.

§ Since this memoir was written, my attention has been called by my brother, Prof. Wm. B. Rogers of Virginia, to the splendid work of Mr Edward Mammatt, on the Coal-Field of Ashby de la Zouch, published in 1834. This elaborate description contains a clear announcement of an under clay for almost every coal-seam, and mentions, moreover, the presence "of a distinct single vegetation" in that of the *main coal*, with other facts and suggestions, since confirmed by Mr Logan (now Sir William Logan), and several other recent writers on the origin of the coal strata. I cannot find that the obvious claims of Mr Mammatt to priority as a discoverer in this interesting subject have been anywhere acknowledged. It is to be regretted that the still earlier opinions of Werner, De Luc, and Adolph Brongniart, attributing the vegetable matter of the coal-beds to a growth on the spot where the coal now exists, should have escaped so generally the attention of British geologists, with the exception of Mr Lyell (now Sir Charles Lyell).‖

The following passages from Mr Mammatt's work will convince us how very near he was to a clear conception of the relations of the Stigmaria, and to a sound doctrine of the circumstances under which the coal-beds were accumulated: "Seams of fire-clay abound in the Ashby coal-field, and there are very few coal-measures (coal-seams?) which do not rest upon it, as the Sections will show." And again: "From the circumstance that so many cases occur where a tolerably pure fire-clay lies immediately under and in contact with a

‖ After this paper was written, Dr Buckland's admirable "Anniversary Address to the Geological Society of London, for 1841," appeared, in which he mentions that this doctrine has been entertained by De Luc, McCulloch, Jameson, Brongniart, Lindley, and other writers.

The Stigmaria presented in its structure, according to Lindley and Hutton, a low, dome-shaped, fleshy trunk, or centre, from the edge of which there radiated a number of horizontal branches, supplied with a multitude of slender, cylindrical, and exceedingly long leaves. The fire-clay, or Stigmaria clay, as we may indifferently call it, abounds in these delicate leaves, in a flattened and distorted condition; and it is partly to them, and partly to the comminuted state of the argillaceous material itself, that the stratum owes its characteristic tendency to crumble in every direction. The branches of the Stigmaria, which usually lie parallel to the plane of the stratum, and are most abundant nearest the coal, it has been suggested, were hollow cylinders, composed entirely of spiral vessels, and contained a thick pith. The plants, according to Dr Buckland, probably floated on the water.

Such were the views entertained of the nature of Stigmaria at the time this essay was written (1842); but subsequent researches by M. Brongniart rendered it probable, and actual observation by Mr Binney of Manchester, made a little later, proved, that Stigmaria is simply the *root* of *Sigillaria.*

OF THE ROOF OF THE COAL.

If we examine, in the next place, the strata which immediately rest upon the coal, we shall discover a condition of things in striking contrast with the phenomena of the under-clay. Instead of one uniform material almost invariably present, composed of finely-divided particles, the beds overlying the coal consist of nearly every variety of rock embraced in the formation, though they are more usually some form of laminated carbonaceous slate. Both in its composition and structure, the roof rock manifests signs of having been deposited by a more or less rapid current. In place of a single species of fossil plant, it usually includes a prodigious variety; and the delicate ramifications of these, instead of intersecting the bed in various directions, as the processes of the Stigmaria do in the fire-clay, lie in a singularly disordered and fragmentary condition, in planes almost invariably parallel to the bedding. Lindley and Hutton, in their work on the *Fossil Flora of Great Britain,* give the following very accurate description of the mode in which the organic remains occur in the roof-slates in England, and the account is equally applicable to those of the United States: "It is the beds of shale, or argillaceous schistus, which afford the most abundant supply of these curious relics of a former world, the fine particles of which they are composed having sealed up and retained in wonderful perfection and beauty the most delicate forms of the vegetable organic structure. Where shale forms the roof of the workable seams of coal, as it generally does, we have the most abundant display of fossils. The principal deposit is not in immediate contact with the coal, but from 12 to 20 inches above it; and such is the immense profusion in this situation, that they are not unfrequently the cause of very serious accidents, by breaking the adhesion of the shale-bed, and causing it to separate and fall, when, by the operation of the miner, the coal which supported it is removed. After an extensive fall of this kind has taken place, it is a curious sight to see the mine covered with these vegetable forms, some of them of great beauty and delicacy; *and the observer cannot fail to be struck with the extraordinary confusion, and the numerous marks of strong mechanical action, exhibited by their broken and disjointed remains.*" Such is the nature of the roof when it consists of the usual carbonaceous shale or slate; but in the Appalachian coal-fields it is oftentimes a much coarser rock, being either an argillaceous flaggy sandstone, or a coarse arenaceous grit, or even occasionally a silicious conglomerate. In these instances the enclosed vegetable remains are for the most part fragments of the larger stems or branches of gigantic arborescent plants, their fronds and leaves being less abundant. These fragments occur in all postures as respects the plane of the bedding—horizontally, obliquely, or perpendicularly; and betray, in their broken condition and irregular mode of dispersion, the sudden and tempestuous character of the currents which drifted and entombed them. Though the arenaceous rocks having these features sometimes rest in immediate contact with the upper surfaces of the beds of coal, they more frequently lie at a moderate distance over them, an argillaceous laminated slate interposing to form the actual roof. A further indication of the violence of the currents which strewed these coarse materials over the coal is sometimes to be detected in the composition of the lowest portion of the overlying bed of grit or sandstone, in which a large amount of coal, in the state of powder or sand, is disseminated in the rock, giving it a dark speckled appearance. This is of very common occurrence in the anthracite

bed of coal, it may be inferred that such clay stratum could not have been the soil where the vegetable matter grew which produced the coal, unless this vegetable matter was a moss, a peat, or some aquatic plant; because in the clay there is no appearance of trunks or other vegetable impressions, beyond slender leaves, as of a long grass.

"The fact that particular strata accompany the main coal for many square miles would support the idea that an immense flat was originally covered with the substance of this fire-clay many feet thick, and that upon this flat there took place a uniform growth of a distinct single vegetation, which must have occupied the position for a long period, and thus furnished the substance which composes the *main coal.* The alternations of fire-clay and coal-seams would favour the notion that these materials were originally mixed together in a fluid, and that those of the former, by their gravity, would first subside, whilst the vegetable matter, or those of the latter, would undergo a more gradual deposition. Hence, by a repetition of the process, the alternations of the strata would be produced. Besides, it may be supposed that if the strata of coal have derived their origin from the growth and destruction of a forest, some portions of them would have been thicker than others, and altered in quality, or have retained at least some traces of forest trees; whereas, on the contrary, most extraordinary uniformity in quality, compactness, and thickness of the seams, prevails to a great extent." *

* *Geological Facts,* by EDWARD MAMMATT, p. 73.

coal-strata of Pennsylvania, where the coarse grit not unfrequently rests immediately on the coal. It implies, I conceive, the erosion of a certain portion of the upper surface of the soft carbonaceous mass by the friction of the sandy current. The coaly matter, thus disturbed, would subside with the first layers of the sand with which it was mingled. Sir William Logan has mentioned a still more striking proof of the energy of the movements which occasionally occurred during the formation of the Coal-measures. He gives an account of actual boulders, or rounded pebbles of coal, in the Pennant grit, and other coarse strata of the coal-field of South Wales.

OF THE DIRECT CONTACT OF COAL-BEDS AND MARINE LIMESTONES.

In the preceding account of the strata immediately below and above the seams of coal, I intentionally omitted to introduce the limestones which occasionally compose the floor or the roof, sometimes in direct contact with the coal. The portion of the Appalachian coal-formation in which this remarkable contiguity of marine calcareous strata and vegetable or terrestrial coal occurs, is the great W. basin of the Alleghany and Ohio rivers. I have already mentioned the abundance of unquestionably oceanic limestones in this coal-field, and stated my inferences from the interesting fact, that they augment in thickness and multiply in number in crossing the region N.W. As, however, the actual contact of beds of coal and limestone is of rare occurrence in the coal-fields of other countries, and as the circumstance must have an influential bearing on all our speculations concerning the physical conditions prevailing at the formation of the strata, and, to a certain extent, on our whole theory of the origin of coal, I shall here describe some of the best-known instances before I reason concerning them.

Confining our attention to the great W. basin, where the most striking cases occur, the following instances of this contact present themselves in the ascending order :—

First. In the lower division of the main Coal-measures there occurs, near the town of Mercer in Pennsylvania, a seam of good coal, having a thickness of about 2 feet, which is immediately overlaid by a bed of very pure limestone, also about 2 feet thick, containing a variety of marine organic remains of the genera *Terebratula*, *Bellerophon*, &c. In some spots the pure coal is not separated from the pure limestone by more than a single inch, or at most 2 inches, and then the interval is filled with a calcareo-carbonaceous shale.

Secondly. Higher in the series, but still in the lower part of the main Coal-measures of Western Pennsylvania, we meet with a bed of fossiliferous limestone, the thickness of which, in many neighbourhoods near the Alleghany River, is about 15 feet. It contains several oceanic species, among them some *Crinoideæ*, two species of *Terebratula*, and a *Goniatites*. In some places this stratum embraces a thin seam of coal, 4 inches thick, in almost direct contact with the limestone.

Thirdly. The limestone, which is the first underneath the Pittsburg Seam, contains a bed of coal 1 foot in thickness, separating two of its lower layers.

Fourthly. Near Pittsburg, the great coal-seam frequently rests within a few inches of this underlying limestone, in which are a few occasional fossils, all of marine genera. In these places the dividing layer is only a few inches thick, and consists of a bluish fire-clay.

Fifthly. In Fayette County, Pennsylvania, the great limestone, which lies above the Pittsburg coal-bed, encloses very generally two thin seams of perfect coal, immediately in contact with the layers of the rock. These coals appear to have a considerable range, extending into the adjoining counties. The largest is occasionally 2½ feet thick, and a few inches of black calcareous slate alone separate it from the hard limestone. The other coal-bed has a thickness of about 1 foot, and its surfaces are in equally close contact with the limestone. Neither of these beds is as widely expanded as the including limestone.

Sixthly. Underneath the uppermost workable bed of coal in Western Pennsylvania, or that which I have termed in my Reports the Waynesburg Seam, there is a stratum of limestone, which sometimes encloses a thin coal-bed, measuring about 1 foot.

Seventhly. At Putnam Hill, near Zanesville, in Ohio, a bed of limestone, 5 feet thick, rests, according to Dr Hildreth, on a seam of coal 1 foot thick, there not being more than 2 inches of fire-clay interposed. The limestone contains *Encrini*, *Terebratulæ*, and other marine fossils.*

Eighthly. The same writer mentions that, on the Clear Fork of Little Muskingum, in Ohio, there is a seam of good bituminous coal, 3 feet thick, reposing directly on a dark, carbonaceous, fossiliferous limestone 8 feet in thickness. It is overlaid by another limestone, measuring 6 feet, from which it is separated by a very thin layer of shale.

Ninthly. Dr Hildreth further states, that on Wills's Creek, in the same region, a coal-seam 5 feet thick occurs, resting immediately on a bed of limestone, the thickness of which is 20 feet.

I might cite a large additional number of cases in Pennsylvania, Virginia, and Ohio, in proof of the frequency of the contact of the coal-seams and beds of limestone ; but I have been disposed to establish the fact chiefly from instances in different portions of the formation, and to show that the contiguity of the coal and limestone is often maintained throughout a considerable extent of country.

* HILDRETH, in *American Journal of Science*, p. 31.

THEORY OF THE ORIGIN OF THE COAL STRATA.

Having presented what, I trust, is a sufficiently full sketch of the leading phenomena of the Appalachian Coal-measures, and shown their correspondence, in several essential features of structure, to the coal-formation of Europe, I shall proceed now to consider what inferences we are entitled to draw respecting their origin, and that of the coal-formation generally. But before taking this theoretical survey, it will be expedient to state succinctly the views of the several eminent geologists who have recently written on this subject. I feel it the more incumbent to do this, since some of the speculations I shall advance are but modifications of hypotheses already published.

From a passage* in Lyell's admirable work, *The Elements of Geology*, it appears that M. Adolphe Brongniart, after comparing the phenomena of the ancient coal and its fossil plants with the great peat-mosses of the present day, states, in a memoir published in 1838, that he continues to adhere to the opinions originally advanced by Werner and De Luc, that the vegetation entombed in the carboniferous strata chiefly grew in the localities where the coal is now found.* Whether M. Brongniart, however, endeavours to conform this view to all the phenomena of the Coal-measures under any general theory of their origin, I am not informed, not having seen his memoir.

Mr Hawkshaw, in a communication to the Geological Society of London in 1839, describes the remarkable phenomenon of five fossil trees, exposed in a cutting on the Manchester and Bolton railway, standing erect in relation to a bed of coal, 8 or 10 inches thick, and in the same place with their roots. The largest of these was 5 feet in diameter at the base, and 11 feet high. He conceives it probable that they grew where they occur.† In a subsequent paper, read February 26, 1840, Mr Hawkshaw, after mentioning the discovery of another fossil tree, standing on the same coal-seam, makes this observation: "If the coal be considered as the debris of a forest, it is difficult to account for not finding more trunks of trees than have been discovered in our coal-basins; and it is only, perhaps, by allowing the original of our coal-seams to have been a combination of vegetable matter, analogous to peat, that the difficulty can be solved." ‡

After Mr Hawkshaw's first communication, Mr Beaumont, in a paper read to the same Society, November 6, 1838, upon the subject of the same trees, states several objections to the drift theory of coal, and conceives that the vegetation grew where it is found. Upon comparing these objections with my own, as given in the foregoing pages, I find that they all rest upon a different class of facts, and are wholly distinct in their bearings. Mr Beaumont states that the vegetation which formed the coal grew on swampy islands, that it consisted of *ferns, calamites, coniferous trees*, &c., which operated, through their decay and regeneration, to form peat-bogs; and that the islands, by subsiding, were covered with drifted sand, clay, and shells, till they again became dry land, and supported another vegetation; and this process, he supposes, was repeated as often as there are coal-seams.§

Dr Buckland, in commenting on this hypothesis, observes, that, "in denying altogether the presence of drifted plants, the opinion of the author seems erroneous; universal negative propositions are in all cases dangerous, and more especially so in geology. That some of the trees which are found erect in the coal-formation have not been drifted, is, I think, established on sufficient evidence; but there is equal evidence to show that other trees and leaves innumerable, which pervade the strata that alternate with the coal, have been removed by water to considerable distances from the spots on which they grew. Proofs are daily increasing in favour of both opinions, namely, that some of the vegetables which form our beds of coal grew on the identical banks of sand and silt and mud, which, being now indurated to stone and shale, form the strata that accompany the coal; whilst other portions of these plants have been drifted to various distances from the swamps, savannahs, and forests, that gave them birth; particularly those that are dispersed through the sandstones, or mixed with fishes in the shale beds. || In these views of Dr Buckland Sir Charles Lyell would seem to concur, as, in quoting the above passage in his Elements, he says that "it can be no longer doubted that both these opinions are true, if we confine our attention to particular places."

Another paper, on the same subject of the fossil trees, found on the Manchester and Bolton Railway, was read contemporaneously with the last communication of Mr Hawkshaw. The author, Mr Bowman, is of opinion "that the theory of the subsidence of the land during the carboniferous era, receives much support from the phenomena presented by these fossil trees." He does not deny that plants may have been carried into the water from neighbouring lands; but he conceives it difficult to understand whence the vast masses of vegetables necessary to form thick seams of coal could have been derived, if drifted, and how they could have been sunk to the bottom without being intermixed with the earthy sediment which was slowly deposited upon them. Another difficulty of the drift theory, he says, "is the uniformity of the distribution of the vegetable matter throughout such great areas as those occupied by the seams of coal." I have myself shown that this uniformity extends even to the subordinate divisions of each seam. Mr Bowman believes that the coal has been formed from plants which grew on the areas now occupied by the seams; that each successive race of vegetation was gradually submerged beneath the level of the water, and covered up by sediment, which accumulated till it formed another dry surface for the growth of another series

* LYELL'S *Elements*, ii. 135, Boston edition.

† HAWKSHAW, in "Proceedings of the Geological Society, London," No. 64.

‡ *Ibid.*, No. 69.

§ BEAUMONT, in "Proceedings of the Geological Society, London," No. 65.

|| Anniversary Address to the Geological Society, 1841.

of *trees* and plants, and that the submergences and accumulations took place as many times as there are seams of coal.

In reviewing the above facts and opinions, Dr Buckland conceives that a luxuriant growth of marsh plants, as *Calamites, Lepidodendra, Sigillaria*, &c., may have formed a superstratum of coal, resting on a substratum of the same, composed exclusively of remains of *Stigmariæ*; and in accounting for the marine and fresh-water strata alternating with the coal-beds, he appeals to the intermitting and alternate processes of subsidence, drift, and vegetable growth.†

The above summary of the recent researches and speculations of geologists, conveys, I believe, a correct view of the state of opinion at the present time, in relation to the interesting problem of the origin of the coal strata. I may now venture to advance my own explanation of the phenomena, and to indicate wherein I differ from the able authors I have cited. The several hypotheses proposed, do not attempt to account for some of the most remarkable relationships among the strata, such as the extraordinary frequency, beneath the coal-beds, of the Stigmaria clay, the very general occurrence of laminated slates immediately above the seams, and the singular contrast which these underlying and overlying rocks present, in the variety and condition of the imbedded vegetable remains. Nor do they explain satisfactorily why the coal itself contains so few traces of the forest trees of the period, either in a prostrate or erect position; while their broken stems are mingled with the fragmentary parts of the Stigmaria, in more or less abundance, in all the coarser rocks. Perhaps the following hypothesis will account for the phenomena.

Let us imagine the areas now covered with the coal-formation, to have possessed a physical geography, in which the principal feature was the existence of extensive flats, bordering a continent, and forming the shores of an ocean, or some vast bay, outside of which was a wide expanse of shallow but open sea. Let us now suppose that the whole period of the Coal-measures was characterised by a *general* slow subsidence of these coasts, on which we conceive that the vegetation of the coal grew;—that this vertical depression was, however, interrupted by pauses and gradual upward movements of less frequency and duration, and that these nearly statical conditions of the land alternated with great paroxysmal displacements of the level, caused by those mighty pulsations of the crust which we call earthquakes. Let us further conceive, that during the periods of gentle depression, or almost absolute rest, the low coast was fringed by great marshy tracts or peat-bogs, derived from and supporting a luxuriant growth of *Stigmariæ* (*Sigillaria* and *Lepidodendra*), and that along the landward margin, and in the drier places of these extensive sea morasses, grew the *Coniferæ, Tree-Ferns, Lycopodiaceæ*, and other arborescent plants, whose remains are so profusely scattered throughout the coarser strata between the coal-seams. In this condition of things, the constant decomposition and growth of the meadows of *Stigmariæ* would produce a very uniform, extended stratum of pulpy but minutely-laminated pure peat. This would receive occasional contributions from the droppings by the scattered trees of their leaves, fronds, and smaller portions, which, being driven by winds or floated on the high tides, would lodge among the Stigmariæ in the marshes, and slightly augment the deposit. These leaves and fronds, covered over more or less rapidly by the growing *Stigmariæ*, or varying in their tendency to decay, according to the abundance or deficiency of their juices, would, when thus enclosed, pass at once either to the pulpy state, and ultimately form coal, or, by the more rapid extrication of their volatile portions, remain as mineral charcoal, and preserve their vegetable fibrous structure. In both of these conditions of coal and charcoal, we often find the smaller parts of plants retaining their organised forms among the laminæ of the purest coal-seams. Upon this view of a gradual accumulation from the *Stigmariæ*, assisted by the deciduous parts of the trees, it is altogether unnecessary to suppose that any portions, even the upper layers of the coal-beds, derived their vegetable matter from the stems of the trees themselves. Thus the absence of trunks and roots from the coal is reconciled with the occasional occurrence of their fronds and lighter extremities. Upon no other hypothesis respecting the physical condition of the region which produced the coal vegetation than that here imagined, can I explain the singular infrequency of fossil trunks standing on or in the coal, or account for their occasional occurrence, as in the instances described by Hawkshaw and Bowman. No other supposition seems to furnish a cause for the absence of all traces in the coal itself of the larger parts of arborescent plants, and for their equally remarkable abundance in a broken and dispersed state in the overlying strata.

Assuming such to have been the condition of the surface during the tranquil periods of the accumulation of each coal-bed, we may conceive the other strata to have been produced in the following manner. Let us suppose an earthquake, possessing the characteristic undulatory movement of the crust, in which I believe all earthquakes essentially to consist, suddenly to have disturbed the level of the wide peat-morasses and adjoining flat tracts of forest on the one side, and the shallow sea on the other. The ocean, as usual in earthquakes, would drain off its waters for a moment from the great Stigmaria marsh, and from all the swampy forests which skirted it, and, by its recession, stir up the muddy soil, and drift away the fronds, twigs, and smaller plants, and spread these and the mud broadly over the surface of the bog. In this way may have been formed the laminated slates, so full of fragmentary leaves and twigs, which generally compose the immediate covering of the coal-beds. Presently, however, the sea would roll in with impetuous force, and, reaching the fast land, prostrate everything before it. Almost the entire forest would be uprooted, and

* BOWMAN, in "Proceedings of Geological Society, London," No. 69.

† Anniversary Address to Geological Society, 1841.

borne off on its tremendous surf. Spreading far inland, compared with its accustomed shore, it would wash up the soil, and abrade whatever fragmentary materials lay in its path, and, loaded with these, it would then rush out again, with irresistible violence, towards its deeper bed, strewing the products of the land in a coarse promiscuous stratum, imbedding the fragments of the broken and disordered trees. Alternately swelling and retiring with a suddenness and energy far surpassing that of any tide, and maintained probably in this state of tempestuous oscillation by fresh heavings of the crust, the waters would go on spreading a succession of coarser or finer strata, and entombing at each inundation a new portion of the floating forest. Upon the dying away of the earthquake undulations, the sea, once more restored to tranquillity, would hold in suspension at last only the most finely-subdivided sedimentary matter, and the most buoyant of the uptorn vegetation—that is to say, the argillaceous particles of the fire-clay—and the naturally floating stems of the plants. These would at last precipitate themselves together by a slow subsidence, and form a uniform deposit, exhibiting but few traces of any active horizontal currents, such as would arise from a drifting into the sea from rivers. The chief portion of the coarser fire-clay would settle first, and then the more impalpable particles, in company with the stems and leaves of the uprooted vegetation. Thus we may account for the constant reproduction of the peculiar soil of the coal-seams, and for the preservation, particularly in its upper clayey layers, of the Stigmaria (Sigillaria); the simple consequence of the final subsidence of these materials being the production of the necessary substratum of another coal-marsh. The marine savannahs becoming again clothed with their matting of vegetation, and fringed on the side towards the land with wet forests of arborescent Ferns and other trees, all the essential conditions and changes that constituted this wonderful cycle in the statical and dynamic processes belonging to each seam of coal, and the beds enclosing it, would be completed, and ready to be once more renewed.

Though the train of actions here imagined enables us to reconcile the indications afforded by the coal-beds of periods of prolonged tranquillity, with the evidences of violent aqueous currents, as shown in the composition of the coarser mechanical rocks; yet a complete theory of the coal-formation calls for the introduction of other considerations connected with the existence and positions of strata derived from chemical and organic agencies, as the limestones, cherts, and beds of carbonate of iron. The analysis already given of our Appalachian Coal-measures will be seen to imply a slow general subsidence, alternating with occasional and less-prolonged movements of elevation, and these gentle changes of level interrupted by sudden or paroxysmal heavings of the crust. Mr Beaumont was the first, I believe, to suggest a subsidence of the land during the progress of the coal-formation; he supposes the coal-beds to be the result of a "luxuriant vegetation, covering swampy islands, which, by the settling down of the disturbed crust of the earth, were covered over with drifted sand, clay, &c." Subsequently Sir Charles Lyell, in an early edition of his *Elements of Geology*, proposed a somewhat similar view. He says, "If the superposition, on a great scale, of purely marine strata to others containing coal and fresh-water shells, leads us to infer that large areas, once constituting estuaries, deltas, and marshes, sank down and became sea during the carboniferous period, so are there reasons for concluding that in many cases the depression of the ground took place gradually, and that, in consequence of the deposition of sediment, the same space was again and again converted into land, and laid under water." In another passage he suggests, that "if we appreciate the full strength of the evidence in favour of continued subsidence in the coal-field of South Wales, we shall be the less surprised to learn that the vertical depth of the superimposed strata is enormous, amounting in some places to no less than twelve thousand feet."* Though a vast perponderance of subsidence over elevation is plainly indicated in the prodigious thickness of the Coal-measures, each particular coal-seam in which, was produced successively at the surface, I cannot conceive that either an alternation of periods of subsidence and repose, or an uninterruped prolonged depression, will explain the phenomena of the Appalachian coal-rocks, as they have been here described. A general subsidence, throughout the coal period, of all the great area now occupied by the Appalachian basins, is proved, independently of the above evidence derived from the nature of the coal-beds, by the interesting fact, that the lower seams of Ohio and Western Pennsylvania have their E. limit more than 150 miles to the W. of the general E. boundary of the upper ones; and as we ascend in the formation, the beds extend successively more and more to the E., or in the direction of the ancient land. But considering the many striking instances which I have recorded of the close approach or actual contact of certain beds of coal and oceanic limestone, we cannot resist the conclusion, that the gradual downward movement was frequently interrupted by a slow upward one. In all the instances that I have cited, where the limestone stratum immediately underlies a coal-seam, it is obvious that an upward movement of the land must have taken place, so gradually as to be unattended by any sensible commotion of the waters. A considerable and sudden lifting of the bed of the sea would infallibly have caused the production of violent currents, competent to spread over the quiet precipitate of limestone, one or more coarse arenaceous or argillo-arenaceous strata. That the intervals of repose indicated by the limestones were, like those of the beds of coal, sometimes suddenly terminated by earthquake disturbances, strewing over the marine sediments the materials of the land, is manifest from the phenomena, though it is not less clear that the cessation of the periods of relative tranquillity, marked by very gradual subsidence, must in all cases, where the coal-beds are overlaid directly by marine limestones, have been effected by simply a more rapid process of depression. Every superimposed limestone, with-

* LYELL's *Elements*, Boston edition, vol. ii. pp. 128, 134.

out an intervening roof-slate or sandstone to separate it from the coal, affords, I conceive, a conclusive proof of this increased rate of submergence. Perhaps it will be objected, that a merely accelerated subsidence, such as I have here supposed, if taken in conjunction with the hypothesis of a drifting of the land-materials by rivers, will satisfactorily explain all the facts which I have ascribed to the turbulent movement of the sea against the land during earthquakes. But though it is highly probable, from the phenomena of nearly every extensive coal-field, that rivers did carry into the parts of the ocean and its estuaries, now drained and occupied by the coal strata, a considerable quantity of argillaceous deltal deposits, yet it is difficult to imagine how any moderately rapid subsidence, if unaccompanied by some *paroxysmal* movement, could create a current energetic enough to uproot and float away nearly the whole of those vast forests, which evidently grew close to the site of each seam of coal, and to snap off to the stumps even the most colossal trees. Nor is it easy to explain why such a quiet submersion of the swampy forests did not result in the preservation of the trees in their original erect posture, by the drifting around them of the supposed river sediments. It is fair to infer, that so long a line of coast as we must conceive bordered the Appalachian ocean, if we may judge from the great longitudinal extent of some of our coal-seams, was not destitute of rivers, and we are therefore constrained to admit that some amount of sedimentary matter must have entered the sea in that manner; but at the same time, we have only to notice the striking deficiency of earthy matter in the numerous coal-beds, and in many of the strata of limestone, to be persuaded that the amount of material contributed to the Coal-measures by fluviatile transport was relatively inconsiderable. It may be fairly questioned, whether any sensible proportion of river silt could spread itself to the distance of 150 or 200 miles seawards, over the great coal-morasses of such a coast; and yet we are compelled to assume this, if we deny the above paroxysmal theory.

That the geological and geographical changes known to have been caused in modern times by earthquakes, entitle us to speculate upon their agency in suddenly shifting the level of the low tracts once occupied by the marshes and swamps of the coal-seams, must, I think, be conceded. Few geologists will deny the probability of frequent changes, in the carboniferous period, analogous to that which took place in the great plain at the mouth of the Indus in the year 1819. It is mentioned in Lyell's *Elements*, that "extensive flats bordering the Indus sank down, and, for many years after, vessels were forced through the boughs of the tamarisk trees, still standing erect." *

Should the foregoing theory, based on the complicated statical and dynamic phenomena of the Appalachian coal strata, be correct, then have we, in every stratum of the series, not merely a new picture of the physical geography of the region, but a clear legible record of the very changes, gradual or tempestuous, of which each in its turn was the result. We unclasp, as it were, a whole volume of hydrographic charts, displaying, for a vast succession of epochs, the ever-changing relations of the land and waters. A wide tract of ancient coast is at one time occupied by the ocean, at another by an immense plain filled with green marshes and swamps, and at another by dry land clothed with a tangled forest. But we behold more than merely these several conditions of the surface: we perceive the very transitions themselves which revolutionised the geography; we discern the ocean in the very act of encroaching on the land, forming extensive marshes where before the whole was solid shore; we actually trace it in its gradual retreat, exposing its own marine sediments to form a fertile soil for vast savannahs, and again we see the entire region embracing the dry land, the marshes, and the sea, heaving and undulating in the billows of the irresistible earthquake, the ocean and the land contending for mastery in the tremendous conflict.

If the Appalachian coal strata, whose history I have here endeavoured to interpret, exhibit truly the above-imagined conditions and events, we may consider the entire formation as constituting a stupendous tide-gage, registering the lengthened ebbings and flowings of that ancient sea, and the stormy agitations of its oscillating waters, as the epoch of its last greatest movement and final drainage drew near.

GRADATION IN THE PROPORTION OF VOLATILE MATTER IN THE COAL OF THE APPALACHIAN BASINS.

There prevails a very interesting law of gradation, in the quantity of volatile matter belonging to the coal, as we cross the Appalachian basins from the S.E. towards the N.W. The extraordinary extent of area over which this law obtains, and its intimate connection with corresponding gradations in the structural phenomena of the region, the description and theory of which have been given elsewhere by Professor W. B. Rogers and myself, seem to claim for it a place in the present general account of our coal-measures. The gradation may be thus briefly described:— Crossing the Appalachian coal-fields, N.W. from the great valley to the middle of the main or W. trough, by any section between the N.E. termination of the formation in Pennsylvania and the latitude of Tennessee, we find, as the result of multiplied chemical analyses, a progressive increase in the proportion of the volatile matter, passing from a nearly total deficiency of it in the driest anthracites, to an ample abundance in the richest gaseous coals. The existence of this singular law of transition was first ascertained by me in 1837, in which year I made mention of it in some public lectures. It was communicated to the Association of American Geologists, at their first annual meeting, in the spring of 1840; but I did not publish it in print until the following winter, when it was briefly alluded to in my Fifth Annual Report on the Geological Survey of Pennsylvania. Evidence of the existence of such a gradation in the

* LYELL'S *Elements*, vol. ii. p. 136.

coals of Western Virginia will be found in the annual reports of the Geological Survey of that State for the years 1839 and 1840. These historical references are here introduced, because the determination of the general fact was the result of many laborious analyses of our coals, made by my brother and myself, and because attempts have been made by others to establish a claim to the discovery. The lists of analyses contained in the Reports of the Surveys of Pennsylvania and Virginia, and similar data not yet published, show the following as the general proportion of the bituminous matter in the different belts of the formation, as we cross the region from S.E. to N.W.

First, In the most S.E. chain of basins the coal is, for the most part, a genuine anthracite, containing, however, sometimes a small per-centage of bitumen, and always a little gaseous matter, chiefly hydrogen. The quantity of the volatile matter varies, according to geological locality, from about six to twelve or fourteen per cent. This first belt of basins embraces all the anthracite coal-fields of Pennsylvania, the slightly bituminous ones of Broad Top on the Juniata, of Sleepy Creek, of the Little North Mountain, of Catawba Creek, Tom's Creek, Strouble's Run, and Brushy Ridge, in Virginia. The coal of the Little North Mountain is, however, a true anthracite. All of these coal-fields, and insulated patches of the formation, belong to the most disturbed portions of the Appalachian chain, and they are associated with some of the boldest flexures and greatest dislocations of the whole region. The first or S.E. anthracite basin of Pennsylvania presents innumerable sharp flexures and close plications, with inversion, of the strata.

Secondly, In the next well-defined range of basins farther towards the N.W.—that, namely, of the Alleghany Mountain, and the general escarpment of which it is a part—the proportion of volatile matter varies usually from sixteen to twenty-two per cent, but is generally about eighteen or twenty per cent. This belt includes all the coal-fields situated immediately to the N.W. of the Alleghany Mountain in Pennsylvania, also the Potomac basin, in nearly the same line, and the coal-fields of the Little Sewell, and the E. side of the Big Sewell Mountain in Virginia. The position of this belt of the Coal-measures is somewhat W. of the region of steep flexures of the strata, and beyond all the considerable dislocations, while it embraces a few very extensive, regular, and nearly symmetrical anticlinal axes of the flatter form, distinctive of their intermediate position between the E. and W.

Thirdly, The great Appalachian basin, with its subordinate troughs, forming the wide coal-field watered by the Ohio River and its tributaries, embraces a series of coal-beds, which are all distinguished by a still larger amount of volatile matter. In crossing the breadth of this wide coal-field, we find a very material alteration in the character and composition of the coal. Along its E. side, or near the last considerable axis of the Appalachian chain, the amount of volatile matter is commonly from thirty to thirty-five per cent. Westward of this line, on the Monongahela River, both in Pennsylvania and Virginia, the proportion approaches to forty per cent; while still farther in the same direction, or near the Ohio River, it ranges from forty to even fifty per cent, according to local circumstances. In this most Western or main coal-field, the flexures of the strata are extremely gentle, and comparatively wide apart; but even here we observe a beautiful progression in the amount of the bitumen, as we recede from the very low axes which traverse the S.E. side of the great plain. What renders the foregoing comparison of the several ranges of the coal-formation particularly exact and satisfactory, is the circumstance that, in more than one instance, we are enabled to trace the very same coal-seam, through its various degrees of bituminisation, from an almost true anthracite to a form in which it possesses a full proportion of volatile matter. Thus the great Pittsburg Bed, to take it as an example, contains on the Potomac, in some localities, as little as 15.5 per cent; but near the Eastern margin of the great Western basin, as at Blairsville, and again in Virginia, it has about thirty-one per cent; and towards the middle of the main basin at Pittsburg and on the Kenawha, as much as from forty to forty-three per cent.

The cause of the different degrees of de-bituminisation of the coals, in different parts of their range, I am disposed to attribute to the prodigious quantity of intensely-heated steam and gaseous matter emitted through the crust of the earth, by the almost infinite number of cracks and crevices which must have been produced during the undulation and permanent bending of the strata. All the phenomena of modern earthquakes and volcanoes warrant us in supposing that the elevation of our coal-rocks, if effected in the manner I have imagined, must have been accompanied by the escape of an immense amount of hot vapours, the chemical and thermal agency of which cannot be overlooked, upon any hypothesis of the rending and uplifting of great mountain-tracts. It is easy to conceive that the coal, throughout all the E. basins, if thus effectually steamed, and raised in temperature in every part of its mass, would discharge a greater or less proportion of its bitumen and other volatile constituents, as the strata were more or less frequently and violently undulated by earthquake action. It is also obvious that the more Western beds, remoter from the region of active movements, less crushed and fissured, and presenting a greater resistance to permeation by the subterranean vapours, would, in virtue of their mere geographical position in the chain, be much less extensively de-bituminised. The striking fact that we nowhere, not even in the most dislocated and disturbed districts of the anthracite coal-field, find any traces of true igneous rocks, that, by their contiguity to the coal, could have caused the loss of its bitumen, is a circumstance in their geology which goes far to confirm the truth of the hypothesis. Precisely in proportion as the flexures of the strata diminish in our progress W., does the quantity of the bitumen in the coal augment; but it is difficult to conceive how any such law of gradation could have been the result of a temperature transmitted by conduction from the general lava mass beneath the crust, for that would imply a corresponding increasing gradation in the thickness of the crust, advancing W. under the coal-fields; whereas such an inference is in direct conflict with the fact of the general diminution W. of the Appalachian rocks, besides being inconsistent with all correct geothermal considerations, which forbid our imagining so unequal a conduction, to the surface, of the earth's interior temperature.

FOSSILS OF THE COAL-FORMATION.

Without attempting here a full enumeration of the organic remains of the Appalachian Coal-measures, it is essential that we examine into the nature of those which may assist us to explain the physical conditions under which the different materials of the formation were produced.

The vegetable remains nearly all imply a humid climate, and a growth in a wet or marshy soil. The predominant plants of this wide coal-field, as of all the other chief coal-fields of the world, appear to be *Ferns*, some of them herbaceous, some arborescent. Their stems and fronds are very seldom to be met with either in the under-clays of the coal-beds or in those shales which are nearest allied to these under-clays in their composition. On the other hand, they abound in the strata which by their lamination imply deposition from gentle currents, such as the argillaceous sandstones, but especially the dark carbonaceous slates and shales, which in many instances immediately overlie the coal-seams, or are imbedded in them. The perfectly smooth or unrumpled condition in which so many of the fern-leaves, even to their most delicate and silky leaflets, are preserved between the laminæ of the slates, indicates that they cannot have been borne along by turbulent currents, but must have floated tranquilly in nearly still water, until they became imbedded in soft sediment on a quiet bottom.

Another abundant fossil is the *Lepidodendron*, a genus of which more than fifty species are already known to palæontologists. Of these, several kinds occur in the Appalachian coal-fields, their beautifully-marked stems being found in a more or less mutilated and crushed state in the coarser rocks, especially the sandstones, but sometimes also in the argillaceous beds, and even in the laminæ of the coal itself, in which, and in the black slates adjoining the coal-beds, we often meet with the slender grass-like leaves ascribed by botanists to this class of plants. In Pennsylvania the remains of Lepidodendra appear on the whole to be more abundant in the lower Coal-measures than in the upper, while the reverse of this is true of the ferns. This curious tribe, supposed to belong to the order *Lycopodiaceæ*, and to be represented by the living club-mosses abundant in tropical climates, was evidently one of the chief coal-producing plants of the Carboniferous era. Their huge flattened stems lie imbedded in the roof-slates of the coal-beds, or impressed between the laminæ of the coal itself, in a manner which suggests that they grew in a matted or tangled manner upon the surfaces of the broad wet plains in which the coal was formed. It is probable, indeed, from their great abundance, and their supposed capacity for taking root wherever the stem touched the soil, that they constituted a predominant feature in the vegetable landscape of the wide coal-producing savannahs, where this gigantic cryptogam played the part of the moss or sphagnum of the peat-bogs of the present day. The frequent occurrence of crushed and broken stems of Lepidodendron in the coarser rocks of the Coal-measures, especially in those which directly overlie the beds of coal, would seem to intimate that this plant was particularly susceptible of being torn or floated away by the currents which overspread the coal-meadows with the sandy and other detrital matter of these rocks.

Of equal importance with the Ferns and Lepidodendra is the plant called *Sigillaria*. This is a tree-like fossil, of cryptogamic structure, it is believed, but of somewhat higher organisation than any flowerless plant at present in existence. In the structure of some of its vessels it closely resembles the Ferns, to which it, moreover, bears some affinity in the scars left by the leaf-stalks upon the surface of the stem It deviates from the Ferns and other Cryptogamia, however, in displaying slender linear leaves. Of the genus there are at present more than forty-five species known to botanists. Some new ones, from the anthracite coal-fields, are figured on Plates XV. and XVI. of this work. Though allied to living plants of humbler stature, the Sigillaria, in some of its species, grew to a stalwart height and bulk. Their stems, which appear to have been regularly cylindrical, and destitute of branches, have been seen from 1 to 5 feet in diameter, and from 40 to 70 feet long. We remember one, visible in a compressed and flattened state, in the roof-slate of the coal at Carbondale, which had a length of more than 50 feet, and a diameter of 2 feet at its broader end. Colossal as this genus of plants was, it appears to have possessed a mode of growth of only the more lowly organised plants of the present day; for, in addition to the features already described, it subdivided towards its top by simply forking, not by throwing off true branches. The stem, moreover, appears to have consisted largely of soft cellular tissue, in virtue of which it was very easily prostrated, and very compressible when thrown down; and hence we so rarely find this fossil standing erect in the strata, but generally see it in a squeezed and flattened form, imbedded between the strata, and its interior or even the entire mass filled with, or converted into, the material of the rock which encloses it. But the most remarkable discovery connected with Sigillaria is the finding *Stigmaria* connected with it as its roots—a relation which has cast a flood of light on the whole theory of the origin of coal. This fossil (the Stigmaria), as already intimated, was at one time regarded as an independent plant, and was supposed to be the chief plant concerned in the production of the coal; but the eminent French botanist, M. Brongniart, guided by certain analogies of structure between Sigillaria and Stigmaria, shrewdly suggested that they might be respectively merely the stem and root of the same organism; and this astute scientific inference was soon afterwards (about the year 1846) amply corroborated by the almost simultaneous discovery, in Great Britain and Nova Scotia, of the physical connection of the two fossils. Several stumps of Sigillaria were detected by Mr Binney in a railway-cutting terminating downwards in well-formed roots, identical with Stigmaria, the Stigmaria resting in a coal-seam, and the stump or trunk enclosed in an overlying bed of sandstone. Soon afterwards, Professor Dawson found near Cape Malagash, in Nova Scotia, an instance of the same connection, which was nearly as conclusive.* Later in the same year, Mr Robert Brown, of Sidney, discovered still more perfect and convincing instances of erect Sigillaria, terminating in Stigmaria as roots, in the coal-strata near Sidney. As these and other instances have been already cited in my account of the Nova Scotian coal-fields, I need not multiply examples of this important fact.

Various other forms of vegetation, common in the coal-fields of Europe, are to be met with throughout nearly every part of the wide Appalachian basin and its outlying troughs; but as these are less essential to the theory of the origin of the Coal-measures than the preceding, I shall pass them over with the bare mention of their names. The genus *Calamites* is one of them, existing in several species: these fossil plants, once regarded as allied to the existing Horse-tails or common Equiseta, but in gigantic proportions, have been pronounced by Brongniart as of probably higher structure than any of the flowerless plants. He has indeed brought them under a new genus *Calamodendron*, which is now regarded as an internal pith of a larger plant; its place in the vegetable kingdom is very imperfectly understood. Asterophylites is another coal-plant frequently found in our coal-slates.

The sandstones of the Coal-measures not unfrequently exhibit fossilised stems of what seem to be coniferous trees; these, and the other tree-like stems, as they are seen in the Appalachian coal-fields, almost invariably lean at a low angle in the thick sandstone strata which enclose them; they seldom occur in the shales, but are nearly restricted to those coarser rocks which appear to have been deposited by rapidly-flowing currents. It is not a little curious that nearly all of these trunks dip towards an opposite quarter from that towards which the false bedding or oblique lamination of the surrounding sandstone itself declines. This fact, noticed by me not merely in Pennsylvania, and on the Ohio River above Gallipolis, but also in the instance of the celebrated Craigleith tree near Edinburgh, and in the great tree of the Granton quarry, near the Firth of Forth, goes far, I think, to demonstrate that all these leaning stems have been imbedded in the manner of *snags* in actively-moving currents, their butt-ends settling first, and their lighter tops pressed forward by the waters, which at the same time piled the sand obliquely about them with a forward dip.

OF THE FORMATIVE ACTIONS CONCERNED IN THE PRODUCTION OF THE PALÆOZOIC AND OTHER STRATA.

Geology recognises four classes of actions in the production of the stratified envelope or outer crust of the globe: 1*st.* Igneous action, or the effusion of mineral matter in a melted state; 2*d*, Vital action, or the production of organic forms by vital secretion of the elements; 3*d*, Chemical action, or precipitation of matter in a solid form from aqueous solution; and 4*th*, Mechanical action, or the strewing of mineral fragments, or particles already solid, by the waters—and in a less extent by the winds, in more or less active motion. It is chiefly of the last function, or that of stratification by moving water, that I propose to treat in this place.

The essential dynamic conditions of sedimentation by water, are, first, the force of terrestrial gravitation acting perpendicularly upon suspended or floating matter; secondly, the approximately horizontal force of moving water exerted either continuously or intermittently; and, thirdly, the resisting force of friction, operating between the strewn matter and the floor over which it is propelled, and between fragment and fragment of the moving material itself.

Water will deposit or let go solid particles suspended or floating in it at all angles of subsidence, from a nearly perpendicular one, when it is in a state of almost absolute repose, to an approximately horizontal one, when its velocity is very great in comparison to the sinking tendency of the material it floats. This latter element, called buoyancy, is itself dependent upon the specific gravity and the degree of comminution of the suspended particles; for the degree of

* Proceedings of the Geological Society of London, for January 1846.

comminution measures by a certain law the ratio of surface, and therefore of resistance, through friction, to the force tending to sustain the weight or downward tendency.

Perpendicular Deposition.—In the case of water nearly at rest, the conditions of precipitation of suspended matter heavier than itself, either chemically or mechanically derived, are extremely simple. The subsidence is nearly perpendicular, only varying in slowness as the solid matter is more or less buoyant, and in depth of accumulation as the time is more or less protracted, and the amount of matter in suspension more or less abundant. Strata thus produced are remarkably uniform in their thickness, and constant in their composition and degree of fineness, are free from lamination, and are very massively bedded. Where the sedimentary matter is impalpably fine, and the water in nearly absolute repose, a true stratification or division into layers scarcely takes place, for this requires either some interruption of action, change of material, or partial horizontality of movement. On the other hand, the entire mass is of the nature of a homogeneous pulp without horizontal divisional planes or partings. Instances of this mode of deposition are not infrequent in nature, and the processes of the industrial arts furnish abundant instances of it, for example, in the pulpy magmas of the precipitating vats of every large chemical work. But deposition without stratification may and does occur, where the fragmentary matter is coarse and heterogeneous, as when a torrent or surge of water sweeps or pushes a body of coarse gravel and sand into dead water, or into an opposing current, capable of producing at their line of mingling a local and temporary cessation of the onward motion. I conceive that the unstratified Till of the Boulder-drift has been simply a deposition under these circumstances. The drift-conveying current has encountered a check from some rebounding wave or oscillating pulsation of the ground over which it has been rushing, has reached a pause in certain places long enough for a perpendicular heaping together of its promiscuous materials, without the onward motion necessary to laminate them.

Stratification, or Deposition with Strewing, by Water in Motion.—The formative or reproductive function of moving water deserves, I conceive, a far more careful study than it has hitherto received from geologists. Through inattention to some phases of the action, the gravest mistakes of theory are constantly committed, and even serious misestimates made respecting the depths and dimensions of formations.

We may view water in motion as possessing two modes of transportation: it can drive before it a mass of fragmentary mineral matter, too coarse or heavy to be actually suspended in it, propelling it against much mutual attrition, and the retarding friction of the ground, with a rolling motion, until it spreads it in a broad sheet upon the surface which itself previously occupied; or it can hold the sedimentary matter in a state of suspension, and waft it onward, gradually depositing it as it flows.

Stratification without Suspension.—Inasmuch as nearly all rocky substances lose almost two-fifths of their weight when immersed in water, it is obvious that the rolling material, being so much lighter than in air, encounters so much the less impediment to its progress from resistance by the bottom, and by mutual friction of its lumps and particles. This mode of strewing of the loose debris of the land produces necessarily an obliquity in its bedding, precisely as when a rake or harrow is propelled over movable earth or gravel to smooth it down; the surface will be even, and approximately horizontal, while the mass will be formed of forward-dipping layers, successively and slantingly deposited. As the action in such cases is necessarily more or less paroxysmal or intermittent, there will arise in this mode of dispersion much re-strewing of the upper exposed portions of the already deposited sediments. If the movement of the water is energetic, the outward-pushing current will be followed by a pause, and this by a rebounding or shoreward motion; and the result of this change will be the deposition of a horizontal layer upon the previously-formed inclined ones, and immediately upon the top of this a second series of obliquely-bedded strata dipping towards the land; and this cycle of oblique and horizontal bedding may be repeated several times before the waters return to rest, or assume a permanent current-movement. In many instances, the second push of the waters, especially in the outward direction, will be strong enough to sweep up and re-disperse a part of the matter previously laid down, and thus the lower sheet

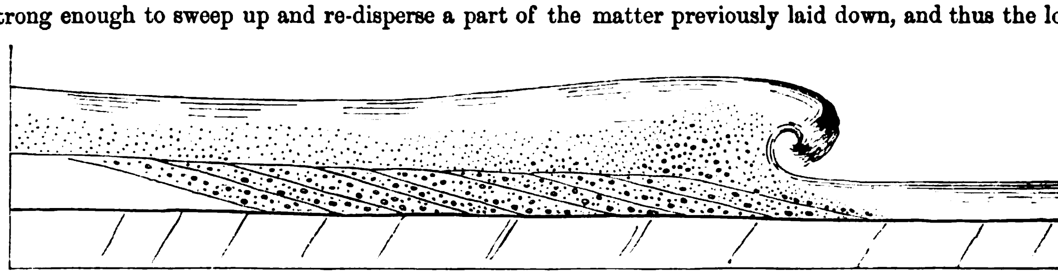


FIG. 587.—Oblique Deposition by Strewing.

will have its beds shaved down or truncated, and a new series of layers superposed upon them, either dipping to the same or opposite quarters. It is not necessary to the production of this oblique or cross-bedding that the surface or floor strewn by the deposit should be beneath the permanent or tranquil level of the sea or other recipient basin, nor is it at all essential that the floor should slant. Every one who has carefully examined the detrital matter left by a violent wave or torrent that may have suddenly swept over the dry land, as when a great river-dam gives way, must have noticed that the materials which it pushed before it, even upon slightly-ascending ground, were thus slopingly laid down. Indeed it is obvious that any heavy surge of water, rushing across an upland tract, will, as long as it retains a high velocity, and meets with a supply of loose fragments, or with strata which it can abrade, necessarily deposit its rolling dregs in this forward-tilted posture. It is literally a case of *smearing* on a grand scale, the advancing front of water, or most actively-moving wave within it, being the knife edge; and as in all examples of this mode of distribution of plastic matter, the front, being resisted below and propelled above, takes on the sloping attitude.

In the mensuration of the strata, thus slantingly deposited, great errors may be committed, whether the bed retains their original posture or are uplifted by a subsequent movement of the crust; as will appear, if we consider the amount of discrepancy which exists between the actual thicknesses of the strata, measured from one horizontally original layer to another, and their calculated thickness, as compiled from the diameters of the oblique divisions of which they consist. And when the originally horizontal partings are wanting, or obscurely traceable, the difficulty of avoiding this error from obliquity is very great, and vitiates many patient measurements. This source of error insinuates itself, in fact, into all trigonometrical estimates of strata, where the distances across their outcrops are comparatively great, or exceed by many times the spaces between the main divisions of the formation; for, as I shall presently show, *all mechanically-derived deposits are obliquely bedded upon one another on a greater or less scale.*

Stratification from a State of Suspension in Water.—In all instances where the relation of the velocity of the water to the bulk of the particles or fragments—or, in other words, their buoyancy—is such as to keep them from reaching the bottom for a shorter or longer distance from the shore or permanent water-line, the stratum which they form, whatever may be its horizontal dimensions, will exhibit a thin edge towards the land, gradually thicken as it recedes, and then still more gradually attenuate till it ceases. This arises from the floating and rolling matter coming to rest only as the velocity of the current declines, from the precipitation increasing as the retardation proceeds, and from the materials becoming ultimately exhausted. It is obvious that between the two limits of too high a velocity and a low supply of slowly-falling particles, there must exist a space where the two conditions of lessening speed, and repletion of material, are to gather at a maximum. Every stratum—every formation, indeed, however wide—which is the product of one formative transporting current, even though its deposition may have occupied many ages, possesses this tapering-off towards both its landward and seaward margins; in other words, its cross section is fusiform. But while it displays this attenuation in both directions, its component fragments, whether boulders, pebbles, grains of sand, or particles of clay, will, in the aggregate, show a steadily lessening size from the inner to the outer edge of the deposit; and wherever we meet with exceptions to such a progressive declension in their coarseness in a given direction, we may be sure that some change arose in the velocity, or in the course of the current; and when the change is conspicuous, we are to regard the deposit as marking another and different formative stage.

Now it should be observed that all depositions of land-derived mineral substance must take place on shelving bottoms, and the sediments themselves must form a succession of gently-inclined planes. Absolute horizontality can scarcely arise, nor can there be a near approximation to it, except in tracts far removed from the shore, and where the currents are very gentle, steady, and long-continued. Thus, then, the feature of oblique bedding, or the successive overlapping of slanting deposits from original obliquity of deposition, is a primary fact of all mechanical strata. It is obvious that if the members of a formation, thus slopingly accumulated upon a bottom more horizontal than themselves, be measured for thickness by the usual trigonometrical process of taking their angles of dip, and the breadth of their outcrops, we shall be liable in many cases to commit the grossest exaggeration in our estimate of their total depth or thickness. As a general rule, the difference between their actual and their calculated mass will be greater, the greater the length of our section, other things remaining constant; for the greater the breadth of outcrop, the more room is there for the thinning out and coming in of deposits, nowhere to be found vertically superposed. I think it

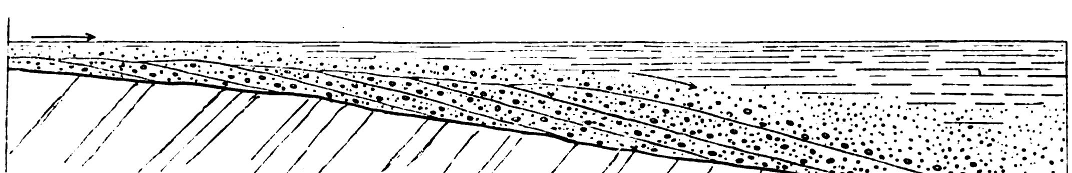


FIG. 588.—Oblique Stratification from Suspension.

will be found, too, that conglomerates and coarse sandstones, by tapering more rapidly in their dimensions than the finer argillaceous strata, will be the most subject to over-estimation.

From the considerations here presented, it seems highly probable that the astonishing thicknesses recorded by geologists of many mechanically-formed deposits—for instance, the Coal-measures of South Wales, computed at

9000 feet, and those of the Joggings in Nova Scotia, estimated at 14,000 feet; or again, the Old Red Sandstone of Scotland, calculated at 5000 feet—are all egregiously too great for Nature. The serious detriment to scientific and practical geology of an habitual over-estimate of the depth of the several formations, more particularly the Carboniferous, needs no comment. In computing the spaces which separate the seams of coal in a group of Coal-measures, I have long ceased to place any reliance upon trigonometrical measurements of the included coarser mechanical rocks. Where the strata outcrop at angles sufficiently steep to admit of direct measurements from coal to coal, either perpendicularly to these beds—the surest of all guides—or on a horizontal surface across a narrow interval, very little error need creep in; and there is an equal correctness where the stratification of the coal-field is approximately horizontal, and we measure perpendicularly through all the rocks intersecting coal after coal.

Perhaps the most remarkable example of original obliquity of deposition, on an extended scale, to be met with anywhere, is that which is presented by the Mesozoic red sandstone of the Atlantic slope in the Middle States. This formation exhibits, in New Jersey and Pennsylvania, a width in many places of more than 25 miles, yet it displays but one direction of dip, or one series of original planes of sedimentation, throughout this entire space. The slope of the beds is everywhere N., and at angles varying from 10° to 30°. Now, if computed trigonometrically, this formation should possess a depth of many miles; yet there is the amplest evidence in the physical geography of the region and, above all, in the exposure by denudation, of the floor upon which it rests, that it is *extremely shallow*. In the neighbourhood of New Hope, some 13 miles from its S. margin, where the formation should have, by the usual rule of estimation, a depth of not less than 10,000 or 12,000 feet, its bottom is actually exposed, and its thickness is not more than 50 feet. It was deposited, in truth, in a wide shallow estuary or tidal bay, ascending S.W. into a broad shallow river, but its materials were swept in from the S. and S.E. *across* its channel, which evidently lay next its N.W. shore, and were slantingly laid down, the whole process assisted probably by a gradual lifting out from beneath the water of its S.E. coast, accompanied by a rising of the land in that direction.

Having discussed as succinctly as possible the mechanical conditions of the sediments, coarse and fine, upon a stationary floor, I might, if space permitted, consider with profit the effects on stratification upon a great scale, produced by movements of the crust, or shiftings of level of the land and sea, both secular, or gradual and prolonged, and paroxysmal, or sudden and violent. Even in the now existing comparatively quiescent state of the earth's crust, the relative level of the ocean, and the lands confining it, remains nowhere absolutely constant, but is ever slowly shifting, secularly or paroxysmally, or in both modes combined. In some regions it is with elevation, in others with permanent subsidence of the land. But these changes must have been both more extensive vertically and more rapid in the ancient periods, when the earth's crust was manifestly more flexible. Let us take a glimpse of some of the more obvious results of these grand mutations of level.

1. Wide tracts of coast, including the shelving bed of the adjoining sea, are liable, and have been in all geological ages, to a general equably-distributed uprising and subsidence. If, while deposition is steadily proceeding, the watery floor receiving it is either gradually or by sudden shocks permanently lifted by a self-parallel movement, it is plain that, throughout the space thus shifted in level, the sediments formed at successive stages must be more and more restricted in their horizontal limits. Each later sea-margin will lie somewhat more seaward than its predecessor, while the opposite or seaward edge of the deposit will overlap or lie beyond in the same direction. Thus we see that no two successive parts of a formation so produced will be strictly superposed, but will lie like a pile of paper whose leaves have slipped a little obliquely on each other. The stratification of the great Appalachian coal-field offers, I think, some interesting exemplifications, hereafter to be adverted to, of this important feature of the under and over-lapping of the original edges of parallel beds.

2. If, on the other hand, the coast and adjacent sea-bottom gradually or intermittently sinks with a self-parallel movement, the successive sheets of sediment will encroach landwards, and both their margins will shift from the previous area of the water towards that of the land. Here the overlapping will be next the land-side, each later deposit having its margin farther in.

The views now presented apply not merely to sediments produced on the level of the sea, or on a water-covered floor, but equally to accumulations, limited by physical conditions, only prevailing at the water-side. They apply, in other words, as well to the terrestrially-formed beds of coal as to the more purely aqueous deposits of shale and sandstone which commonly enclose them. Every coal-seam was once a wide level peaty meadow or morass, resting at or very little above the sea-level, or the level of some broad sheet of water; and its accumulation, from a redundancy of vegetable life, depended upon a nice adjustment of the conditions of humidity and dryness. The extension of this vegetation must have been restricted, on the side towards the water, by an excess of moisture, on the land side by a deficiency; for we are sufficiently familiar with the structure of the coal-producing plants to know that, while they could not have grown entirely immersed in water, they could as little have flourished upon an upland-rolling surface, where their roots and lower stems could not be kept constantly moist.

Other modes of fluctuation of level of land and sea, introducing their own special conditions of stratification and superposition of sediments, present themselves to our notice. Such are chiefly—1. A secular or paroxysmal rising of the land, and adjoining sea-bottom—the ocean remaining always stationary,—with broad undulation; and, 2. A depression of a coast, and the contiguous watery floor, with a similar departure from self parallelism. Each of these modes of alteration of level may be, or rather must be, accompanied by either a greater rapidity in the rising or in the sinking of the shore than of the sea-bottom, or by the reverse—a more rapid rising or sinking of the bed of the sea than of the land. In other words, an unequal rate of subsidence or elevation of a coast, compared with its opposite sea-bed, includes four categories—1. A more rapid lifting of the coast than of the remote watery floor; 2. A more rapid lifting of the latter than of the former; 3. A more rapid sinking of the shore than of the sea-bottom; and, 4. A more rapid sinking of the sea-bottom than of the shore.

With each of these slow or secular movements, there is, and always must have been, associated, but more actively in the earlier geological ages, occasional paroxysmal undulations of the surface; and these long-continued secular sinkings and risings of the land and abrupt paroxysmal ones resulted in permanent low flexures of the crust in great alternate zones. But to enter upon a special analysis of the effects of these several modes of displacement of the relative level of land and water, would take me too far from my present purpose of this essay, which is to discuss only those laws of geological dynamics which possess a direct scientific and practical bearing.

ORGANIC REMAINS OF THE PALÆOZOIC STRATA OF PENNSYLVANIA.

FOSSILS OF THE PRIMAL STRATA.

THE only organisms hitherto anywhere discovered in the Primal strata are two or three plants of obscure affinities, a worm-like form called *Scolithus*, one or two molluscs, and a few trilobites of an humble type.

The few vegetable structures seen are, without exception, related to the marine Algæ, or sea-weeds; or, more strictly, they belong to that doubtful group of fossil plants called *Fucoids*.

The best specimens met with in the Geological Survey of Pennsylvania were found in the Primal upper slate of Chiques Ridge at the Susquehanna. The most clearly defined form is not unlike the marine plant, *Fucoides duplex* of Hall, described by him from the Primal sandstone of Lake Superior (see Foster and Whitney's *Lake Superior*, Plate A, 23), though I would by no means affirm that it is the same species.

Of *Animal Remains*, by far the most abundant form is the *Scolithus linearis* (see Fig. 589). This curious fossil, alluded to in the Annual Reports of Virginia and Pennsylvania under the name of *Tubulites*, is a nearly straight cylindrical simple stem-like impression, usually almost smooth, but in some specimens faintly waved or grooved transversely to its axis. Its diameter is from one-eighth to half an inch, its length from a few inches to 2 or 3 feet. Its position in the rock is invariably perpendicular to the bedding, suggesting the idea of perforations by some marine worm. One end of the fossil always terminates at the upper surface of the bed of sandstone enclosing it, and usually in a rudely-flattened knob or head, giving to the whole a likeness to a large long pin. This knob is probably a cast formed in a wide conical funnel-shaped mouth of a cylindrical perforation.

Similar stem-like forms occur in some of the other sandstones of the higher Appalachian formations, but none are so well characterised as this species of the Primal white sandstone. (Our figure represents the corrugations of the surface rather too distinctly.) An excellent locality is Chiques on the Susquehanna.

This fossil occurs in great abundance in the Blue Ridge of Virginia.

The Primal sandstone is also characterised by a species of *Lingula*, the *L. prima* of Conrad, a small obtusely-oval shell, resembling somewhat the *Lingula curta* of the Matinal limestone (which see). Its surface is faintly marked by concentric lines and delicate longitudinal striæ. It is by no means so common as the Scolithus. This shell is not unlike the *Lingula Davisii* of the Lingula flags of North Wales, one of the oldest fossils known in the Palæozoic rocks of Europe.

FIG. 589.—Scolithus linearis.

It is not a little curious that these extremely ancient Lingulæ are represented by other species of the same genus in strata of nearly all later geological dates, and by several now living in the existing waters of the globe. The occurrence of the same genus, so little modified through so vast a lapse of geological time, bespeaks a general uniformity in those physical conditions of the ocean affecting the less sensitive forms of life, which is instructive. As, however, the few primoidal species are not identical with any belonging to subsequent ages, we are not entitled to infer that the physical circumstances, especially the conditions of temperature and pressure with which they were in harmony, were at all identical with those of later or present times, for many existing marine genera, and eminently so this genus Lingula, possess species adapted to extremely dissimilar climates and zones of depth in the ocean.

In extent of complexity of organisation, the genus Lingula by no means ranks among the humblest of the Molluscæ.

It is an interesting fact, that the shells of the fossil Lingula abound in the *phosphate of lime*, an essential element of bone. Their comparative deficiency in the carbonate of lime may perhaps account for their frequency in pure sandstones and other non-calcareous strata. The presence in the earliest Palæozoic deposits of creatures thus constituted to furnish appropriate food to the races endowed with bony skeletons, leads naturally to the inquiry whether fishes or some forms of vertebrate life may not have existed to prey upon them; nevertheless, we are scarcely warranted in placing so mere an inference in the scales of evidence where we have on the opposite side the universally-admitted absence of the equally indestructible bones and ganoid scales of the fishes of the earlier age.

Associated with the *Lingula* is a species of Obolus, a discoid Brachiopodous shell, equally characteristic of the oldest Palæozoic strata of Europe. It has been met with in Wisconsin (see Owen's Report); and I have myself found a few obscure specimens in the Primal slate of Pennsylvania.

Perhaps the most interesting organic remains of the Primal strata are their Trilobites; of these crustaceans, eight or nine species are already known to characterise the formation, though hitherto not a relic of the kind has been discovered in either of the Primal rocks of Pennsylvania. Of the known species, seven occur in the Primal sandstones of Wisconsin and Minnesota; they are described and admirably illustrated by Dr David Dale Owen, in the Report of his Geological Survey of Wisconsin, Iowa, and Minnesota. They are named *Dikelocephalus Minnesotensis, D. Miniskaensis, D. Iowensis, D. Granulosus, D. Pepinensis, Loncho-cephalus Chippewaensis, Crepicephalus Wisconsensis;* these species bear a marked general likeness to the genus Paradoxides of Brongniart. Until this discovery by Dr Owen, no trilobite remains were known in any American formation older than the Auroral limestone. More recently a small specimen of apparently a new species of Calymene has been found in the Potsdam sandstone of the W. side of Lake Champlain, near Keesport, New York; the only instance in which a trilobite has yet been detected in this formation within the Appalachian chain.

About two years ago some very distinct impressions of an unusually large trilobite were discovered in Eastern Massachusetts, S. of Boston, upon altered argillaceous sandstone, in a geological zone previously regarded as entirely destitute of organic remains; they were submitted to Prof. Wm. B. Rogers, who recognised their trilobite structure, and after farther search for better specimens, ascertained their specific affinities. He has shown that they belong to the genus Paradoxides, and very probably to the also European species *Paradoxides spinosus*, a genus and species characteristic of the oldest fossiliferous formations of

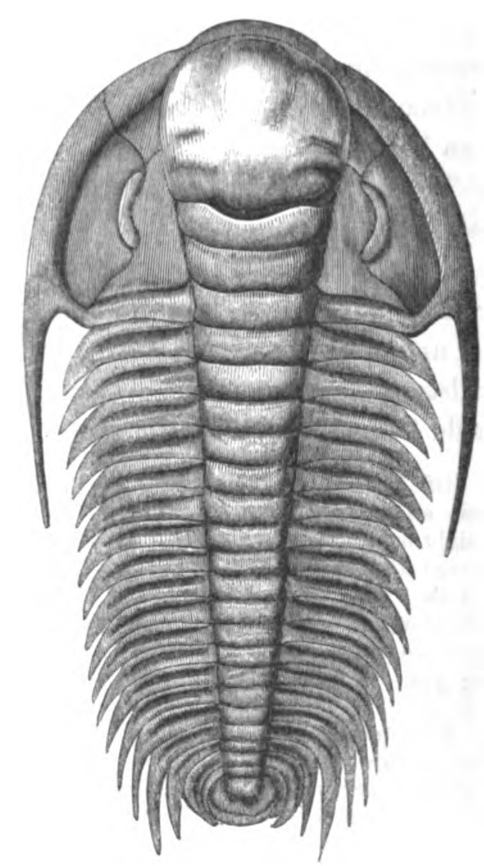


FIG. 590.—Paradoxides spinosus, from a quarry in Quincy. Massachusetts, one-third its natural size.

Europe.* These relics render it highly probable that some of the altered rocks of Eastern Massachusetts are coeval with the Primal series of the Appalachian basin.

An interesting analogy presents itself in the general structure of all these Primal or Primordial trilobites; it is their resemblance to the immature forms, or earlier stages of metamorphism, of the more complexly organised trilobites of later geological ages: evidence of this likeness will appear upon comparing *Paradoxides dikelocephalus*, or, in truth, any of these earlier crustaceans, with the figures upon Barrande's plate, exhibiting the transitions through which his species, *Sao hirsuta*, has passed from its lowest stages of development to full maturity. But a true homology of parts must be established to lend this resemblance any value.

ORGANIC REMAINS OF THE AURORAL STRATA.

None of the organic remains of the Primal strata recur in the Auroral or next overlying series. The total number of fossil species from the Appalachian Auroral rocks at this time recognised, cannot be less than one hundred, and all of them appear to have come into existence after the revolution in the physical geography of the Palæozoic waters, which closed the Primal formations, and initiated the very dissimilar Auroral ones. Marine plants, zoophytes, molluscs, and crustaceans, comprise the great organic types hitherto discovered in the Auroral limestones, the humblest forms being a few so-called fucoids or sea-weeds, and the highest, certain species of trilobites.

Of the PLANTS, the only species seen in Pennsylvania has been the *Palæophicus tubularis* of Hall (see *Palæontology of New York*, Vol. I. Plate II.), and even it is rare.

Of the Polyzoans, the *Retepora incepta* (*Palæontology of New York*, Plate IV.) may be frequently met with in the blue Auroral limestone of the anticlinal valley of Centre, Blair, and Bedford counties.

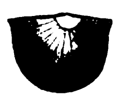


FIG. 591.—Leptæna incrassata.

FIG. 592.—Atrypa plicifera.

FIG. 593.—Murchisonia bicincta.

FIG. 594.—Raphistoma staminea.

The mollusca proper are much more numerous, nearly all the species figured and described in the *Palæontology of New York* being met with, though for the most part difficult of development, from the partially metamorphic limestone imbedding them.

A somewhat common species is the *Leptæna incrassata* (see Fig. 591), seen in Kishicoquillas and Nittany valleys. Another abundant brachiopodous shell occurring in the same lines of outcrop is the *Atrypa plicifera* (see Fig. 592).

Among the gasteropodous molluscs the *Pleurotomaria umbilicata*, *P. nucleolata* (see *Palæontology of New York*, Vol. I. Plate X.), *Ophileta levata*, *Murchisonia bicincta* (see Fig. 593), *Raphistoma striata*, *R. staminea* (Fig. 594), and the beautiful fossil *Maclurea magna* of Leseuer (Fig. 595), are perhaps the most common.

FIG. 595.—Maclurea magna.

In the lower or sandy beds I have found *Euomphilus ungulatus*, *Maclurea matutinas*, and *Pleurotomaria turgida*, but this member of the formation is seldom well enough exposed in Pennsylvania to yield good fossils. The *Orthocerata* are not common; perhaps the species most frequently met with is *Orthoceras multicameratum*, a figure of which is here given (see Fig. 596). *Ormoceras tenuifilum* occurs, but more seldom. The commonest crustacean in this formation, in Pennsylvania, is the *Isotelus canalis* of Conrad. There also occurs a species of *Leperditia* (Cytherina), the *Leperditia ovata* of Rupert Jones—(see Fig. 697, p. 834).

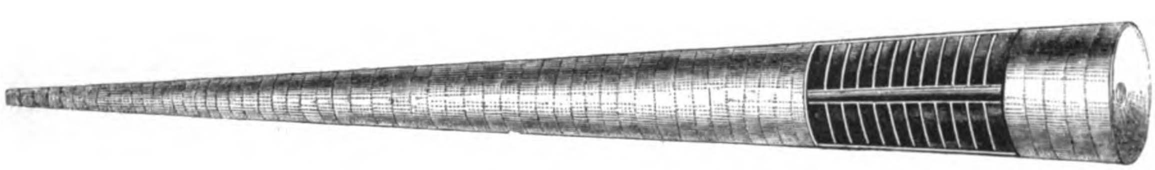


FIG. 596.—Orthoceras multicameratum.

* See "Proofs of the Protozoic Age of some of the Altered Rocks of Eastern Massachusetts," by Professor W. B. ROGERS (*Proceedings of the American Academy of Arts and Sciences*, vol. iii.)

ORGANIC REMAINS OF THE MATINAL STRATA.

Matinal (*Trenton*) *Limestone.*—The entire Matinal series has up to this date afforded naturalists not fewer than 300 fossil species, and at least 200 of these are restricted to the Matinal limestone. It is a striking fact, that though this limestone stratum succeeds immediately other limestones, and without any physical break between them, its organic remains are almost entirely different—less, probably, than ten per cent being common to the two formations. So abrupt a transition in the inhabitants of the early Palæozoic waters is perhaps in part explained by the argillaceous nature of the Matinal rock, the muddy sediment unfitting the waters for the species of the magnesian limestone sea, and adapting them to new races in more express adjustment with them. It is worthy of remark, that some of these species, confined to the Trenton rock, New York, pass down into the Auroral limestone in Pennsylvania and Virginia.

In Pennsylvania the Matinal limestone is not always present in the series, and in none of its discovered localities is it as favourably exposed for the detection of its organic remains as in the districts lying N. and W., for it is never horizontal, nor free from more or less of metamorphism; still it presents a good variety of its well-known fossils. Those more commonly met with, or by which the formation may be most readily recognised, are here referred to and figured.

Fig. 597.—Chætetes lycoperdon.

Fig. 598.—Strictopora acuta.

The Plants of the formation consist in our State, as elsewhere, of those obscure forms called *sea-weeds;* one of the commonest I am disposed to identify with the *Buthotrephis gracilis* of Hall.

Of the Corals, perhaps the most abundant is the *Chætetes lycoperdon*, especially the spherical form of it, shown in the annexed figure, which represents one margin broken, disclosing the slender radiating tubes.

Another frequent zoophyte is the *Strictopora acuta*, here shown (Fig. 598), with a portion of one branch magnified to show its oval cells. This supposed coral resembles much in structure the genus *Eschapora*, which naturalists no longer regard as belonging to the zoophytes, but to the class *Polyzoa* (or *Bryozoa*) of the Mollusca: there can be little doubt, indeed, that such is its true place in the animal kingdom.

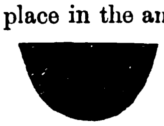


Fig. 599.—Leptæna sericea.

Fig. 600.—Leptæna alternata.

Among the fossil Shells of the formation, one of the most common is the beautiful little semicircular brachiopod *Leptæna sericea* (Fig. 599). This small species is recognised by its fine radiating striæ, grouped between occasional more prominent ones, and by its fine granulated surface. Another very common brachiopod, of the same genus, is the *Leptæna alternata* (Fig. 600), a large half-oval shell, with a minutely-perforated beak, the dorsal valve here shown being very convex, especially towards the margin, but flatter towards the hinge: its surface exhibits delicate rounded radiating striæ or threads, unequally alternating with coarser ones.

Fig. 601.—Orthis testudinaria.

Another brachiopodous genus, *Orthis*, is represented in this rock by *Orthis testudinaria* and *Orthis pectenella*, both very abundant fossils in Pennsylvania—(Figs. 601, 602). The *Orthis testudinaria*, named for its fancied resemblance to a turtle, is interesting as being also a characterestic species of the lower Palæozoic rocks of Europe, and therefore one of the links serving to link together the formations of the two sides of the Atlantic.

Fig. 602.—Orthis pectenella. (N. S.?)

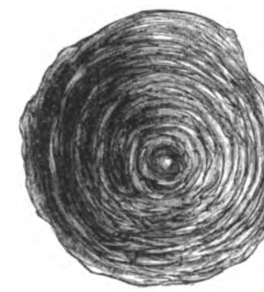


Fig. 603.—Orbicula. (N. S.?)

The other species, *Orthis pectenella*, if not likewise a European form, resembles one, the *O. calligramma*, very closely. Another brachiopod, not so frequently met with as the preceding, is an *Orbicula* or *Crania* (Fig. 603), a large discoid shell, with a small elevated conical apex, somewhat centrally placed, and a surface rough with rather irregular concentric scaly ridges. It differs from any already-described older Palæozoic *Orbiculæ* in the subcentral position of the apex, and is probably a new species.

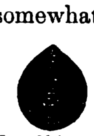


Fig. 604.—Lingula curta.

A very beautiful small brachiopod, the *Lingula curta* (Fig. 604), is also somewhat common; and in the Valley of Virginia, where the Matinal limestone abounds in black slate, it is very abundant. This fossil is one of the few which occur also in the Matinal black slate. It is to be met with in both formations in the Kittatinny Valley, and in Centre and Bedford counties.

Of the lamellibranchiate shells, or bivalves, one of the most common is the *Ambonychia bellastriata* (Fig. 605), a beautiful fossil, with a long slightly-curved beak, very oblique to the short cardinal line. Its surface shows fine radiating striæ, intersected by concentric lines, marking successive growth. The ambones are very protuberant.

In the Gasteropods this formation, in Pennsylvania, most abounds perhaps in species of the widely-ranging genus Pleurotomaria. One of the best-defined is the *Pleurotomaria subconica*, here presented (Fig. 606). This neatly-shaped univalve, often mistaken for a *Trochus*, has an elevated conical spire about five volutions, and a slightly-projecting carina or ridge above the suture or groove. The aperture is squarish, and the surface marked with fine bending striæ. Our figure is derived from a cast.

Fig. 605.—Ambonychia bellastriata.

Fig. 606.—Pleurotomaria subconica.

Another beautiful and common fossil of the formation is the *Bellerophon bilobatus* (Fig. 607), found also in the overlying Matinal shales. This fossil is not distinctive of the Matinal period, for it occurs likewise in Surgent strata; and, as is usually the case with long-enduring species, it has a commensurately wide geographical distribution, being one of the best-known shells of the Cambrian (Lower Silurian) rocks of Great Britain.

Fig. 607.—Bellerophon bilobatus.

The nature and affinities of the animal in the shell called Bellerophon are rather doubtful, some naturalists regarding it as a Gasteropod; others viewing it to be a Cephalopod destitute of the usual partitions; and others, again, believing it to be a Heteropod, allied to the creature called *Carinaria*, one of the floating glass-shells.

Among the Orthocerata of the Matinal limestone, one of the most frequently encountered is the curiously-ringed *Orthoceras vertebrale* (Fig. 608). This appears to have been a rather fragile shell, for I have never seen it entire.

A curious fossil, sometimes referred to the Cephalopodous mollusca, but believed by many naturalists to rank with the Pteropods, is the Conularia, one species of which, *Conularia Trentonensis*, is not infrequent in the Matinal limestone of Pennsylvania, but the specimens are seldom perfect. The annexed figure is therefore copied from an excellent representation (Fig. 609) given by Professor Hall in his *Palæontology of New York*, Plate LIX., fig. 4.

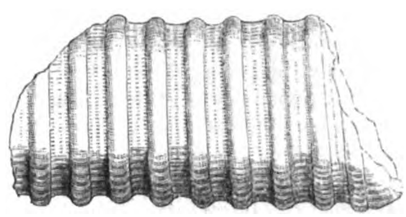


Fig. 608.—Orthoceras vertebrale.

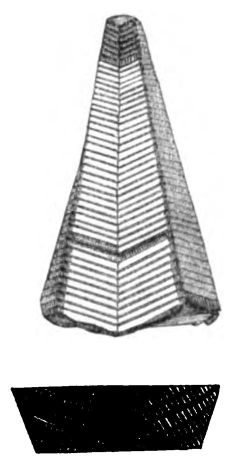


Fig. 609.—Conularia Trentonensis.

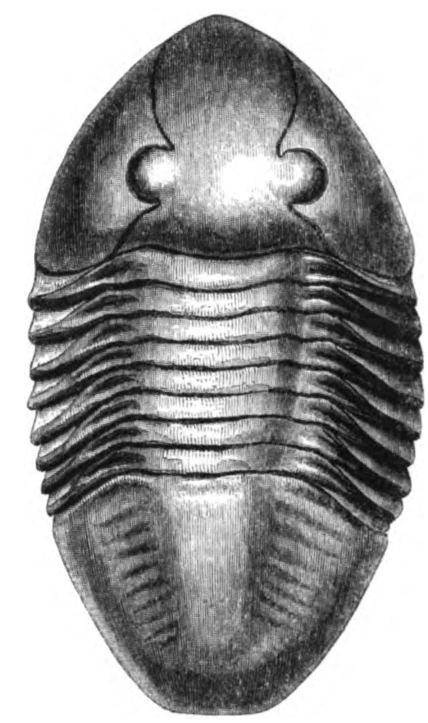


Fig. 610.—Isotelus gigas.

But by far the most attractive organic remains of the formation are its *Trilobites*. Of these there are nearly twenty species known, more than one half of which are restricted to the Matinal limestone, the remainder ascending into the Matinal shale. One of the most frequently found is the *Isotelus gigas*, Dekay, or *Asaphus platycephalus*, Stokes, of which a figure is here presented (Fig. 610). This fossil, occasionally found also in the Matinal shale, is eminently distinctive of the Matinal formations, and is equally restricted in Europe to the rocks of corresponding age—the Upper Cambrian or Lower Silurian. According to Barrande, the foremost authority on the subject of Trilobites, the American genus *Isotelus* has not the value of a distinct genus, but is subordinate to the great genus *Asaphus*—*Isotelus gigas* being identical with *Asaphus platycephalus*. This interesting crustacean is sometimes of enormous size, fragments having been found in the Matinal shales of Ohio, which indicate that the perfect animal must in some instances have been nearly 2 feet long—exemplifying the general law, that the size of a race is usually greatest in that formation in which it seems to culminate, either in the variety of its species or in the multitude of its individuals. In Pennsylvania I have occasionally, though rarely, met with this fossil in the Matinal shales. Its greater abundance and size in Ohio are obviously, as Professor Hall suggests, connected with the very calcareous nature of the same formation in that region; possibly it is likewise due to the greater remoteness of the western locality from the shore of the ancient Matinal waters, and therefore to more perfectly marine conditions.

Another interesting trilobite common in the Matinal limestone is the *Trinucleus concentricus* (Fig. 611). This, like the *Isotelus*, characterises both divisions of the Matinal series, but is found nowhere else in the Palæozoic column; and it is, equally with that fossil, distinctive of the Upper Cambrian or Lower Silurian deposits of

England. This beautiful and easily-recognised fossil is of common occurrence in the Matinal limestone of the anticlinal valleys of Central Pennsylvania. It occurs with *Isotelus gigas*, *Calymene senaria*, *Beyrichia lobatus*, and *Leperditia ovata*, abundantly in the neighbourhood of Pine Grove, Aaronsburg, and Potter's Fort, in Penn's Valley, and also in Nittany and Nippenose valleys, and in Milligan's Cove. This trilobite may be recognised at first sight by the semicircular shape of its buckler, which, when perfect, is prolonged into a slender spine at each side. At each end the marginal band is pitted with three, four, or five rows of deep round punctures, very like those upon a thimble. An opinion prevails among naturalists that the animals of the genus Trinucleus were, in their mature state, destitute of eyes, though some of the species appear to have possessed them while in the younger stages of their growth.

FIG. 611.—Trinucleus concentricus.

As no higher organisms have been discovered in the much-ransacked strata of this Matinal period, the crustaceans here described must be viewed as the dominant races of the animal world of that day.

ORGANIC REMAINS OF THE MATINAL SHALE.

The upper member of the Matinal series, the Matinal shale (Hudson River group of New York), is characterised by the organic remains of the same classes of animals as are entombed in the lower member, or Matinal limestone. Viewing the black slate which intervenes between the limestone and the shale as a member of the latter, there are about seventy known species in this upper Matinal formation, more than twenty of which are common to it and the underlying Matinal limestone. The two divisions of the series are furthermore linked by a still larger proportion of common genera. The Matinal shale, moreover, contains no fossil remains belonging to races higher in the scale of organisation than the highest seen in the limestone under it. Trilobites are still the most advanced forms of extinct animal life.

A prevailing state of metamorphism, amounting often to a more or less developed cleavage, and always to a tendency to transverse fracture, obstructs greatly the recognition of the smaller and more obscure fossils; and an extensive infiltration of the surface-waters, consequent upon it, has dissolved out nearly all the organic remains, leaving mere casts of their surfaces. The number, therefore, of well-identified species is much less than in those tracts of New York and the Western States where the strata repose in their original horizontal position, and have escaped metamorphic and crushing action. But notwithstanding these drawbacks, I am able to exhibit figures here of an ample number of characteristic forms. Beginning with those which occur most abundantly in the Matinal black slate, we have first the *Graptolithus pristis* (Fig. 612). These delicate fossils, some of which resemble a minute quill, have a straight central stem, margined by a compressed membrane, notched with small acute teeth like a little saw. The true nature of the graptolite remains a matter of some uncertainty. It is believed that its nearest known modern representative is the genus Virgularia.

Another common fossil of the black slate is the *Lingula curta*, already mentioned as of frequent occurrence in the Matinal limestone, to which rock, indeed, the black slate is nearly as subordinate as it is to the Matinal

FIG. 612.—Graptolithus pristis.

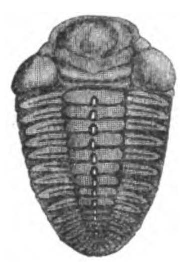


FIG. 613.—Calymene Beckii.

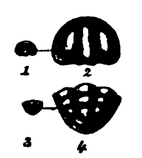


FIG. 614.—Agnostos lobatus. (1 and 3 natural size, 2 and 4 enlarged.)

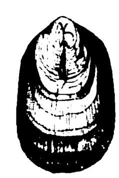


FIG. 615.—Lingula quadrata.

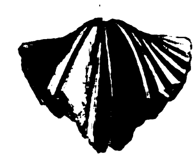


FIG. 616.—Delthyris lynx.

shale. Associated with these, we not unfrequently find the delicate trilobite, *Calymene Beckii*, (Fig. 613). They are met with together in Penn's Valley and in Milligan's Cove. This fossil is not often found entire; it

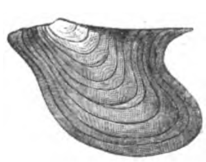


FIG. 617.—Avicula insueta.

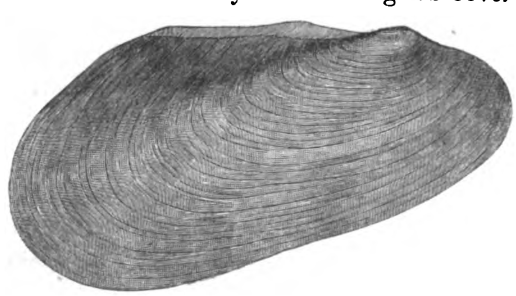


FIG. 618.—Modiolopsis modiolaris.

FIG. 619.—Cyrtolites ornatus.

FIG. 620.—Pleurotomaria bilix.

seems to have been too slightly articulated to retain its form after death; the buckler or head-piece is its most easily recognised portion. There is another little crustacean, *Beyrichia* (*Agnostos*) *lobatus* (Fig. 614), sometimes seen in the Matinal shale. The shells of this great argillaceous formation belong to all the great classes of Mollusca. The brachiopods are represented by *Lingula quadrata* (Fig. 615), an unusually large robust species, with an approximately square outline, whence its name. Another brachiopod is *Delthyris* (*spirifer*) *lynx*, (Fig. 616). To these may be added several of the brachiopods of the Matinal limestone, *Leptæna sericea*, *L. alternata*, and *Orthis pectenella*, &c.

Among the Conchifers, or common bivalve shells, best preserved or oftenest seen, are the *Avicula insueta* (Fig. 617), and *Modiolopsis modiolaris* (Fig. 618). *Cyrtolites ornatus* (Fig. 619), probably the shell of a pteropod, is a very common fossil of the Matinal shale, and in Pennsylvania is restricted to it. Our figure is copied from Plate LXXXIV. of Hall's *Palæontology of New York* (which see).

FIG. 621.—Ormoceras crebriseptum.

Another univalve, likewise confined to it, is the *Pleurotomaria bilix* (Fig. 620). This beautiful little shell, which has hardly the character of a true Pleurotomaria, occurs occasionally in the Matinal shale in the limestone valleys of Centre County. It is much more common in the Western States.

FIG. 622.—Glyptocrinus decadactylus.

The Matinal Orthocerata are occasionally seen in Pennsylvania. The annexed cut (Fig. 621) represents a fragment of one of them, *Ormoceras crebriseptum*, displaying the internal structure, but not very clearly.

The middle and upper beds of the Matinal shale contain layers abounding in the joints of unknown species of Crinoidea. Possibly some of them belong to the beautiful fossil *Glyptocrinus decadactylus* (Fig. 622), abundant in the corresponding formation in Ohio and Kentucky. The annexed figure is from Cincinnati.

The prevailing fossils of the Matinal shale in the great limestone valleys of the mountain-chain of the State are—

Heterocrinus, *Ambonychia radiata*, *Avicula insueta*, *Modiolopsis modiolaris*, *Pleurotomaria bilix*, *Murchisonia gracilis*, *Cyrtolites ornatus*, *Lingula quadrata*, *Lingula curta*, *Leptæna sericea*, *L. alternata*, *Orthis testudinaria*, *Atrypa increbescens*, *Spirifer lynx*, *Ormoceras crebriseptum*, *Endoceras proteiforme*, *Leperditia fabulites*, *Trinucleus concentricus*, *Isotelus gigas*, &c.

ORGANIC REMAINS OF THE LEVANT STRATA.

The formations which immediately succeed the Matinal deposits are singularly destitute of fossils, not one species of the nearly 300 met with below reappearing in this group. It would seem, indeed, that the changes in the earth's surface which terminated the Older, and ushered in the Middle Palæozoic sediments, swept out of existence all previously-created races, without yet adapting the region for the reception of new forms of animal life to replace them.

These did not come upon the scene in any number until the next succeeding or Surgent period, nor even then in the profusion of their predecessors of the Auroral and Matinal ages. The transition at which we have now arrived—that from the Matinal shale to the Levant sandstone—is by far the widest break we know in the chain of Palæozoic life. It amounts, as I have elsewhere shown, to an almost total extinction of all the earlier species, and the substitution at successive epochs of wholly new ones. In Pennsylvania and Virginia this break is even more complete than it is in New York; for, in the latter State, relics of three or four species characteristic of the Matinal rocks, or about one per cent, have been met with in the Surgent and Scalent strata, whereas in Pennsylvania not a single species has been found on both sides of this great gulf. This important fact, and the commensurate one of a widely-extended physical break between the Matinal and the later formations, amounting in many quarters to positive unconformity, and throughout the Western States to a wide gap or hiatus in the succession of formations, have influenced me to classify the three lower groups apart from the middle formations upon which we are now entering.

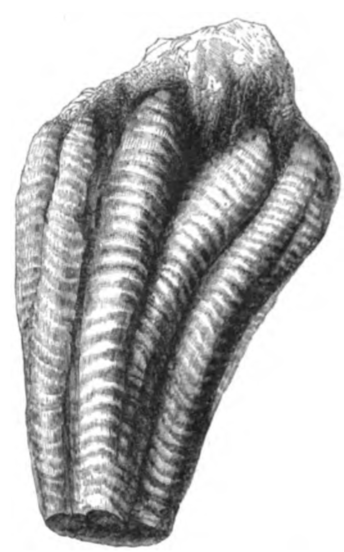


FIG. 623.—Arthrophycus Harlani.

The principal organic relic seen in the Levant strata of Pennsylvania is the curious fossil, *Arthrophycus Harlani*, here represented (Fig. 623). It is supposed to be a marine plant, and for a long time bore the name of *Fucoides Harlani*. Our figure represents only the upper branching extremity, the whole plant consisting of a rounded and apparently articulated or transversely-grooved flexible stem, with simple subdivisions of nearly the same thickness throughout. The long flexible stems are often seen penetrating the upper layers of the Levant white sandstone perpendicularly through a length of from one to two feet, and spreading on the upper surfaces of the beds in large curled bunches resembling closely-matted tufts of hair. Their usual position suggests the notion of sea-weeds floating perpendicularly just above the bed of the ocean, and, while in this position, quietly imbedded by sand silted in among them.

Hitherto this curious fossil has been found only in the Upper Levant sandstone, the equivalent of the Medina sandstone of New York. It is particularly abundant in some of the outcrops of this formation which cross the

Juniata River, especially in Mifflin County. A very much reticulated variety occurs plentifully in the "Long Narrows," below Lewistown, upon the uppermost beds of the sandstone, just under the base of the Surgent slates. In none of the specimens do we see any traces of the vegetable tissue, but only a cast of the general surface of the plant in the sandstone.

FIG. 624.—Bucania trilobatus.

In some of the layers of the same upper sandstone we occasionally, though rarely, discern two or three small shells. One of these is a little spiral fossil, *Bucania trilobatus*, Hall, a cast of which is here figured (Fig. 624). It resembles somewhat a bellerophon. Another small fossil is *Lingula cuneata*, a wedge-shaped lingula, sharply pointed at the beak, whence its specific name. I have only seen it in the highest layers of the Levant sandstone. These are the only organic remains of the formation which I have noticed in Pennsylvania.

ORGANIC REMAINS OF THE SURGENT STRATA.

This very complex formation, composed of fissile slates, calcareous shales or marls, non-calcareous shales, and firmly-cemented ferruginous sandstones, contains a proportionate variety of organic remains. The total list of its species, as described in the *Palæontology of New York*, amounted, in 1852, to more than 100, and we may set down the number now known at not less than 120, or more than six times the whole number hitherto procured from the Levant rocks in all their localities. It is the first or lowest platform upon which we find the true Silurian (Upper Silurian) types of Europe, in the American Palæozoic strata. Only four or five of its fossils belong likewise to the Matinal formations below the great horizon of interruption above spoken of. These are *Bellerophon trilobatus*, *Delthyris lynx*, *Leptæna alternata*, *Leptæna depressa*, and *Calymene Blumenbachii;* but the validity of the evidence as to some, at least, of these being genuine Surgent fossils, is rather doubtful. Some fifteen or sixteen of its species this formation shares in common with the group of strata—the Surgent series—which next succeeds it, proving what the physical evidence also shows, that these two Middle Palæozoic formations are somewhat intimately blended.

Plants, or at least plant-like impressions, rather abound in the laminated argillaceous rocks or slates of the lower and middle members of the Surgent series, but the number of well-defined species in Pennsylvania is apparently small. By far the most common type is that named *Buthotrephis gracilis* by Hall. A specimen of what is perhaps another and new species of Buthotrephis, from Montour's Ridge, is here figured (Fig. 625). Another

FIG. 625.—Buthotrephis gracilis (?)

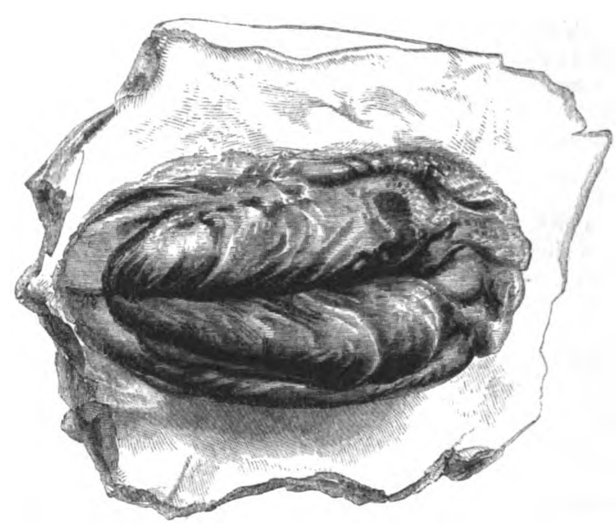


FIG. 626.—Rusophycus bilobatus.

plant-like fossil, less frequently found, is represented in the annexed cut (Fig. 626); it is always two-lobed, and is the *Fucoides bilobatus* of Vanuxem, or the *Rusophycus bilobatus* of Hall. It is crossed by strong wrinkles, and some specimens display a distinct stem proceeding from the groove which divides the two lobes. The two-lobed mass is probably the impression of the root of a plant, the stem of which was too easily disorganised to leave an equally distinct trace of its form.

Of the animal remains imbedded in the Surgent strata, we occasionally come upon a puzzling form, the *Cornulites*, a slender cone-shaped fossil, composed of successive rings transversely striated on their outer surface. The true place of this fossil in the animal kingdom is not at present known; there are probably several species,—one of these is the *Cornulites flexuosis.* Our own specimen (Fig. 627), found in the Surgent ore sandstone, above the fossiliferous iron-ore in Blair County, belongs apparently to another species; but until more is known of their structure, I refrain from giving it a specific name.

The Surgent series, or Clinton group, contains several interesting species of conchifera or bivalve shells belonging to the genera Avicula, Modiolopsis, Tellinomya, and Orthonota, &c. One of the most common and

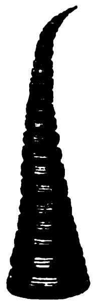


FIG. 627.—Cornulites.

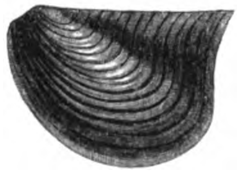


FIG. 628.—Avicula subplana.

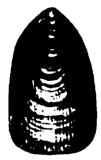


FIG. 629.—Lingula oblonga.


FIG. 630.—Leptæna depressa.

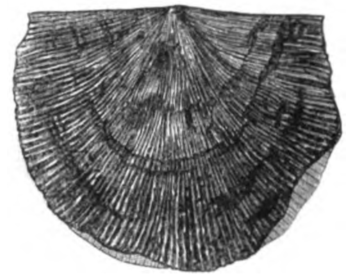


FIG. 631.—Leptæna patenta.

pleasing of these is the *Avicula subplana*, found in the shales of the fossiliferous iron-ore, and sometimes in the ore itself (see Fig. 628). In the *Palæontology of New York* this shell is figured as characterising the Niagara group; several similar instances are known of New York Niagara fossils occurring in the Surgent (Clinton) rocks of Pennsylvania.

This formation abounds in shells of the brachiopodous type, containing several species of Lingula, Leptæna, Orthis, Spirifer, Atrypa, etc.; one of the most common is the *Lingula oblonga*, here shown (see Fig. 629), recognised by its nearly parallel straight sides, pointed and convex beak, and obtusely-rounded corners at the base. It occurs in the slates adjoining the iron sandstone, and also in the fossiliferous ore.

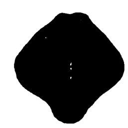


FIG. 632.—Atrypa congesta.

A very distinctive fossil of the formation in Pennsylvania is the beautifully-corrugated shell, *Leptæna depressa* (Fig. 630), found in New York in all the strata from this formation to the Upper Helderberg or Post-meridian limestone; it may sometimes be seen in the slate adhering to the fossiliferous iron-ore. Another shell of the same genus, frequent in the same part of the formation, is the *Leptæna patenta* (Fig. 631); its surface is marked by strong unequal striæ crossed by fine concentric lines of growth.


FIG. 633.—Atrypa reticularis.

Of the abundant genus Atrypa, the Surgent rocks contain nearly twenty species; among the most easily recognised of these are the *Atrypa congesta* (Fig. 632), distinguished by a deep central furrow extending from the beak to the base of the dorsal valve; *Atrypa reticularis*, a more variable species, distributed from the Surgent to the Cadent strata (Fig. 633), and *Atrypa intermedia* (Fig. 634), a wide shell compressed at the base, and having its two valves of nearly equal convexity.


FIG. 634.—Atrypa intermedia.

The *Atrypa reticularis*, like most fossils of a wide range in time, has a correspondingly broad distribution geographically. It is the *Atrypa affinis* of Sowerby, and occurs abundantly in the Upper Silurian rocks of Great Britain.


FIG. 635.—Orthus elegantula.

Orthis elegantula (Fig. 635) is another brachiopod of this formation.

The Cephalopoda of this formation are not abundant. One of the most common is the *Orthoceras imbricatum* (Fig. 636), a species which in New York occurs in the Scalent or Niagara group (see *Palæontology of New York*, Vol. II., Plate 62).

The most common crustaceans of the Surgent strata of Pennsylvania are the *Calymene* (*Hemicrypturus*) *Clintoni*, *Beyrichia lata*, and *Leperdicia Pennsylvanica*.

Calymene Clintoni (Fig. 637) is frequently met with entire or in fragments within or near the fossiliferous iron-ore, and on the iron sandstone. I have seen it in both positions in Montour's Ridge; *Phacops limulurus* sometimes occurs along with it, and so also *Calymene Blumenbachii*, though both of these tribolites are more characteristic of the Scalent or Niagara formation.

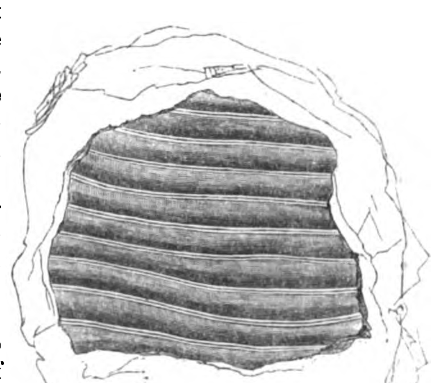


FIG. 636.—Orthoceras imbricatum.


FIG. 637.—Calymene Clintoni.

The *Leperditia Pennsylvanica*, Jones, is a crustacean of a different group, belonging to a bivalve Entomostraca—(Fig. 699, p. 834.) This beautiful *Leperditia*

(*Cytherina*), identified as a new species by T. Rupert Jones, Esq., Curator to the Geological Society of London, is deemed by him to be very near *L. Balthica* of Europe, and *L. Arctica* of North America; it has a very distinct eye-spot. The specimen figured is from a greyish limestone of the Surgent variegated marls near Barre Forge.

The limestone bands of the middle and upper portions of the Surgent series contain two or three species of the minute seed-like fossil formerly called *Agnostus*, and now *Beyrichia;* two of these, *Beyrichia Maccoyiana*, Jones (Fig. 695, p. 834), and *Beyrichia Pennsylvanica*, Jones, identified for me by Mr Jones, are figured on page 834; their natural size is about one-fourth of that represented.

ORGANIC REMAINS OF THE SCALENT STRATA.

The Scalent series of Pennsylvania, on the horizon of the Onondaga salt group and water-lime stratum of New York, contains, except in the latter or Scalent limestone, extremely few organic remains; the Scalent variegated marls, none beyond a few Beyrichiæ and Leperditiæ; and the Scalent grey marls only the same, with scarcely greater frequency. In some of its N.W. outcrops in the Appalachian chain, the Scalent limestone presents numerous specimens of *Beyrichia Maccoyiana*, Jones.

Beyrichia Pennsylvanica, Jones, together with the *Leperditia alta*, Conrad, and the *Tentaculites ornatus*, Vanuxem (Fig. 638), identify this rock as its stratigraphical position does with the water-lime of New York. The Niagara limestone of New York and the Western States does not extend into Pennsylvania, being confined apparently to the N. side of the great Appalachian basin. That interesting formation has furnished the palæontologist of New York with more than two hundred and twenty species of fossils, a small number of which,—less than twenty,—it shares in common with the Surgent or Clinton series—the Surgent of Pennsylvania containing, as already intimated, a somewhat larger proportion of them. The trilobites of the Niagara formation belong to the genera Cybele, Acidaspis, Phacops, Ceraurus, Calymene, Homalonotus, Bumastis, Lichas, Arges, and Proetus. *Phacops limulurus*, *Calymene Blumenbachii*, and *Homalonotus delphinocephalus*, occur in the middle calcareous beds of the Surgent formation, both in Pennsylvania and Virginia; the *Phacops* near Matilda Furnace on the Juniata, and near the hot springs; the *Calymene*, in the slates of the iron sandstone at Danville; and the *Homalonotus* in Blair County.

FIG. 638.—Tentaculites ornatus.

Reviewing the organic remains indicated in the previously-mentioned formations, none of them, it will be perceived, are higher in the scale of organic life than trilobites and cephalopodous molluscs. No remains of fishes, undoubtedly such, have been discovered in these strata, nor indeed in the rocks of equivalent age in Europe. For a while it was supposed that certain long slender bone-like fossils, found in the Niagara limestone and in the Wenlock formation of England, were genuine remains of fishes; and upon this view one of them has been figured and described in the *Palæontology of New York* under the name of *Onchus Deweii*, Hall (Fig. 639, copied from Plate LXXI., *Palæontology of New York*). These supposed relics of Silurian fishes have all of them,

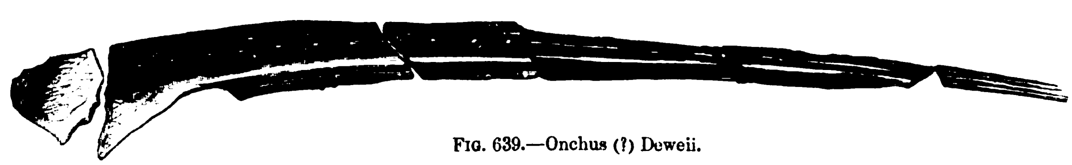


FIG. 639.—Onchus (?) Deweii.

however, been pronounced, after a critical examination, to be merely portions of crustaceans. It must be enunciated then as a general fact, that hitherto no traces have been discovered of any vertebrate animal whatsoever having lived during all those earlier Palæozoic ages which are embraced in the Cambrian and Silurian periods of the English geologists, or the equivalent Primal, Auroral, Matinal, Levant, Surgent, and Scalent periods according to the nomenclature of the Pennsylvania Survey. The earliest date at which actual fishes appeared in the Appalachian or Palæozoic sea of North America was that of the Post-meridian strata, numerous specimens of the ganiod class having been recently found in the upper Cliff or Corniferous limestone of Ohio, locally called the Sandusky limestone. This rock is apparently very nearly on the horizon of the lowest Devonian strata of Europe, in which corresponding icthyic remains are well known.

ORGANIC REMAINS OF THE PRE-MERIDIAN STRATA.

The pre-Meridian series of Pennsylvania, like its equivalent formation, the Lower Helderberg limestone of New York, is in many localities replete in organic remains, though, being generally deficient in the very fossiliferous limestone shales which in New York accompany the limestone, its variety of species is commensurately smaller. The third volume of the *Palæontology of New York*, designed for the description of the fossil of this and the next later formations, not being yet in print, we have no means of learning the total number of species developed by the well-supported and skilfully-conducted palæontological exploration of that State; it is probable, however, that the species about to be brought to light will exceed two hundred. Anticipating the publication, long before this, of the *Palæontology of New York*, the accepted guide to the fossils of the eastern portion of the Appalachian basin, and controlled by the narrow limits of the means placed at my disposal, no attempt was made in the Geological Survey of Pennsylvania to collect any but the organic remains of the coal-formation, for description and delineation;

especially as I was conscious that their state of preservation from well-known geological conditions is far inferior, for all purposes of palæontological research, to the beautiful petrifactions in the less consolidated, more horizontal rocks of New York, the Western States, and Canada. The non-appearance of the long-looked-for fresh descriptions of the fossils of the middle and later Palæozoic formations, compels me to retain, for the species found in Pennsylvania, the names assigned them in the Geological Survey of New York before its special palæontological exploration was commenced, though I am aware that the researches there and elsewhere in progress may alter some of the generic titles, and even some of the specific ones.

The most abundant fossils of the Pre-meridian limestone of Pennsylvania are several beautiful brachiopodous

Fig. 640.—Atrypa peculiaris.

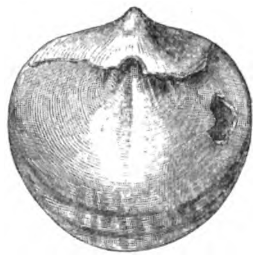


Fig. 641.—Atrypa.

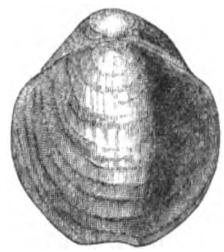


Fig. 642.—Atrypa lævis.

Fig. 643.—Delthyris macropleura.

shells. One of these is the *Atrypa peculiaris*, Conrad (see Fig. 640), assigned in the New York Survey to the Meridian or Oriskany sandstone. This species is easily known by the deep depression of the basal edge of the lower valve. The annexed figure represents another fossil common to the Pre-meridian limestone and the sandy shales which intervene between it and the Meridian sandstone (see Fig. 641). It appears to be a new species of Atrypa; but, under the circumstances explained, I do not deem it worth while to confer upon it a name likely soon to be superseded.

Fig. 644.—Spirifer sulcatis.

Another common fossil is the *Merista* (*Atrypa*) *lævis* (see Fig. 642). A still more abundant shell is *Delthyris* (*Spirifer*) *macropleura* (see Fig. 643); but this, like *Spirifer sulcatis* (see Fig. 644), occurs sometimes also in the Meridian sandstone. Another brachiopod more seldom found is the *Rhynconella nobilis*, Hall (see Fig. 645). In the absence of good printed figures for comparison, I am in some doubt whether this may not be Hall's *Rhynconella mutabulis*—(See *Descriptions of New Species of Palæozoic Fossils*, by James Hall). This shell resembles in many respects the European Silurian fossils, *Rhynconella Stricklandii*, Sowerby; but its profile is somewhat different, and the margins of the valves are much less serrated.

Fig. 645.—Rhynconella nobilis.

One of the most common and distinctive fossils of the formation is the *Pentamerus galeatus* (see Fig. 646), equally characteristic of the Wenlock limestone of England.

A Platyostoma, of which a figure is here annexed (see Fig. 647), is to be met with in some localities within this limestone; but it is rather more frequently found in the cherty layers which form a passage from the formation into the overlying Meridian sandstone. Lamellibranchiate or true bivalve shells are not common in the Pre-meridian limestone. Of brachiopods, *Strophomena* (*Leptæna*) *punctulifera*, Conrad (see Fig. 648) is a characteristic species. This fossil is often seen in the chert, but never, that I know, in the overlying Meridian sandstone.

Fig. 646.—Pentamerus galeatus.

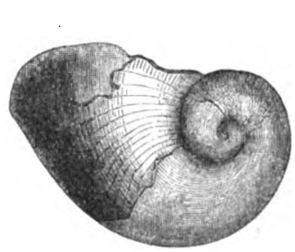


Fig. 647.—Platyostoma.

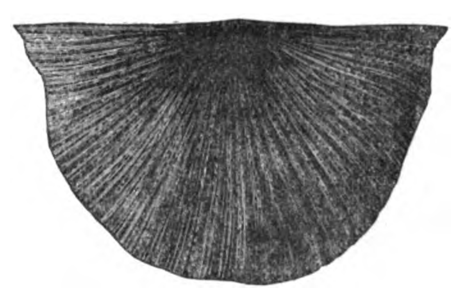


Fig. 648.—Strophomena punctulifera.

ORGANIC REMAINS OF THE MERIDIAN STRATA.

The sandy shales of this series underlying the coarse Meridian sandstone contain two or three fossils which I think are as yet undescribed species, a Calymene and an Orbicula especially. Palæontologists will find access to these fossiliferous layers near Moorestown, N. of Montour's Ridge, and also at Frankstown, on the Juniata.

The Meridian sandstone being arenaceous and porous, and also very generally much jointed, in Pennsylvania, presents its organic remains chiefly in the state of casts or moulds of their exterior surfaces, the fossils themselves having long since been dissolved away. As a consequence, the more fossiliferous beds are at their outcrops usually deeply pitted with the cavities once occupied by the fossils. These are the more conspicuous from the unusual size of nearly all the organic remains, all of which are nearly brachiopodous molluscs. I shall present here figures of the three species most usually met with. One of these (see Fig. 649) is the *Meganteris ovoides*, Sp. Eaton, formerly the *Atrypa elongata*, Conrad. The outline of this shell is a remarkably beautiful oval. Judging from the pits in the sandstone, it was an abundant inhabitant of the bed of the Appalachian ocean in the Meridian period, to which it was restricted.

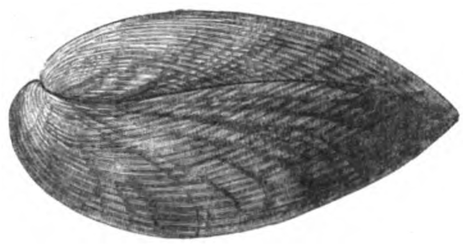


FIG. 649.—Meganteris ovoides.

Another brachiopod of this rock is the *Spirifer arenosa*, Conrad; a large species, having a rather ample hinge area, and 16 or 17 strong ribs (see Fig. 650).

The most remarkable fossil of the formation is *Atrypa unguiformis* (see Fig. 651), found usually as an internal cast, displaying in part the structure of the animal which inhabited the shell. It gets its name from a fancied resemblance to the imprint of a hoof.

FIG. 650.—Spirifer Arenosa.

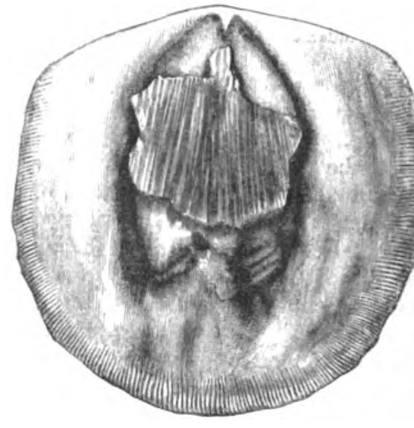


FIG. 651.—Atrypa unguiformis.

ORGANIC REMAINS OF THE POST-MERIDIAN STRATA.

The next Appalachian formation, the Post-meridian series, may scarcely be called a Pennsylvanian deposit, entering only the eastern border of the State a short distance, near the Delaware Water-gap. Its most characteristic fossil in that quarter is a singular sea-weed or fucus-like impression called in the New York Survey the *Fucoides cauda galli* (see Plate XXI. Fig. 1.), from its resemblance to the tail of a cock. It characterises the sandy calcareous shale which intervenes between the Meridian sandstone and the Post-meridian Onondaga limestone.

ORGANIC REMAINS OF THE CADENT STRATA.

The Cadent slates and shales of Pennsylvania entomb a multitude of rather imperfectly-preserved organic remains, for the most part in the condition of casts, from which I shall select several of the more characteristic species.

Beginning with those of the Cadent older or Lower Black Slate, we find the most common of all its Mollusca to be the *Atrypa limitaris*, Vanuxem (see Fig. 652), a compressed nearly circular shell, with regularly-radiating equal ribs. It abounds in some of the calcareous or cement beds. A second common brachiopod is *Orbicula minuta*, (see Fig. 653). Another very common form is the *Orthoceras subulatum* (see Fig. 654), a delicate Cephalopod, always found flattened and crushed, and seldom revealing the distinctive septa. Along with this last we often find small, pointed leaf-like impressions, possibly the leafy appendages of Lepidodendron, which, we shall presently see, is unmistakably present in the Upper Black Slate.

FIG. 652.—Atrypa limitaris.

FIG. 653.—Orbicula minuta.

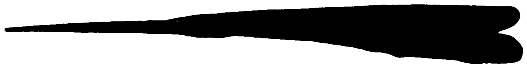


FIG. 654.—Orthoceras subulatum.

Among the humbler animal forms of the Cadent shale is a coral, the *Cyathophyllum turbinatum* (see Fig. 655). Of the Mollusca there are a few species of *Polyzoa*: one here shown belongs apparently to the *Escharadæ* (see Fig. 656). Of the conchiferous molluscs, the *Avicula decussata* (see Fig. 657), *Modiola concentrica* (see Fig. 658), *Avicula* *flabella* (see Fig. 659), *Microdon bellastriata* (see Fig. 660), *Orthonota undulata* (see Fig. 661), and a small Avicula (see Fig. 662), like *A. œvis* of Hall, are apparently the most common. Another Avicula of a very different type is

FIG. 655.—Cyathophyllum turbinatum.

FIG. 656.—Fenestella ?

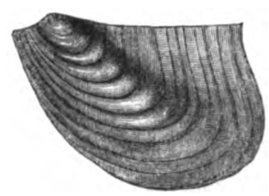


FIG. 657.—Avicula decussata.

FIG. 658.—Modiola concentrica.

here figured (see Fig. 663). To these we may add a Posidonia (perhaps an *Estheria*), here figured (see Fig. 664).

But the most abundant of the Mollusca are the Brachiopoda. Among these I would call attention to the

FIG. 659.—Avicula flabella.

FIG. 660.—Microdon bellastriata.

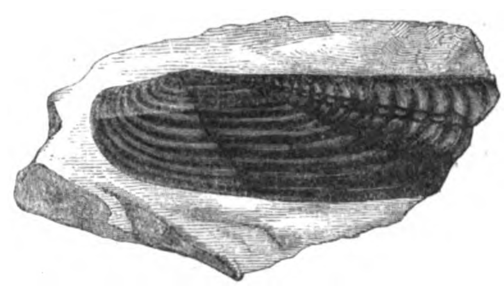


FIG. 661.—Orthonota undulata.

FIG. 662.—Avicula.

following, as useful for identifying the formation: *Strophomena crenistria* (see Fig. 665), and *Strophomena demissa*, (see Fig. 666); *Spirifer spiriferoides; Atrypa concentrica*, not unlike the *Terebratula concentrica* of Bronn (see Fig. 667); *Spirifer mucronata* (see Fig. 668); *Delthyris medialis*, Hall (see Fig. 669), and *Delthyris congesta*

FIG. 663.—Avicula.

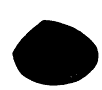


FIG. 664. — Posidonia or Estheria.

FIG. 665.—Strophomena crenistria.

FIG. 666.—Strophomena demissa.

(see Fig. 670); *Atrypa aspera* of Schlotheim (*A. spinosa*), Hall (see Fig. 671), a European shell; and *Tropidoleptus carinatus*, Sp. Conrad (see Fig. 672). A large and beautiful shell, occasionally met with, is the *Delthyris granulifera* (see Fig. 673), proposed by Mr Hall as the type of the genus Tropidoleptus.

Another abundant brachiopod is the *Productus hirsutus* (see Fig. 674), covered with closely-set hair-like spines. This, and one or two other Producta, are interesting links between the Cadent and the Carboniferous for-

Fig. 667.—Spirifera spiriferoides.

Fig. 668.—Spirifer mucronata.

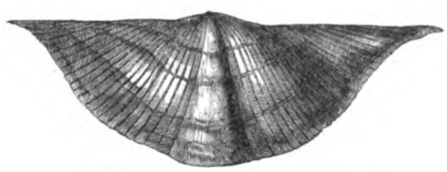


Fig. 669.—Delthyris medialis.

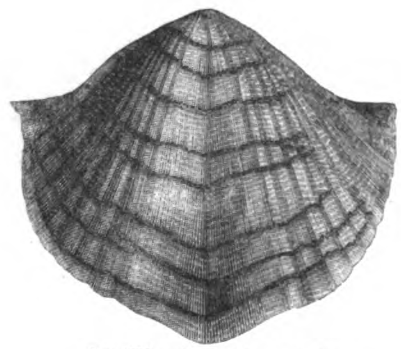


Fig. 670.—Delthyris congesta.

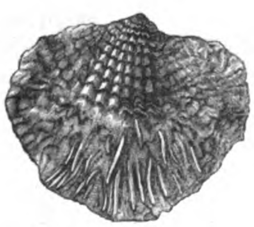


Fig. 671.—Atrypa aspera.

Fig. 672.—Tropidoleptus carinatus.

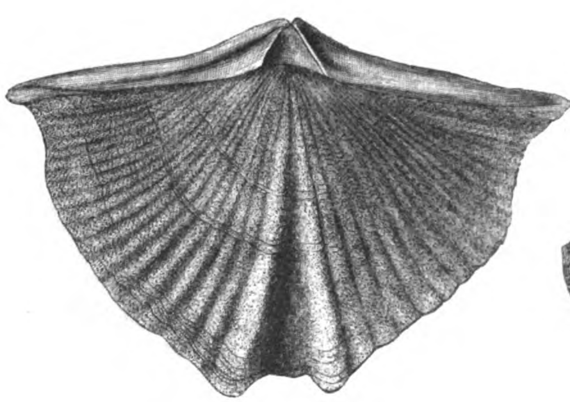


Fig. 673.—Delthyris granulifera.

Fig. 674.—Productus hirsutus.

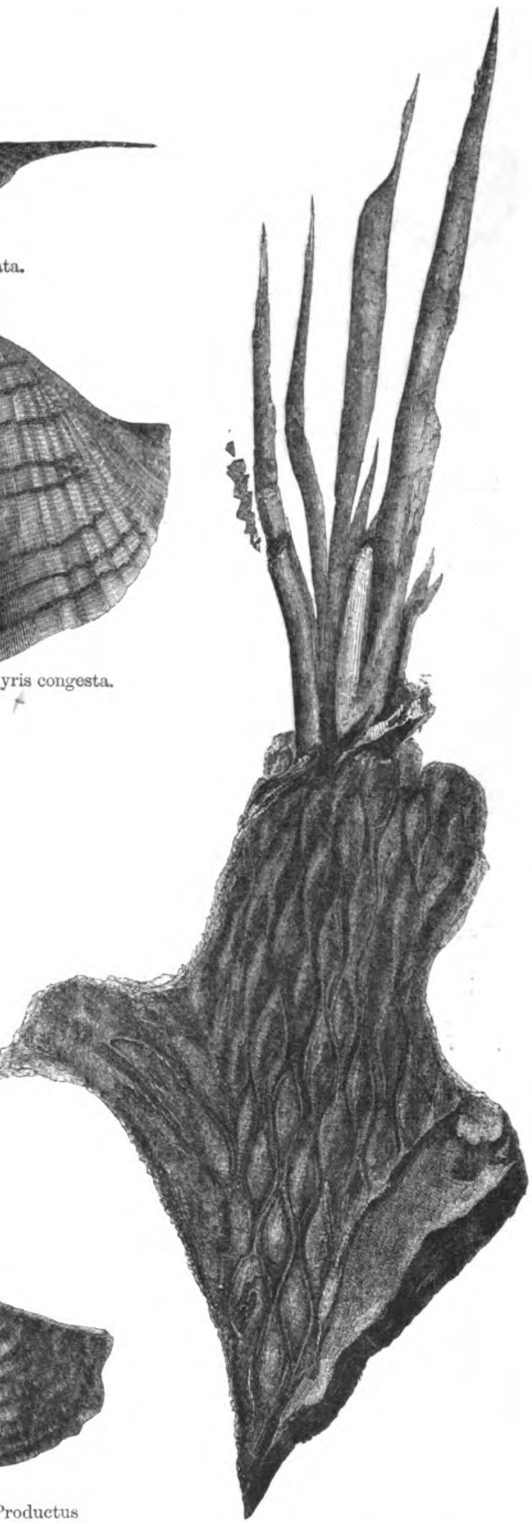


Fig. 675.—Lepidodendron primævis.

mations, the genus Productus being regarded as eminently characteristic of the latter. Ascending into the Cadent upper black slate, we encounter a repetition of some of the smaller species of the Cadent lower black slate, and among them well-developed specimens of an air-breathing plant, a *Lepidodendron*, of which I here present a figure, (see Fig. 675), representing a fragment of a bifurcating stem, surmounted by its grass-like leaves, from a locality of these fossils at the mouth of Standing Creek, just E. of the town of Huntingdon. I propose to call it *Lepidodendron primævis*, as signifying the early age at which one of the main coal-producing types of vegetation made its appearance.

Fig. 676.—Goniatites interruptus (?).

Curiously enough, we find in the very same layers of fissile black slate, between which the Lepidodendron has been flattened and preserved as in the leaves of an herbarium, beautiful specimens of a delicate shell, the *Goniatites interruptus ?* (see Fig. 676), belonging to a type of Molluscs supposed to have inhabited, if not the sea itself, the brackish waters of its margin.

The other associates of these fossils, an Orbicula, two Lingulæ, and an Atrypa, imply the same thing—a deposition of the dark carbonaceous slate beneath waters open to the sea. We may conjecture that the part of the ocean imbedding these remains was very shoal, and that a low marshy coast supporting the lepidodendron, and collecting the carbonaceous matter, could not have been far distant. One of the most expressive facts bearing upon the marvellously vast and uniform features of the physical geography of the Appalachian basin in some of its periods, is the occurrence of the Cadent lower black slate from Tennessee, N.E. to New York, and from New York W. to Illinois, and its reappearance far to the N.W. in British America, along the McKenzie River, even to the Arctic Sea.*

The most abundant trilobite of the Cadent series in Pennsylvania is the *Calymene bufo*, Green.

Another quite common trilobite, *Homalonotus* (*Dipleura*) *Dekaii*. As far as known, this species is restricted to the Cadent shales. The *H. delphinocephalus* of the Niagara group of New York has not been found in Pennsylvania. No fish-remains have been discovered in the Cadent strata of Pennsylvania.

ORGANIC REMAINS OF THE VERGENT SERIES.

This great formation, notwithstanding its thickness, is so uniform in composition, and so generally destitute of calcareous matter, that its organic remains are inferior in their abundance to those of the much thinner Cadent series beneath it.

Of Plants, it contains, besides several fucoids, chiefly characteristic of the lower member or Vergent flags, occasional specimens of what appears to be a *Lepidodendron* (see Fig. 677). This is apparently the same fossil

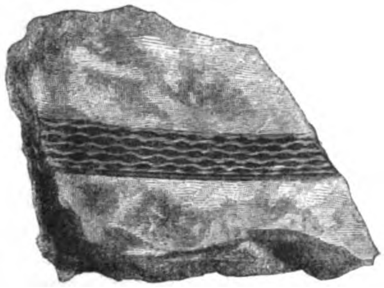


Fig. 677.—Lepidodendron.

Fig. 678.—Avicula damnoniensis.

Fig. 679.—Avicula.

which is figured in the *Geology of New York*, Part IV., by Prof. Hall, under the name of *Sigillaria Chemungensis*. This confessedly terrestrial plant is interesting as forming one of a series of steps through which we trace the gradual advent of that remarkable flora which flourished in such exuberance in the later Carboniferous or Coal period.

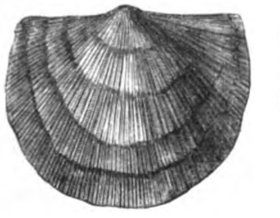


Fig. 680.—Strophomena Chemungensis.

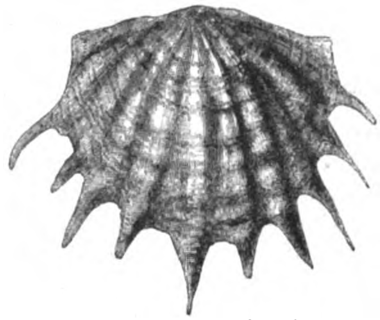


Fig. 681.—Atrypa hystrix.

Fig. 682.—Atrypa eximia.

Fig. 683.—Delthyris cuspidata.

Among the conchiferous molluscs special to the Vergent formation are two or three Aviculas, as *Avicula damnoniensis* (see Fig. 678), a beautiful form characteristic of the Upper Devonian strata of Europe. Another

* See "Geology of the Hudson Bay Territories," &c., by A. K. Isbister, M.A.—*Quarterly Journal of the Geological Society*, vol. xi.

species found high in the series (see Fig. 679) is somewhat common. I suspect it to be a new species, but do not presume to name it.

The most numerous shells of the formation are its brachiopods; one of these is the *Strophomena Chemungensis* (see Fig. 680.) A remarkable Atrypa, the *A. hystrix*, is distinguishable from every other of its genus, by the size of its ribs and the long spines which proceed from them (see Fig. 681). Another species is the *Atrypa eximia*, Hall (see Fig. 682). Some of the Spirifers or Delthyri of this formation are of unusual size; a common species of the genus is *Delthyris cuspidata* (see Fig. 683).

ORGANIC REMAINS OF THE PONENT ROCKS.

The Ponent series (Catskill group), like most deposits of red sandstone and red shale, destitute of calcareous matter, are very deficient in organic remains. One may search through large tracts of it in Pennsylvania, and not meet with a solitary fossil. This is especially so in its outcrops in the Appalachian chain. Near the N. border of the State, some of its lower layers do contain a few relics of extinct life; by far the most interesting of these are the bones and scales of two species of fishes of the genus Holoptychius, discovered near the Tioga River by the engineers constructing the Tioga Valley Railroad. The reader will find a brief description of these, with figures, in the *Geology of New York*, Part IV., page 281. In the Appalachian chain we occasionally meet with traces of vegetation in the upper strata. One of these plant-impressions is the fern-like form here represented (see Fig. 684); it bears some resemblance to the genus Noeggerathia, but its characters are too vague to enable us to settle its affinities. Another curious plant, equally obscure in its relationships, represented on Plate XXII., is now and then met with: see the note upon it kindly furnished me by Professor Balfour of Edinburgh, at the end of the chapter on Organic Remains.

FIG. 684.—Ponent Fern?

ORGANIC REMAINS OF THE VESPERTINE AND UMBRAL STRATA.

One of the least fossiliferous of the formations of the Palæozoic system in Pennsylvania is the Vespertine sandstone. Consisting as it does throughout its outcrops in the Appalachian chain of pebbly grits, argillaceous sandstones, and sandy shales, all destitute of the carbonate of lime, so essential to the marine organisms susceptible of fossilisation, it is absolutely deficient in molluscan or other types of aquatic life. Towards the N. border of the State, one or two thin layers of partially-calcareous rock do appear in it, and these contain a few obscure casts of what seem to be bivalve shells. Adjoining the anthracite coal-fields, this deposit, somewhat resembling the conglomeritic group at the base of the Coal-measures, presents a further analogy to the true coal-formation, in possessing some vegetable fossils identical in their generic characters with those which are distinctive of the true coal strata. These belong chiefly to the fern-like genus Noeggerathia and to the coal-producing genera Sigillaria and Lepidodendra. The most common Noeggerathia is *N. obtusa*, Lesquereux, figured on Plate I., fig. 11, among the fossils of the coal-formation; it occurs likewise in the Ponent rocks, the lowest position in which we have found the genus. The most common air-breathing plants are, however, the Lepidodendra; all of these hitherto seen have comparatively slender stems, and are characterised by the smallness of their leaf scars.—(See Plate XVI., fig. 2, of the fossils of the coal-formation). Lepidodendra of this type are to be found in the Vespertine formation, all along the Appalachian chain to South-west Virginia. Our coloured figure, Plate XXI., fig. 2, represents another specimen. Among the upper beds of the formation in the gap of the Mahoning Mountain at Mauch Chunk, there occurs, associated with the Lepidodendron, a small Stigmaria, the *Stigmaria minuta*, Lesquereux.—(See Plate XVI., fig 1, and Mr Lesquereux's description, in his Essay on the Fossil Plants.)

It is an interesting fact, that the small-scarred Lepidodendra of the Vespertine formation are represented by a very similar group in the lower carboniferous rocks of Great Britain and Ireland, furnishing an argument, independent of that from their stratigraphical position, for placing these two respective formations upon nearly the same horizon in time.

The only organic remains ever met with in the Umbral red shale of our E. coal-fields, are some rare impressions of a large plant-like form, discovered by us in the valley immediately S. of Sharp Mountain, at Pottsville, and in a few corresponding localities. This imprint upon the red sandstone has often the aspect of a large fleshy leaf, curiously corrugated, as if it had been crumpled, while in a flaccid state, by compression beneath a newly-deposited load of sediment. Each leaf-like portion exhibits a raised rib like an obscure rachis, but in other respects it bears a general likeness to some tribes of the Algæ, or Sea-weeds. Professor Balfour has kindly favoured me with a note upon it (see end of chapter on Organic Remains).

We sometimes find associated with this feather-like plant another marking in the rock, which traverses the strata perpendicularly, and branches downward like a root, and which, from its generally occurring in the same layers with the flattish, fucus-like impression, we may conjecture to have been its actual root. In one or two instances this root-like form has been seen to proceed from a large rudely-spherical body of similar structure, impressed on the surface of the same layer of red sandstone which contained a quantity of the flatly-expanded supposed sea-weed; a further evidence of their being related as the upper and lower parts of the same vegetable. The leaf-like portion is sometimes between 2 and 3 feet long, and several inches wide, and the impressions regarded as its root are of the length of some inches.

Amid a very general paucity of animal remains, the Vespertine formation contains some very interesting vestiges of animated creatures in the shape of footprints. The relics of this class hitherto brought to light have only been met with at the S. outcrop of the formation, in the neighbourhood of Pottsville. One species, the largest, was discovered in 1849, by Isaac Lea, Esq. of Philadelphia, on a slab of Umbral red sandstone, also impressed with the wave-like structure called "ripple-mark." It was stratigraphically situated about 700 feet below the top of the formation, or its contact with the base of the coal-formation just S. of Sharp Mountain, at Mount Carbon. These footmarks, of which there are four in number, alternately right and left footed, forming a line of nearly a yard in length, have been attributed by Mr Lea to a Saurian reptile which he has called *Sauropus*.

About 1500 feet lower in the formation, or farther S. in the same locality, the Geological Survey brought to light another species of footprints of much smaller dimensions; and soon afterwards two other varieties; at a spot not far S. of the West-Branch Gap in Sharp Mountain. The largest of the three species, identical apparently with the Sauropus of Lea, consists of footprints, each about 2 inches in diameter, alternately right and left footed, and quadrupedal, with the fore and hind feet of nearly equal dimensions; the length of stride being about 9 inches, the straddle between the right and left footsteps nearly 4 inches, and the imprints of the hind-feet but little behind those of the fore-feet. A somewhat indistinct grooving of the surface of the stone, in two or three places centrally between the two rows of footsteps, suggests that the creature leaving these marks may have dragged a tail behind it, and the whole aspect of the impressions is suggestive of an animal allied rather to the Saurians than to the Batrachian or Chelonian reptiles. All of the three species of footmarks are quadrupedal, and all of them five-toed, and right and left footed, with an alternation also implying both fore-feet and hind-feet. In the smallest species, the toes are very divergent, like the fingers of the human hand firmly outspread upon a table. Each footprint is about half an inch in diameter, and the length of stride is from 2 to 4 inches. No traces of reptilian bones were discovered with these impressions, nor indeed in any part of the formation. I have invariably noticed that the surfaces bearing these supposed reptilian impressions, which considerations of economy have compelled me to omit engraving, exhibit various indications of having been exposed to the air in a wet state at the time the imprints were formed. They are always at the incohering partings between easily-separating beds of sandstone; and the indented surface is glazed with a fine slimy clay, such as retreating turbid water leaves behind it: the scaling off of this coating of clay soon obliterates the smaller footprints. These glazed surfaces are furthermore impressed with delicate watermarks and groovings, such as water trickling down a slimy or wet sandy beach always produces. In some instances we see them imprinted with the markings called "rain-spots;" and in rarer cases they show cracks filled with sand, such as geologists are wont to attribute to shrinkage in mud from the sun's heat. So exclusively are the footprints confined to these glazed and seemingly half air-dried surfaces, that it is in vain to look for them by splitting open the cohering layers of the sandstone, for they occur only where the beds spontaneously separate. All the associated phenomena confirm the inference drawn from the footprints themselves, that the creatures which left them were air-breathers in their organisation.

The annexed cut represents a locality where the sun-cracks above alluded to are exposed in a roadside quarry, near the village of Dauphin, on the Susquehanna (see Fig. 685). The shrinkage and cracking took place in a layer of slimy mud, now smooth red shale, and the cracks are occupied by sand sifted in at the strewing of the immediately overlying layer, which is one of red sandstone. Frost and weather have long since defaced the surface, which, when it was freshly uncovered many years ago, offered a very striking example of the phenomenon. No reptilian or other footprints were visible when we examined it.

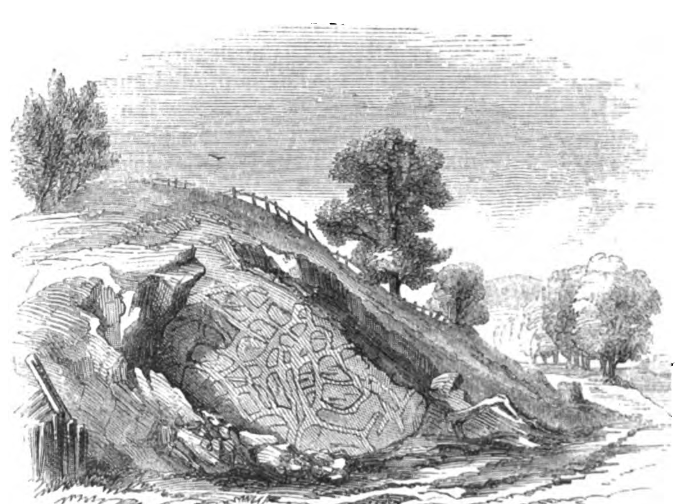


FIG. 685.

Upon some of the parting surfaces of the beds of the Umbral formation, we meet with curious corrugated impressions of the character shown in the accompanying figure (see Fig. 686). These are of various aspects, but the most common sort, that here illustrated, is about half an inch wide, and includes three separate bands of corrugation, the central strip having this feature on an exceedingly minute scale. One margin of the impression invariably shows a narrow sharp groove, 2 or 3 inches long, gradually diverging from the centre in a very gentle curve to a point outside of the edge of the corrugation. The whole impression looks like the trail left by some crawling mollusc, and we may fancy that the slender groove which is always on one side only, has been made by the edge or lip of the creature's shell, ploughing the mud or sand as it advanced. It is worthy of note, that these trails have not been seen upon the same class of surfaces as those imprinted with the footsteps, but upon partings in the strata which are more uneven and less glazed, and which look as if they had been covered with sediment while under water.

Fig. 686.—Trail of a Mollusc?

Trails of other patterns, some of them more sharply punctated than these now noticed, as if by the fins of fishes, are occasionally seen in the strata of some of the underlying formations; they are not infrequent in the lower and middle layers of the Vergent series, particularly on the Lehigh River, N.W. of the Lehigh Water-Gap, below Weissport.

No vestiges of reptilian life have been met with in Pennsylvania, nor indeed anywhere among the Appalachian formations, lower in the strata than the impressions above spoken of as occurring near Mount Carbon, and their horizon is about 2000 feet below the base of the Coal-measures, or upper Carboniferous series. As, nevertheless, the actual remains of reptiles have been found in Scotland, and elsewhere, in deposits of Devonian or old-red-sandstone date, or on the parallel of our Ponent strata, two formations lower than these in the Appalachian system, we are not entitled to look upon them as altogether the most ancient traces of reptilian life, and it is very probable that future geological researches will bring to light, if not the bones, at least the footprints of creatures of that class, even as low down among the strata as the Vergent series, where we meet with so many indications of air-breathing plants, shore-marks, trails of molluscs, and other proofs of the conditions compatible with the existence of those races.

That any races higher by an important interval in the scale of organic beings than the reptiles which have left their traces in the Carboniferous and Devonian strata, coexisted with them, must appear, I conceive, very improbable, when we reflect that no vestiges of any such have ever yet been met with, though we are assured by the reptilian footprints, and other independent evidences, that the physical conditions of the surface were every way favourable for the preservation of their tracks. The successive disappearance of the traces of the higher forms of life, as we recede into remoter geological times, is one of the clearest proofs which we can have of a progressive elevation in the scale of structure of the races successively created. The law of the successive appearance of the footprints is quite as conclusive as that of the parallel introduction of the actual skeletons and remains of the creatures themselves. It is perhaps of even more weight as precluding all discussion upon the differences of degree of destructibility of the bones or carcasses of the several classes of animals which peopled the ancient world. Some of the bird-tracks and reptilian footprints left on the once soft surfaces of the old rocks, are as clear and legible as any impressed yesterday on surfaces of moist mud or sand by the creatures of corresponding structure. Once bedded and sealed up, their preservation has been independent of the lapse of time. This law of a progressive rise in the footprints, like that so generally recognised in regard to the organic remains themselves, distinctly refutes the view taken by some disciples of the Huttonian theory of the earth's history, that, the higher animal forms being inhabitants of the land, we ought not to look for their remains in strata of marine or aqueous origin, but must suppose they were never entombed. But the negative evidence from footprints is of positive force when it appeals to appearances in the imprinted surfaces of the rocks, which show that they were exposed in a moist state to the air above the level of the waters, and in situations as accessible to mammalia as to birds,—in the instance of the Connecticut red sandstone, and in the case before us of the still earlier formations, as accessible to both mammalia and birds as to the reptiles which left their tracks upon them.

The only district within the State in which the umbral strata contain any actual organic remains of the extinct species themselves, is the tract commencing in Cambria County, and extending through Somerset County to Maryland. Here the formation assumes a more calcareous character than it possesses anywhere to the N.E., and even admits a thin stratum of limestone, which, expanding towards the S.W. and W., becomes the Great Carboniferous Limestone of the Southern, Central, and Western portions of the Appalachian basin. This limestone, especially in the districts of its full development, abounds in fossil remains of a marine type—zoophytes, echinoderms, and molluscs—many of them analogues of the fossils distinctive of the carboniferous limestones of Europe, to the horizon of which it seems to approximate. Among the few fossils imbedded in this rock in Somerset County, where it is thin and near its ancient Eastern limit, one of the most common is a *Productus*, with a comparatively short hinge, and great elongation of the dorsal valve. I think it is equally typical of this stratum in the Western States, but I have not been able to learn the specific name there conferred upon it. (See Fig. 687).

The beautiful fossils called *Pentremites*, a group of stemless echinoderms equally distinctive of the Umbral or carboniferous limestone, are rarely met with in Pennsylvania; but the species here shown does occur, and is very common, farther S. in Virginia. (See Fig. 688).


FIG. 687.—Productus.

ANIMAL REMAINS OF THE COAL STRATA OF PENNSYLVANIA.

The Coal-measures of Pennsylvania, except near the W. side of the State, possess but few species of animal remains; the Anthracite-measures almost none at all. This paucity of molusca and other aquatic forms is attributable to causes already amply explained—the generally littoral or land-derived character of the sediments, and corresponding scarcity of calcareous matter in the shales. Until very lately the anthracite fields had failed to disclose a single fossil-shell, but in the summer of 1857, my nephew, W. B. Rogers, jun., discovered the casts of two or three (an Avicula? and a Tellinomya?) in coal-slate near the mouth of the Ravensdale tunnel.

The limestone layers and beds of calcareous shale of the bituminous coal-fields of the Western counties contain some well-preserved species; among them a small *Avicula*, here shown (see Fig. 689), and another shell, apparently a new species of Nucula? (see Fig. 690), an ornamented *Pleurotomaria* (see Fig. 691), and a Nautilus, apparently *N. decoratus*, Cox (see Fig. 692), somewhat like


FIG. 688.—Pentremites.


FIG. 689.—Avicula.

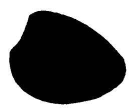


FIG. 690.—Nucula?


FIG. 691.—Pleurotomaria.


FIG. 692.—Nautilus decoratus.

the *N. tuberculatus*, Sowerby. This last shell is often seen in a fossiliferous layer in the cliffs of the Monongahela River, opposite Pittsburg. Another mollusc of the Coal-measures, seen occasionally in the same strata, but more common in Western Virginia, is the *Goniatites Nolenensis*, Cox, a species found also in Kentucky. We likewise meet sometimes with a delicate little elliptical *Lingula* (see Fig. 693), especially interesting from the position in which it is usually found.


FIG. 693.—Lingula.

It is most apt to occur in carbonaceous fissile black-slate—indeed it is seldom seen but in the roof-slate of a bed of coal. The specimen here figured is from this position, just above a coal-seam at Nelsonville, Ohio; and I have met with it in the same position above a coal-bed in Mercer County, in Pennsylvania. I have also seen a Lingula, apparently the same species, in the black roof-slate of a coal-seam on the E. slope of the Cumberland Mountain, in Tennessee. As it is well known that some of the living Lingulæ inhabit shallow waters, the occurrence of these remains so immediately above a stratum which was demonstrably formed in contact with the air, need not surprise us, if we adopt the explanation of the origin of the coal strata presented in the foregoing pages, and suppose the coal-bed overlaid by the Lingula slate to have been a level savannah bordering the sea, and to have quietly sunk beneath the level of the waters, enabling the marine organisms to take up their abode above it.

The Western Coal-measures contain a large Spirifer, here represented (see Fig. 694). It is of a type often met with in the carboniferous limestone.


FIG. 694.—Spirifer of the Coal Strata.

Of the remains of vertebrated animals the coal strata of Pennsylvania have hitherto revealed but few traces. No well-identified fish-remains have yet appeared; but some years ago some interesting reptilian footprints were found by Dr King of Greensburg, Westmoreland County, on a slab of sandstone of the coal-formation in the neighbourhood of that town. These were subsequently examined by Sir Charles Lyell, who makes the following mention of them: "The foot-marks were first observed standing out in relief from the lower surface of slabs of sandstone, resting upon thin layers of fine unctuous clay. One of these masses displays, together with footprints, the casts of cracks of various sizes, referred to the drying and shrinking of mud, and the subsequent pouring in of sand into open crevasses. No less than twenty-three footsteps were observed by Dr King in the same quarry before it was abandoned; the greater part of them so arranged on the surface of one stratum as to imply that they were made successively by the same animal. Everywhere there was a double row of tracks, and in each row they occurred in pairs, each pair consisting of a hind and fore foot, and each being at nearly equal distances from the next pair. In each parallel row the toes turned, the one set to the right, the other to the left. In the European Cheirotherium both the hind and fore feet have five toes, and the hind foot is about five times as large as the fore foot. In the American fossil the posterior foot is not even twice as large as the anterior; and the number of toes is unequal, being five in the hind and four in the anterior foot. In this, as in the European Cheirotherium, one toe stands out like a thumb. The American Cheirotherium was evidently a broader animal than the European. We may assume that the reptile which left these prints on the ancient sands of the Coal-measures was an air-breather, because its weight would not have been sufficient under water to have made impressions so deep and distinct."

NOTES ON THE BEYRICHIÆ AND LEPERDITIÆ OF PENNSYLVANIA.

By T. RUPERT JONES, Curator, Geological Society of London.

I am indebted to my friend T. Rupert Jones, F.G.S. of London, for the following very clear descriptions of the species of Beyrichiæ and Leperditiæ, found by the Survey in Pennsylvania. The reader will see an interesting paper, on nearly all the known North-American species of these obscure genera, which Mr Jones has studied with great success, in the *Annals and Magazine of Natural History* for April 1857.


FIG. 695.—Beyrichia Maccoyiana.

FIG. 696.—Beyrichia Pennsylvanica (different stages of growth).


FIG. 697.—Leperditia ovata.

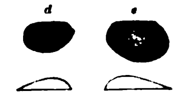


FIG. 698.—Leperditia Gibbera, *var.* Scalaris.

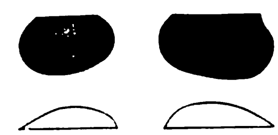


FIG. 699.—Leperditia Pennsylvanica.

BEYRICHIÆ.

1. The species of Beyrichiæ (Fig. 696, *a b c*) which occurs in such numbers as to constitute the chief material of the limestone bands of the Scalent marls of Pennsylvania, is new, and presents several varying forms, probably indicative of successive conditions of growth. Three of these I have selected for illustration, but intermediate forms frequently occur. This is a bisulcate Beyrichia, having general resemblances to some other forms, but distinct specific characters, which latter are chiefly found in the proportion of the surface-lobes of the valves and their finely-sculptured ornament. I have named it *B. Pennsylvanica.*

There are two individuals of apparently a smooth variety of this species, showing a strongly lobed surface (as in Fig. 696 *c*), in the greyish limestone from near Barre Forge, where it is associated with *Leperditia Pennsylvanica.*

2. *Beyrichia Maccoyiana* (Fig. 695), a species of rather rare occurrence in the Upper Silurian limestone of Sweden (strewed as boulders over parts of Prussia), occurs in a piece of the Beyrichia limestone from the marls of the Scalent series, where it is of rather a larger size than the European specimens, and, excepting its delicate marginal frilled rim, is in good preservation.

LEPERDITIÆ.

1. A single specimen, *L. ovata* (Fig. 697), in the dark-grey Auroral limestone from Potter's Fort, Penn's Valley, affords good evidence of a species of Leperditia, characterised by a simplicity and ovateness of form not present in any other known to me.

2. *L. Pennsylvanica* is the name imposed by me on a handsome species in the grey limestone from near Barre Forge. It has relations with *L. Balthica* and *L. Arctica*, but differs from both, chiefly in its relative narrowness and great convexity (Fig. 699). It is an important species, in my esteem, as being probably a geographical representative of its European and Arctic allies.

3. A variety of *L. Gibbera*, a species founded by me on good specimens from Beechy Island, occurs in the black limestone of the Scalent series, in good condition, showing a want of the surface-pittings which the type possesses, and a smaller dorsal hump on its left valve (Fig. 698, *d e*).

Casts of the same variety (*L. Gibbera* var. *Scalaris*) occur also in the grey "Waterlime" rock of Williamsville (Museum Geol. Soc.)

A thin seam of hard grey limestone, half an inch thick, from a rather higher horizon than that of the black limestone, has its surfaces thickly beset with badly-preserved valves of Leperditia, apparently of the same variety as the one last described.

These Pennsylvanian species are important additions to the crustacean fauna of the Lower Palæozoic age, and enlarge the number of the North-American bivalved Entomostracæ, of which I now know twenty-three chief forms, besides minor varieties. These are either mentioned or described in the *Annals of Natural History* for April 1857. There are four other forms mentioned by Professor James Hall (*Palæont. New York*), which I have not yet met with, and of which it is difficult to form an opinion by the figures given.

FOSSIL PLANTS OF THE COAL STRATA OF PENNSYLVANIA.

The following new species of fossil plants, one hundred and ten in number, are some of the results of a systematic investigation of the fossil flora of the carboniferous strata of Pennsylvania and the adjacent coal-fields of Ohio and Virginia, undertaken a few years ago by my able assistant in this department of the geological survey of Pennsylvania, Leo Lesquereux, Esq., formerly of Switzerland, now of Columbus, Ohio.

By far the greater part of the specimens were collected by himself. A few of the new species were first seen and studied by him in the rich local cabinets of Mr Clarkson, of Carbondale, and of the Rev. W. Moore, of Greensburg, to whom our best thanks are due for their liberality in thus opening their collections for the description of what was new. Many of these hitherto undescribed forms were discovered in the slates, associated with the beds of anthracite in the coal-fields of Eastern Pennsylvania, which, compared with the bituminous Coal-measures of Western Pennsylvania, appear not only to contain a greater variety of species, but to present them in a condition of more perfect preservation for study.

The new species here briefly described by Mr Lesquereux constitute about one-half of the total number of well-defined forms hitherto detected by him in the Coal-measures and lower carboniferous rocks (the Vespertine series) of Pennsylvania; more than one hundred of the two hundred and twenty species examined by him proving to be entirely identical with species already recognised in the European coal-fields, and some fifty more of them showing differences so slight, that a fuller comparison with better specimens may result in their identification likewise. As a further evidence of the near affinity of the North-American to the European fossil flora of the carboniferous age, he has remarked, in the course of his investigations, that even these new species, which seem restricted to this continent, are every one of them in close relationship with European forms. It deserves mention, moreover, that the commonest European species are likewise the most common American ones.

A future comparison of the fossil plants of the several broad coal-basins of the United States, in their order from E. to W., will probably disclose a corresponding reduction in the number and variety of the species,—a view already suggested by their relative paucity in the bituminous coal-fields of Western Pennsylvania and Ohio, as measured against their abundance in the anthracitic basins.

Wherever I have studied either the anthracite fields or the great Appalachian basin, I have remarked that the lower or "White Ash" division of the Coal-measures gives indications of more violent and frequent disturbances of level in the surface at the time of the deposition of the strata than are noticeable in the composition of the upper or "Red Ash" part of the formation. Among the proofs are, more abrupt and frequent alternations of coarse and fine deposits, more diversified and rapid changes in the thickness, composition, and arrangement of the strata, both of the mechanical deposits and the life-derived beds of coal, and the far greater mutability and inconstancy of all those strata, even the most quietly deposited, within the same area or extent of outcrop. The lower strata of the anthracite Coal-measures are indeed remarkable for diversity in the coarseness of the sandstones, and for unsteadiness in thickness of the coal-beds themselves. Though these carbonaceous layers are the accumulations of once perfectly level sea-meadows, at successive depressions of the surface, it is evident, from their comparatively rapid thickening and thinning, and frequent coalescing and diverging, that the floors upon which they were collected were neither so wide as those which sustained the vegetation that resulted in the bituminous coal-beds, nor so uniform and gradual and horizontal in their slow movements of elevation and depression.

Commensurate with the more fluctuating size, and more restricted range of these lower coal-seams, is a greater inconstancy and diversity in their fossil flora. The more widely extended upper beds appear to exhibit a more limited specific vegetation, expanded over wider areas.

As far as our researches have gone, we notice that the lower strata, both in the anthracite measures and in the great Appalachian coal-field, abound in the larger species, especially in Lepidodendra, while the higher seams are characterised by the smaller *herbaceous species*, most generally the herbaceous ferns.

We conceive that the large proportion of species common to the coal strata of North America and Europe clearly establishes identity of age between the two deposits, and a close accordance, if not identity, in the geographical and climatal conditions prevailing at their formation. A yet closer agreement is noticeable between the species found in the several coal-fields of the United States. Indeed, so much alike are all the anthracite basins in their fossils, that Mr Lesquereux already recognises more than twenty familiar European species as common to these once continuously united coal-fields. It has been indicated above, that the two different groups of the coal strata of Pennsylvania, the lower or white ash, and the upper or red ash, are characterised by somewhat different species, though these more or less intermingle. Satisfied of this fact, of a general prevalence of certain forms in certain parts of the Coal-measures, we have aimed at carrying our inquiry a step farther, to ascertain whether or not any or all of the individual coal-seams themselves are separately recognisable by their fossil plants. Undoubtedly, in some of the broadly-deposited and uniformly-conditioned coal-beds and coal-slates of the W. bituminous coal-fields, a most striking prevalence is observed of the same species within the same layer, on comparatively wide areas; but amid the more regularly accumulated beds, of especially the lower or white-ash anthracite strata, formed on a less stable portion of the nowhere absolutely stationary crust, the inconstancy in the vegetation of even the same coal-seam is, for the most part, if not entirely, too great to permit an attempt to identify it by its fossils merely. Again, in some instances, coal-beds, which are demonstrably different, are almost absolutely identical in their fossils. This is the case with the "Gate" and "Salem" coals, near Pottsville. So strikingly alike are they in their vegetation, that Mr Lesquereux strongly inclines to regard them as but the detached parts of originally one sheet of coal, and to suspect that there is some error or obscurity in my section, which shows them to be separated by several hundred feet of strata, including a number of beds of coal. Of the validity of the proofs showing the so-called Salem vein to be a different coal from the Gate vein, and several stages higher in the series, there cannot, however, be any question, and the palæontological evidence for identity must therefore give way before the higher and more decisive demonstration, from superposition, of their difference in age.

Before entering upon the description of the new species, Mr Lesquereux presents the following introductory essay :—

GENERAL REMARKS ON THE DISTRIBUTION OF THE COAL-PLANTS IN PENNSYLVANIA, AND ON THE FORMATION OF THE COAL.

By LEO LESQUEREUX, Esq. of Columbus, Ohio.

The distribution of the fossil plants in the great coal-basins of America, especially in comparison with the vegetation of the same geological date in different parts of the world, is certainly one of the most interesting and important questions of geology. Before coming to any general considerations on this subject, it is necessary to look to the distribution of the fossil plants in the coal-basins of Pennsylvania,—apparently narrowing our point of view, but only to ascertain our premises, and to follow afterwards our deductions with more security.

The examination of the fossil plants of Europe has led many geologists to suppose that there had been some appreciable difference in the vegetation of each peculiar bed of coal, and that, by a close observation, it would be possible to identify the same veins of coal, or at least some of them, at two very distant points from each other. The geological formations are nowhere more continuous and homogeneous on larger surfaces, and nowhere better characterised, than in the great Mississippi Valley; and we think that a better confirmation of the opinion above alluded to could not be found anywhere else.

The anthracite basins of Pennsylvania, cut into many fields by the upheaval of the inferior strata, required first to be examined in its different sections, from its Eastern limits at Carbondale to its Western, to ascertain if those different sections following the vegetation are only parts of the same original formation.

But before enumerating the plants for a proof of the identity of the different basins, it is necessary to remark that we cannot expect to find in two different parts of any coal-field, a perfect concordance of all the species. It would be absurd to suppose that, at the same time, the same plants have been distributed on large surfaces exactly in the same proportion. As it happens in our own time, there are some plants of which the presence suffices to give a general feature to the vegetation. These are the plants most commonly found, whilst many others of which the distribution is not so general, cannot in any way, either by their presence or their absence, change the character of the whole. It is also not unnecessary to remark that, in a flora of which so few species have been preserved, and which is consequently so limited, the number of the characteristic species cannot be great. And it suffices that we meet a few of them, either in the different basins of anthracite, or in the different parts of the coal-basin, to justify our conclusion on the identity of those parts. It is well to recall to mind that such is the difference in the flora of the geological ages, that, in the nearest formation to the coal, or in the Permian period, there is scarcely a single species left which can be related to the vegetation of the coal.

We will then admit, as truly characteristic of the coal-formation of America, the following species:—1. *Asterophyllites equisetiformis*, Bt.; 2. *A. tuberculata*, Lindl.; 3. *Annularia sphenophilloides*, Ung.; 4. *Sphenophyllum Schlotheimii*, Bt.; 5. *Calamites approximatus*, Bt.; 6. *Noeggerathia*; 7. *Neuropteris hirsuta*, Lesq.; 8. *N. flexuosa*, Bt.; 9. *N. heterophylla*, Bt.; 10. *Dyctiopteris obliqua*, Bunb.; 11. *Sphenopteris Lesquereuxii*, Newb.; 12. *Alethopteris lonchitidis*, Sternb.; 13. *A. Serlii*, Göpp.; 14. *Pecopteris polymorpha*, Bt.; 15. *P. arborescens*, Bt.; 16. *Stigmaria ficoides*, Sternb.; with many species of *Sigillaria* and *Lepidodendron*.

Of these species, there are very few that have not been found in all the separate basins of the anthracite coal. To give only a few examples, *Neuropteris hirsuta*, *N. flexuosa*, *Sphenophyllum Schlotheimii*, are met everywhere. The first four plants enumerated above belong especially to the upper veins, open at Pottsville and around that place. They were found also at Shamokin, at Wilkesbarre, at Room Run mines, and at Tamaqua, in the lower Coal-measures. The genus *Noeggerathia*, as we shall remark farther on, pertains to the Vergent and Ponent (Devonian) formations. The same species of the genus were found below Pottsville, and in the Lehigh Gap at Mauch Chunk. No. 10, *Dyctiopteris obliqua*, Bunbury, is at some places very abundant, as at South Salem vein, opposite Port Carbon, and at Trevorton, behind a wall of Sigillaria. Nos. 11, 12, and 13, belong to the low beds, and are found at both extremities of the anthracite basin, at Room Run mines, Wilkesbarre, Shamokin, Trevorton, and also at Minersville and Tremont, with many identical species of *Sigillariæ* and *Lepidodendra*. Nos. 14, 15, 16, have been found also in all the localities of the anthracite basin.

But it would be useless to pursue this enumeration further, the identity of the different basins of anthracite becoming more evident by what we have to say upon the identity of their different beds.

It would, nevertheless, be going too far to promise an enumeration of the species belonging to each bed of coal or anthracite, for the fossil plants are found well preserved only in the highest and in the lowest strata of the American basins.

It is in the lowest strata of the coal and anthracite basins that we find the largest species of vegetables of the time, especially the *Lepidodendra*, with their bark, their fruits, and their leaves. On the roof-shale at Carbondale there is imprinted in one of the galleries the bark of a Lepidodendron, 2 feet in diameter, and 75 feet long. The same diameter is preserved in the whole length without any material diminution. On the contrary, the highest beds of the basin have the small and herbaceous species, and also the tree ferns; but more generally the herbaceous ferns, of which the leaves and the smallest branches have been preserved.

These highest beds crop out in the vicinity of Pottsville, and this place is particularly interesting for the great abundance of the fossil plants found in a good state of preservation at the Salem and the Gate veins. The relation of the vegetation of both these beds is so close, that after long and careful research, and though the dynamic (structural) geology does not agree with this conclusion, we are not able to point out a difference which will authorise a separation or a distinction between them. There is only—and this not at every place where these veins are worked—a slight difference in the colour of the roof-shales, which are grey at the Salem vein, and more black at the Gate. But this difference is scarcely appreciable. Following, then, our point of view, and taking the vegetable palæontology as the basis of our identification, we may assert that the South Salem vein, opposite Port Carbon, is the same as the Salem vein of the New Breaker; the same also as the Gate vein of Pottsville, and of Port Carbon, and the Lewis vein of Mill Creek. In all these veins the bed of coal, varying in thickness from 4 to 8 feet, is separated into two by a greyish shale 6 to 12 inches thick, which contains the great abundance of fossil plants of which we have spoken above: viz. *Asterophyllites*, *Annularia*, *Sphenophyllum*, and *Calamites*, are there especially abundant, with *Neuropteris hirsuta*, Lesq.; *Neuropteris heterophylla*, Bt.; *Neuropteris flexuosa*, and its varieties; *Odontopteris Schlotheimii*, Bt.; *Dyctiopteris obliqua*, Bunb.; *Sphenopteris latifolia*, Bt.; *Sphenopteris polyphylla*, Lesq.; *Pecopteris oreopterides*, Bt.; *Pecopteris arborescens*, Bt.; *Pecopteris cyathæa*, Bt.; *Pecopteris arguta*, Bt.; *Pecopteris unite*, Bt.; *Pecopteris loschii*, Bt.; *Sigillaria reniformis*, &c. The same plants are found in the same abundance, and on the same kinds of slates, up the Schuylkill Valley, at Port Carbon, New Philadelphia, and Middleport, where the vein is named Gate, and on the other side below Westwood, or West-Branch, and at W.-West Branch, where the vein is also named the Gate. Crossing the anthracite basin in a perpendicular direction, we find the same plants we have already mentioned as occurring at the South Salem, Salem, and Gate veins at Pottsville; at Lewis vein of Mill Creek, and at Norwegian; then N.W. of Westwood, where the vein is named Black vein, at Muddy Creek, between Pottsville and Tremont, and at the Tremont new vein. But though the plants above mentioned are the ones which give the true character to the vegetation of these strata, we will renew our observation on the general distribution of the plants, and show that each locality has also some species of plants which have not been found elsewhere. So at the Salem vein of the New Breaker of Pottsville we collected one fine *Cyclopteris fimberata*, Lesq.; *Cyclopteris Germari*, Göpp.; *Neuropteris delicatula*, Lesq.; *Neuropteris gibbosa*, Lesq.; and *Neuropteris dentata*, Lesq. The South Salem vein of Port Carbon has *Calamites decoratus*, Bt.; and *Calamites undulatus*, Bt.; *Annularia sphenophylloides*, *Neuropteris adiantites*, Lesq.; *Odontopteris squamosa; Sphenopteris flagellaris*, Lesq.; *Sphenopteris polyphylla*, Lindl.; and *Alethopteris muricat*, Göpp. At the Gate vein of Pottsville we have found *Neuropteris fissa*, Lesq., and *Neuropteris rotundifolia*, Bt.; *Neuropteris tenuinervis*, Lesq.; *Alethopteris urophylla*, Göpp.; *Pecopteris notata*, Lesq.; *Pecopteris concinna*, Lesq.; *Pecopteris decurrens*. The Gate vein of Port Carbon is particularly marked by the beautiful *Neuropteris Rogeri*, Lesq., found only at this place, as the same vein behind the hill E. of Port Carbon furnished us the remarkable *Alethopteris serrula*, Lesq. The Gate vein of New Philadelphia, like the same vein at W.-West Branch, is especially rich in the fruit of *Asterophyllites*—viz. *Asterophyllites tuberculata*, Lindl.; *A. lanceolata*, Lesq., and *A. aperta*, Lesq.; with many fine species of *Sigillaria*—as *Sigillaria reniformis*, Bt.; *Sigillaria Brardii*, Bt.; and *Sigillaria Sculpt*, Lesq. When at Muddy Creek and Middleport the same vein has also many beautiful *Sigillariæ*, as *Sigillaria fissa*, Lesq.; *Sigillaria Schimperii*, Lesq.; *Alethopteris distans*, Lesq., and *Neuropteris undans*, Lesq., &c. The vein named Black vein, N.W. of Westwood, is particularly marked by *Sphenopteris intermedia*, Lesq., and *Sphenopteris Gravenhorstii*; while the most different of all, the new vein of Tremont, has, for its peculiar plants, *Odontopteris crenulata*, Bt.; *Alethopteris marginata*, Göpp.; *Pecopteris ovata*, Bt.; *Pecopteris pennæformis*, Bt., &c.

The upper division of the Anthracite measures, characterised by the red colour of the ashes, contains, with the beds above named, a few veins with which we have become acquainted by many cross sections around Pottsville, and at Mill Creek. These are below Salem bed; the Tunnel vein, which has very black roof-slates, and is entirely covered with *Neuropteris hirsuta* and its stems, without any other plant, and the Black mine, of which the roof-slates are especially marked by the obsolete prints of *Asterophyllites*, *Annularia*, and *Sphenophylla*, in such a state of decomposition, that they are scarcely distinguishable, though very numerous. We have found this bed with the same slates at many places of the basin. Below it are the two Selkirk veins, which have no fossils at all, but of which the roof and bottom shales are impregnated with oxide of iron, becoming rusty coloured when they are exposed to the action of the atmosphere. Below the Selkirk vein is placed the Gate vein, which, as we have said, is the same as the upper bed—viz. the Salem vein.

Between this upper group (the red ash) and the lower one (the white ash), there is an intermediate one containing 4 or 5 veins of coal worked upon Mill Creek, and of which the slates, though very fine grey coloured, show no trace of plants. It is impossible to characterise them by the plants, but only by the colour and the nature of the slates.

But as soon as we come to the white-ash or lower strata the presence of large-sized fossils becomes apparent, first in the large quantity of *Stigmaria* abounding at the Diamond and Primrose veins, then in the *Lepidodendra*, and some large ferns which distinguish the Mammoth vein. This vein especially merits being mentioned for its peculiar flora. The roof-slate of grey colour, ordinarily charged with a great many nodules of iron, has generally preserved the impressions of the fossil plants in a very good state. While in the upper beds the predominance of small ferns was so striking that frequently on a single slate of about half a square foot we could observe as many as ten or fifteen species, here, on the contrary, there is scarcely any fern to be found, or if any, it appears to belong to the largest species. With the *Lepidodendra* and their fruits, found in great abundance at Wilkesbarre, Carbondale, Minersville, Tamaqua, Lehigh, and Summit Hill, the plant mostly found in these low veins is

Alethopteris Serlii, Bt., with its near relative, *Alethopteris lonchitidis*, Bt., and also *Neuropteris hirsuta*, Lesq., and *Neuropteris Clarksonii*. The fruit and leaves, or needles, of *Lepidodendron*—viz. *Lepidostrobi* and *Lepidophylla*, are also very abundant in the Mammoth vein of the anthracite, and as we did not find any specimen of these fruits anywhere in the other bed above, their presence, we think, may be relied upon as a true character of the lowest beds of the coal-basin in general.

Nevertheless, we find in these lowest strata the same variety as in the upper ones—viz. with a few characteristic plants, many which belong especially to some localities. Carbondale is particularly rich in trees. With nearly all the species of *Lepidodendron* that we have described, we have seen there also the largest number of well-preserved *Sigillariæ*, especially those of which, the bark being smooth and without ribs, we have a section nearly related to *Lepidodendron*. Wilkesbarre has plenty of *Lepidostrobi*, and some large *Pecopteris*. Room Run mines, *Alethopteris Serlii*, with the large *Cyclopteris orbicularis*, Lindl., and *Sphenopteris Lesquereuxii*, Newberry. Lehigh Summit abounds in *Sigillaria elegans*, Bt., and *Sigillaria Brochanti*, Bt. At Tamaqua we find again *Neuropteris hirsuta*, Lesq.; at Miner's Hill, *Alethopteris Serlii*, Bt.; at Shamokin the *Lepidostrobi*, and at Trevorton nearly the same flora as at Carbondale—viz. an abundance of large trees, and both *Alethopteris Serlii*, Bt., and *A. lonchitidis*, Bt. The only place where this low stratum does not afford a striking likeness by its flora with the other localities, is at the vein W. of Shamokin, near the creek, and behind the mill. We scarcely found there any *Lepidodendron*, but only the following species, which are worth mentioning: *Neuropteris hirsuta*, Lesq.; *Neuropteris tenuifolia*, Bt., with its *Cyclopteris elegans*, Lesq., *Sphenopteris glandulosa*, Lesq., *Alethopteris nervosa*, Göpp., *Callopteris Sullivanti*, Lesq. On these species we may remark that the first one is found everywhere from the base to the upper strata of the coal; that *Alethopteris nervosa*, which was certainly a very large fern, was found in the low beds only, and at many localities in the bituminous coal and anthracite basins; and that the fine *Callopteris Sullivanti*, which, by the form and direction of its leaflets, and by its general form also, is much like *Alethopteris Serlii*, ought to be admitted also as a very large fern. *Neuropteris tenuifolia*, Bt., resembles so much *Neuropteris flexuosa*, Bt., that they are scarcely distinguishable. The difference is here established by the age of the strata, as this last species belongs to the upper ones.

We have already alluded to the identity of the great Appalachian coal-field with the different anthracite formations, asserting that this identity is especially striking on a comparison of the flora of the different strata. The great Appalachian formation is divided in two principal groups, each containing ordinarily four veins of coal, and separated by strata of shale, sandstone, and limestone, from 300 to 500 feet thick. This is generally named the Barren formation, for though there are at some places some traces of coal and coal slates, there is not a good bed of coal in this whole group. The lowest bed of the basin rests on the conglomerate, and crops out at the Portage Summit, where we collected some *Lepidophylla*, especially with *Lepidophyllum brevifolium*, Lesq., and at Johnstown, where the black slates of the roof are charged with *Lepidostrobi*, and also with *Lepidodendron*. The only species found there, different from those collected at Wilkesbarre is a fine *Pecopteris velutina*, which looks like a large species. The same vein outcrops also at Cuyuhoga Falls, Ohio, where it abounds in *Lepidodendra*, *Lepidostrobi*, *Alethopteris lonchitidis*, and some *Sigillariæ*. There is also plenty of fruit there, *Cardiocarpon* and *Carpolithes*, as at the low beds of Trevorton. The last place where we had an opportunity to examine this vein, so rich in fine fossil plants, was at Great Kenawha River, 3 miles above Charleston, and there we found the roof-shales covered with *Alethopteris Serlii*, with some fine *Lepidodendra*, and *Lepidostrobi* in abundance. So we shall necessarily be forced to draw this conclusion, that this vein of coal, preserving well its character at such great distances, was formed at the same time, and under the same circumstances, both in the whole extent of the great Appalachian coal-field and in the anthracite basins.

Coming again to the highest vein of the great Appalachian coal, we find the same relation between the species of plants preserved in its roof-slates. We have not had any opportunity of seeing this bed cropping out in Pennsylvania. But at Pomroy, Ohio, the bed of coal there worked is generally acknowledged by geologists as one of the highest, if not the highest, of the basin. It contains an abundance of ferns, the same species as those found at Pottsville, especially *Neuropteris flexuosa*, Bt., which is there in such plenty as to cover entirely the roof-slate. And still higher, at Marietta, there is a red shale perfectly like the shale of the South Salem vein at Pottsville, on which we have seen *Pecopteris arborescens*, *Cyclopteris fimbriata*, Lesq., *Cyclopteris trichomanoides*, Bt., *Asterophyllites equisetiformis*, Bt., *Sphenophyllum Schlotheimii*, Lindl., *Annularia sphenophylloides*, Ung., all the species most commonly found in the highest beds of the anthracite coal of Pennsylvania. The only species peculiar to the place which we did not find at Pottsville, is our *Asplenites rubra*, Lesq., which, without the fructification, cannot be distinguished at all from *Pecopteris arborescens*.

This identity, so well established between the great Appalachian coal-field and the anthracite basins, by the vegetation of both the upper and the lowest veins, is of great importance; the more so as it is nearly the only affinity that it is possible to point out between these two basins. The difference in the nature of the combustible mineral is well enough established, and though it may be possible hypothetically to ascribe the transformation of bituminous coal into anthracite to the influence of heat, we have nevertheless some parts of the coal-basin where the matter does not evidence the slightest change, although apparently subjected to the same influences. Thus the lowest bed of coal at Portage Summit, elevated 2300 feet above tide-water, is still 1200 feet above the same bed of coal at Johnstown, without any appreciable diminution of the volatile matter.

As it is, the identity of the vegetation is the only reliable proof of the identity of both formations. But it is strong enough to eliminate any doubt, and so we are induced to look to some accidental circumstance for the cause of the difference. Perhaps it is especially to be ascribed to the remoteness of the small anthracite basins from the influence of the saline waters.

We would be the more inclined to admit this supposition, as from the base of the Ponent to the highest strata of the Anthracite coal, we could never detect any marine shells, when, on the contrary, these shells are very abundant in the true coal-basin, not only in the beds of limestone intermediate to the beds of coal, but in the shales of the coal itself.

It is not our task to speak of anything that does not directly belong to the vegetation of the coal; nevertheless we cannot omit to mention some geological facts which may help to the identification of the different beds of the great Appalachian coal-basin.

We have mentioned above, the thick Barren formation which separates the two stories of the coal. At the base of these Barren strata there has been formed in some localities a bed of grey shale, abundant in fossil plants. We have observed it at Portage Summit, where it contains especially *Pecopteris polymorphe*, Brongt.; and from the observation of the Rev. Mr Moore, in whose cabinet we have seen the beautiful *Neuropteris Moorii*, Lesq., it appears that this plant was found also at the same station, with many specimens of *Pecopteris polymorphe*. This shale is very often represented either by a thin bed of cannel-coal, or by a very black shale, covered with very small bivalve shells, together with impressions of ferns. We have observed it first at Portage Summit, then at Deer Creek, below Freeport; at Greensburg, three miles from the city, both E. and W.; at Beaver, in Pennsylvania; also at Nelsonville, in Ohio, and at Charlestown, in Virginia. The only bed of coal that we have had an opportunity of examining in Illinois—viz. nine miles E. of Terre Haute—is covered by these shales. A few feet above these shales, near the base of the Barren-measures, large trunks of trees, especially of the genus *Psaronius*, are found imbedded in strata of coarse sandstone. These trees are either transformed into sandstone or into limestone, and they have left only an impression (moulder) marked by a thin crust of coal, or entirely silicified, their internal structure being preserved. Their place in the vegetable kingdom is marked by the form of their vessels. Such trees are particularly abundant at Greensburg, Pennsylvania; at Athens, Ohio; and at Charlestown, in Virginia. We could probably point out another locality with a contemporaneous and identical formation—viz. the standing forest of Calamites and Sigillaria preserved in the sandstone above the bed of coal worked at Carbondale, in the anthracite basin. This may prove a new and interesting geological fact added to the one already mentioned, for the identification of both basins.

We have not made any extensive researches in the other coal-basins of America—viz. the basins of New Brunswick and New Scotia, Illinois, Wisconsin, and Iowa. The geological researches of others have already placed them in the same formation with the great Appalachian basin, and we have seen enough of the fossil plants collected in these different countries, to permit the conclusion that the vegetation of all is identical or contemporaneous. Among the fossil plants that we have received from New Scotia, there is not a single species which we did not find in the anthracite coal-basin at Pottsville; and all these plants, collected in a single place, have proved to us that the vein of coal from which they were taken is the upper vein of the basin. Mr Bunbury has enumerated a larger quantity of these fossil plants collected in New Scotia; yet in the whole number we find scarcely a single species unobserved in Pennsylvania. They are the following:—

Neuropteris cordate, with its variety *angustifolia*, is our *Neuropteris hirsuta*. *N. ingens ?*—very doubtful, the specimen being incomplete, and the extremity of the leaflet broken off. *N. flexuosa ; N. gigantea*, var., of which the author remarks that it is more an intermediate species between *N. gigantea* and *flexuosa*. We think it only a variety of *N. flexuosa*, as the true *N. gigantea* is scarcely an American species, though very often mentioned. All the specimens that we have received under this name belonged to *N. flexuosa*. *N. rarinervis*, Bunb.—a good species, very scarce in the anthracite basin; *Cyclopteris oblique*, Bt.; *Odontopteris Schlotheimii*, Bt. *Odontopteris subcuneata*, Bunb., has a great affinity with our *Neuropteris tenuinervis*, and may belong to the upper part of the frond of the same plant. *Dyctiopteris obliqua*, Bunb.; *Pcropteris emarginate*, Bt. *P. tæniopteroides*, Bunb., is nothing but a variety of *Alethopteris Serlii*, very often found in the lowest veins of coal at Minersville: the specimens received from New Scotia agree perfectly with ours. *P. nervosa*, Bt.; *P. plumosa*, Bt.; *P. abbreviata*, Bt.; *P. polymorpha*, Bt.; *P. cyathea*, *Sphenopteris obtusiloba*, Bt.; *S. artemisiæ folia*, Bt. *Sphenophyllum Schlotheimii*, Lesq.; *S. erosum*, Lesq.; *Asterophyllites foliosa*, Lesq.; *Bechera grandis*, Lesq.; *Pinnuaria capillacea*, and some *Lepidodendra*, *Sigillariæ*, and *Calamites*, identical with our species of Pennsylvania. It would be impossible to find a more striking identity between the vegetation of such distant countries.

The specimens received from Illinois and Indiana are still very few. But we have already mentioned that the only vein of coal that we have examined in this basin—viz. near Terre Haute, is the same in its fossil plants, and also in some other characters, as the first vein below the Barren-measures in the great Appalachian basin. There has not been collected around St Louis, and elsewhere in this basin, a single plant which does not belong to our flora.

The coal of Wisconsin and Iowa has been explored by Mr Dale Owen, who assigns it a position a little lower than that of the great Appalachian coal—viz. below the red shales of the Umbral series. It may stand so, but the plants that he has enumerated and delineated from species of *Lepidodendra*, would place the vein from which they have been taken exactly at the same level as our low bed above the Seral conglomerate. Both these strata of conglomerates and red shale may be wanting in the Wisconsin basin, and, though lying lower, the coal strata would then be, as I think they are, contemporaneous with ours.

From North Carolina we have received of late a fragment of the roof-shale of a bed of coal in a still lower position. This small fragment does not show any trace of vegetable remains, but only the shells of the Chemung (Vergent) group. It may belong to another period, but it is impossible to draw any conclusion from the small specimen alluded to.

The parallelism of the different basins, and even of the different strata, of coal in North America, being so fully ascertained, we have to look to a more general and not less interesting question—the comparison of the vegetation of the same period on both continents, America and Europe.

We could begin our comparison from the first formation where we find some remains of plants, viz., in the fucoids of the older Palæozoic strata; for we have there *Chondrites antiquus*, and many species of the same genus, identical with those found in Europe. But as these species have been described in the Report of the Survey of New York, and as we had not any good opportunity for examining the plants of the Silurian period, we may omit to mention them. We have found these *Chondrites* abundantly preserved in the Surgent group at Bloomsburg, and below the Vergent group at Portage Railroad.

The terrestrial flora of the older Palæozoic is either very limited or scarcely known. There are few localities where the Devonian strata have been entirely unfolded, and their shales, ordinarily coarse, are not fit for the preservation of the plants. This fossil middle Palæozoic flora, excluding the fucoides or marine plants, counts in Europe only about sixty species, distributed in eight genera. Though we are far from having found in America as many of these plants, we have been able to collect enough of them to ascertain the analogy, if not the identity, of the vegetation of the ancient formations, both in Europe and in America.

The *Calamites* are not scarce in the Ponent series of Pennsylvania, which corresponds to the Old Red sandstone. From the *Neuropterideæ*, Göppert, we have mentioned in the Chemung group, or upper Devonian system, our *Noeggerathia Bocksii*, which is the same plant as *Neuropteris Bocksiana* of Göppert, found in the old Palæozoic formation of Silesia. We have still three more Noeggerathia from the same formation in America, and of these *N. obliqua* is identical with the European species, and the two others are perhaps so; for their relation with some species already described is such, that the difference, if there is any, cannot be established without a comparison of the specimens of both countries. This predominance of the *Noeggerathiæ* in the beds of the Devonian age, both in Europe and in America, is itself a remarkable fact. They are the true ferns of the Devonian period, and they disappear entirely when we arrive at the lowest strata of the coal-formation. Pursuing our comparison, we find another point of affinity in the class of *Sphenopterideæ*. In the Devonian rocks of Europe there is only one species hitherto ascertained, viz. *Hymenophyllites Gersdorfii*, Göppert; and we have found in the Ponent rocks near Mauch Chunk a *Hymenophyllites*, which we refer with doubt to *Hymenophyllites furcatus*, Göppert; but which, by a comparison of good specimens, would probably prove to be the same species, the leaflets being often truncate, as *H. Gersdorfii*, the general appearance being alike. We did not see in the Devonian rocks of America any *Pecopteris*, but *Stigmaria Anabathra*, *Didymophyllum Brownianum*, and a *Pinorria*, which were probably found in the Devonian formation of Europe. Our *Stigmaria minuta*, which comes from the Ponent below Pottsville, is perhaps the same species as the undescribed *Sigillaria minutissima* of Göppert. Fruits, leaves, and stems of the undescribable *Lepidodendron* have been found as low as the formation Cadent upper black-slate, in the Juniata Valley near Huntingdon. These species are few in number, but their near affinity, or rather their identity, with those found in Europe, may remove any doubt as to the parallelism of these Devonian formations in both continents.

The same affinity of vegetation becomes much more evident when we come to the true coal. The general likeness in the flora of this period is so great that we could scarcely point out a difference, except perhaps in the *fimbriation* of some species of *Cyclopteris* and *Neuropteris*, and in our new genus *Scolopendrites*. But except this, in about two hundred and twenty species we have examined, there is not any form that has not a close relationship with the European species; and of these there are more than one hundred entirely identical species, and fifty more of which the differences which have necessitated a separation would perhaps prove accidental or invaluable, if better specimens had been procured. What is more striking in the analogy of these floras is, that the most common species in Europe are probably so in America, and this is also the case with the scarce ones. We will only mention a few examples of the most common plants of the coal-formation of Europe: we have *Calamites approximatus*, found in abundance at Carbondale; *Asterophyllites foliosa* and *Asterophyllites tuberculata*, two plants very common in the upper beds of the anthracite basin; *Sphenophyllum Schlotheimii*, which covers the roof-slates of the Salem Vein at Pottsville; *Neuropteris hirsuta*, L. (same as *Neuropteris cordati*, Bt.), *Neuropteris flexuosa*, with their corresponding *Cyclopteris; Neuropteris heterophylla;* very common plants in the American coal, like *Alethopteris conchitidis*, *A. nervosa; Pecopteris polymorpha*, *P. arborescens*, *P. arguto*, with some species of *Sigillaria* and of *Lepidodendron*. The most common fossil vegetation, as well in Europe as in our continent, is *Stigmaria fucoides*, which sometimes appears as if it had alone formed many veins of coal. We may as well mention here, that the remains are plentifully found in the coal itself, though it has been often denied that the coal of Europe preserved any impression of the plants which formed it.

Among the species which are scarce in both continents we find *Cyclopteris Germari*, of which we have obtained a single and small specimen; *Neuropteris tenuifolia*, *N. Willersii*, *Odontopteris Schlotheimii*, *Alethopteris urophylla*, *Callopteris Sullivanti*, a near relative to *Neuropteris conferta* of Göppert, *Pecopteris ovata*, *P.*

abbreviata, &c. These affinities of the vegetation of the coal period serve to give us positive proof that the Palæozoic coal-basins of Europe and of America were formed exactly at the same time; but we do not think that it would be right to draw the conclusion that at this time the vegetation of both continents was identical.* On the contrary, we find, by comparison of the flora of the coal, that, with all its points of likeness, it had as many dissimilar ones as the existing flora has now, and that the distribution of the plants presented about the same proportion and disproportion as in our time.

But before looking at this question, it is necessary to understand what points of reliance we shall find for the security of our comparison, and where we shall find them.

It has many times been questioned if the fossil plants found in the Coal-measures would give us any good general view of the vegetation of the Palæozoic era. This is easy to answer. Either the whole surface of the emerged country was low, marshy, covered with the plants which formed the coal, and the remains of these plants found imbedded in the shales are a pretty accurate representation of the vegetation of the coal; or there were dry and high lands around the marshes, and then the petrified plants found in the Coal-measures would not give us a better view of the general vegetation than the plants of the peat-bogs would give now of the vegetation of the surrounding hills. It has been a mistake of many authors to look at the vegetation of the coal, and draw conclusions from it without a clear understanding of its nature. It is, I think, unnecessary to recall here either the proofs of the formation of the coal by the heaping of vegetable matter, or the growing of the plants of the coal at the place where their remains are now found; there is already evidence enough on that question. But we require to remember a few of the laws of nature, to give us a better view of the subject.

The woody matter of the plants is produced only by the absorption and elaboration of the carbon of the atmosphere. The more the atmosphere is saturated with humidity, the more carbonic acid is absorbed by the plants. The more of light and air there is around the plant, the more this carbonic acid is elaborated to produce the largest proportion of woody matter. This fact, which is directly proved by chemical experiments, is elucidated by nature everywhere around us. The plants entirely covered with water have a very small amount of woody matter in their tissue. And so we can assert that the true marine plants, or the *Fucoides*, have never contributed a large share, if they have at all, in the formation of coal. On the other hand, plants living in a very dry atmosphere have ordinarily a large supply of sap and watery matter, like the Cactaceæ and the fleshy Euphorbiaceæ of sterile regions; but they contain a very small proportion of woody matter; and so we can eliminate at once this supposition that some plants of the coal, the *Sigillariæ*, and the *Stigmariæ* especially, might belong to the family of the Cactaceæ or of the Euphorbiaceæ, as it has been asserted by some authors.

Going farther into this subject, we find that the plants especially composed of woody matter have need of another proceeding of nature to preserve this matter from decay, and to transform it into coal. This is performed by humidity, or by water. Every particle of dead woody matter directly exposed to the air, is by-and-by entirely consumed by the action of the oxygen; it is rotted, as we call it. But when the action of oxygen is tempered by the presence of a large proportion of water, the procedure is slow, and then the decay of wood is exactly like its transformation into charcoal; viz., a true slow burning, and a carbonisation. It is then necessary to conceive the formation of the coal as the result of half-aerial, half-watery vegetation, exactly that of our present peat-bogs. This is the simplest and the most natural way to explain the formation of the coal; and the affinity is so evident that it is scarcely possible to understand how it has been so long overlooked. Naturalists have, one after another, habituated their minds to construct systems and hypotheses which the simplest observations destroy, and have forgotten to look at the work of nature, which is always the same, immutable in its laws as in everything that is great and eternal.

If this were the place, we would like to explain at length our views about this analogy of formations now pointed out, and compare minutely the old formation of the coal with the new ones, or with the peat-bogs, which are nothing but beds of coal not entirely ripe or burned out. We would have to mention some very interesting and striking analogies, such as the presence of bitumen in both formations. It has always been asserted that bitumen could not proceed from plants, and it is now everywhere obtained by the distillation of peat. We would show the identity of the geographical distribution of both formations, though it has been long asserted that the peat formation belongs to a cold climate, and the coal to a warm one; also the affinity of form in their plants, the leaves of which are nearly all either grass-like or small, pointed, and like needles, both forms particularly adapted, it seems, to the absorption of the vapours, and the transformation of carbonic acid in woody matter, and show the large amount of wood in the plants of our peat-bogs, even in the mosses (sphagna), which, though very fragile, soft, and thread-like plants, have a larger proportion of woody matter than the hardest and largest of trees.† This analogy of formation being established, we do not see any reason to theorise about the general flora of the period of the coal-formation. It is useless to experiment on a large amount of plants of our time—especially plants living in conditions that render their presence impossible in the coal-formation, to draw hereafter any conclusions about the number of species of plants living in former ages. It has been already observed by Mr Bunbury, that the careful observations of Mr Lindley on the length of time which some plants may stand immersed in water without losing their form, cannot help in any way to our acquaintance with the flora of the coal. We

* As many authors have done, *vide* Bunbury, &c. Some have gone so far as to suppose that at the coal epoch the Atlantic did not separate both continents, and that the coal-basin of England may be a continuation of that of Nova Scotia.

† All these facts have been stated at length in *Recherches sur les Dépôts tourbeux en général*, by the author of this report.

will here only mention that if the same experiments had been performed only on the plants of our peat-bogs, the conclusions would have been more rational. We take an example from the family of the mosses. Mr Lindley has experimented on six species, viz. *Hypnum striatum*, *H. sericeum*, *Dicranum purpureum*, *D. scoparium*, *Bryum undulatum*, *Polytrichum commune*. The natural function of all these species of mosses is to cover the base of the trees, or their decayed parts, either to protect the roots, or to form the black earth or humus by their decay. So they are quickly-decaying species. The true mosses of the peat-bogs are the *Sphagnum*, all the species; some *Hypna*, especially *Hypnum trifarium*, *H. fluitans*, *H. scorpioides*, *H. niteus;* some species of *Dicranum*, as *Dicranum Schraderi*, *D. palustre*, &c.; and certainly if these mosses, with the bog-rushes (Junci) and the sedges (Carices) of the peat, were subjected to the same experiments, the result would prove very different. We have found in the peat-bogs of Switzerland some beds of *Hypnum trifarium* under 10 feet of entirely black and decomposed peat, which were so well preserved that the species could be perfectly and easily identified. We have also received specimens of *Hypnum fluitans* found in Berlin, under 50 feet of sand and water, which are in as good condition as if they had been preserved in a collection of dry plants. To elucidate this point, and to show what is the vegetation of the peat-bogs of Europe, and what relation this vegetation may have with that of the coal-formation, we will translate a passage from the work already quoted on the formation of the peat-bogs, (page 131, quarto edition):—

"The analogy is not the less remarkable, if we consider the classes of plants which have formed both combustible substances. Mr A. Brongniart found in the old coal—(*a*) About ten species of fucoides. This family of plants is the same as the *Fucaciæ* of our time, which are marine plants found in great abundance in the peat-bogs of the north.* (*b*) About nineteen species of the Horse-tail family, or *Equisetaceæ*. The species of the same class were at one time very abundant in the ditches of the peat-bogs. The family of the *Characeæ*, a near relative to the former, is most abundantly found in the standing water of the marshes. (*c*) More than one hundred and twenty species of ferns, and nearly seventy species of *lycopodiaceæ*, cryptogamic vascular plants, which might be referred to on account of a likeness in tissue and growth to our cryptogamic cellular plants. Our peat-bogs have also more than seventy species of mosses, five or six species of lycopodiaceæ, and as many species of ferns. (*d*) Eighteen or twenty species of palm-trees, reeds, and phanerogamous monocotyledonous plants; and our peat-bogs are now essentially a compound of such plants, sedges, grasses, and reeds, &c. The trees that are now living on our peat-bogs—viz. the pines, the birches, &c.—probably take the place of the large series of palm and fern-trees of the marshes of the Old World. And as is the case in the coal-beds, where no well-characterised remains of dycotyledonous plants are found, so in the peat it is impossible to find any trace of the few dycotyledonous plants living on the marshes, except perhaps some trunks of trees."

The above was written ten years ago; since then the palæontology of the plants has made very great progress, and a great many new species have been discovered. Nevertheless, this analogy in the vegetation of both formations, viz. the coal and the peat, has become more and more evident. It is a peculiar flora, evidently adapted to a peculiar purpose, which in its study ought to be looked at in its entireness, and without any relation to the vegetation of any other part of the country.

Such being the case, our task of comparison between both the coal-floras of Europe and America becomes an easy one, and we shall easily show what is the value of the conclusion of a celebrated English geologist: "Whereas, it appears that of all the fossil plants which have hitherto been procured from the carboniferous deposits of these regions (British America), a great majority are undistinguishable from British species, it is well known that the recent vegetation of Pennsylvania, Maryland, and Ohio, is altogether of a different type from that of Europe." †

In the peat-bogs of North America, ordinarily named cedar swamps, there are first about twenty species of mosses of which the growth directly contributes to the formation of the peat. They are—

1. *Sphagnum cymbifolium*, Ehrh.; 2. *S. squarrosum*, W. and M.; 3. *S. recurvum*, Beaur.; 4. *S. acutifolium*, Ehrh.; 5. *S. cuspidatum*, Ehrh.; 6. *S. compactum*, Bred.; 7. *S. contortum*, Schultz; 8. *Dicranum Schraderi*, W. and M.; 9. *D. palustre*, Br. and Schp.; 10. *Meesia longiseta*, Hedw.; 11. *M. tristicha*, Br. and Schp.; * *Aulacomnium palustre*, Hedw.; 12. *Hypnum trifarium*, W. and M.; 13. *H. stramineum*, Dicks; **H. niteus*, Hedw.; 14. *H. curdifolium*, Hedw.; 15. *H. stellatum*, S.; 16. *H. fluitans*, S.; 17. *H. aduncum*, S.; 18. *H. scorpioides*, S.; 19. *H. paludosum*, Fult.

Of these species the last one only is peculiar as an American plant, all the others, without exception, have the same plan, the same destination, and are found in the same abundance in the peat-bogs of Europe. There are many other species of mosses which are growing only on the peat, but which do not claim a large share in the combustible matter, viz.:—

1. *Splachnum ampullaceum*, S.; 2. *Polytrichum gracile*, Meux; 3. *Dicranum cerviculatum*, Hedw.; 4. *Hypnum cuspidatum*, S.; 5. *H. phatense*, Koch; 6. *H. filicinum*, S.

All species found also on both continents in the same places.

* Since writing this opinion, we have had an opportunity of exploring the peat-bogs of the north of Europe, in Sweden, Denmark, and Holland, and have not been able to find any trace of a true bed of peat formed by marine plants or fucus. And since that time, also, both the explorations of other authors and our own have clearly proved that there is not any true *fucoid* plant in the coal, and that all the impressions which were supposed to belong to such marine plants represent either the roots of some vegetable, or some new species far removed from the fucoides.

† Mr Banbury.

Coming to the ferns in ascending the grades of the vegetable kingdom, we find in the marshes of America—

1. *Woodwardia Virginica*, Willd.; * 2. *Dryopteris thelypteris*, Adam; 3. *D. Noreboracensis*, Adam; * 4. *D. cristata*, Adam; 5. *Osmunda spectabilis*, Willd.; 6. *O. Claytoniana*, S.; 7. *O. Cinnamomea*, S.; * 8. *Ophioglossum vulgatum*, S.; * 9. *Lycopodium inundatum*, S.; *10. *L. clavatum*, S.

Seven of these species could scarcely be distinguished from their European relatives, if they were found in a fossil state, so great is their likeness, and five of them are entirely identical with these.*

The sedges and grasses are distributed also in the same proportion. We will enumerate only the American species, with a mark * for those which are found on both continents.

1. *Narthecium Americanum*, Re.—scarcely distinguishable from the European *N. ossifraga*, Lamark; * 2. *Juncus effusus*, L.; * 3. *J. maritimus*, L.; * 4. *J. acuminatus*, Michx.; 5. *J. molitaris*, Bigel.; * 6. *J. stygius*, L.; * 7. *J. bufonius*, L.; 8. *Xiris bulbosa*, Kunth.—a truly American species, without analogues in Europe; * 9. *Eleocharis palustris*, R. Brown; * 11. *Scirpus cæspitosus*, L.; * 12. *S. pungens*, Vahl.; 13. *S. Torreyi*, Oln.—scarcely distinguishable from *S. mucronatus* of Europe; *14. *S. lacustris*, L.; *15. *Eriophorum alpinum*, L.; *16. *E. vaginatum*, L.; * 17. *E. gracile*, Koch; *18. *Rhynchospora alba*, Vahl.; 19. *R. capillacea*, Torr.; 20. *Cladium mariscoides*, Torr.—very near *C. mariscus* of Europe; * 21. *Carex dioica*, L.; * 22. *C. pauciflora*, Ligth.; 23. *C. polytrichoides*, Muhl.; * 24. *C. teretiusculo*, Good.; * 25. *C. paniculata*, L.; * 26. *C. chordorhiza*, Ehrh.; * 27. *C. gracilis*, Ehrh.; 28. *C. trisperma*, Der.; * 29. *C. stellulata*, Good.; * 30. *C. limosa*, S., and its variety, *C. irrigua*, Smith; * 31. *C. Buxbaumi*, Wahl.; * 32. *C. filiformis*, L.; 33. *C. lanuginosa*, Michx., scarcely distinguishable from the former; 34. *C. folliculata*, L.; 35. *Leersia oryxoides*, Swarth; 36. *L. Virginica*, Willd.; 37. *Glyceria Canadensis*, Trin.; 38. *G. nervata*, Trin.; * 39. *G. aquatica*, Smith; * 40. *G. fluitans*, R. Brown; * 41. *Pragmites communis*, Trin.

To the flora we would have to add the *Typhaceæ*, **Typha latifolia* and **T. angustifolia*, some *Sparganium* (burr reeds) and *Potamogeton* (pond weed), species identical to both continents; and for the trees: **Abies alba*, Michx.; **Larix Americana*, Michx., so near *L. Europea* that it only differs by slender and shorter leaves; *Taxodium distichum* growing in the southern swamps; and a few willows and other dycotyledonous plants, of which the remains are not preserved, or at least never recognisable, as the *Utricularia*, of which the species are also identical in Europe and in America; *Nymphæa adorata*, Act., very like *Nymphæa alba* of Europe; **Nuphar lutea*, Smith; *Sarracenia purpurea*, S., truly American; * *Viola palustris*, S.; **Drosere rotundifolia*, S.; **D. longifolia*, S.; **Parnassia palustres*, S.; *Janguisorba Canadensis*, S.; **Comarum palustre*, S.; * *Vaccinium oxicoccos*, S.; *V. macrocarpon*, Act., distinguishable from the former only by the fruit; **Chiogenes hispidula*, Torr. Sq.; **Andromeda polifolia*, S.; * *Veronica sartellata*, S.; **Scutellaria galericulata*, S.; **Calla palustris*, S.; **Scheuchyeria palustris*, S. There is only a very great difference in the family of the Orchideæ, of which the American peat-bogs have a few very beautiful species entirely different from the European. But this family is the most polymorphous in its distribution, and cannot by itself be taken for a general comparison of a flora. The trees also have some more species which cannot be compared; but a great many of them, the birches and the alders, are nearly alike. How, then, is it possible to assert that two floras of about 100 species, which have more than seventy entirely identical forms, and ten or fifteen more very nearly alike, are *altogether of a different type?* We must necessarily adopt a contrary conclusion. The type of the flora of the peat-bogs is everywhere the same; and if we had time to pursue our comparison, we would prove it easily, as well from our explorations in the great bogs of Southern Virginia, as from the observations of travellers in the Australian hemisphere.

The same identity of type is altogether evident in both the Palæozoic floras of America and of Europe. We remark in them the same analogy and the same difference,—a great many species entirely identical, many so related that their differences are pointed out only with great difficulty, and a few entirely different. This will evidently appear in the examination of our described species; and we are necessarily led to conclude—

1. That at the time of the coal-formation the floras of both continents had the same analogy and the same difference that they have now.
2. That both continents were, as they are now, separated and distinct.
3. That both were *respectively* under the same atmospherical influences.
4. That nothing can authorise us to admit these atmospherical influences as very different from what they are now.

This last assertion, so far different from the conclusions of other celebrated geologists, necessarily needs some explanations.

It has been long asserted, as we have already said, that the peat-bog formation belongs particularly to cold climates, and that the preservation of the woody matter is essentially due to low temperature. Our researches in Europe on this subject have already proved that this is not the case, and that the area of the peat-bogs occupies exactly the same latitudes as that of the oldest coal-formations.† And since we have been enabled to pursue the same exploration in America, we have found on this continent exactly the same distribution. For in this country the peat-bogs are found from far above the northern shores of Lake Superior, as high as 60° of latitude, to the great Dismal Swamp in South Virginia 35°,—exactly in the same latitudes as are occupied by the great coal-

* Moreover, the species of the ferns and Sycopodes of America have in general the greatest likeness to those of Europe.

† Vide *Recherches sur les Marais tourbeux en général.*

basins of America. We have made on this subject very long researches, and we have never obtained specimens of a true coal in the Northern hemisphere from Southern latitudes. The beds of coal mentioned in Texas and the coal of Brazil, are only beds of lignite; a formation entirely different from that of the coal, independent of any peculiar formation, and so without any geological interest.

But those immense trunks of trees, perhaps of fern trees, to which we find an affinity only in the tropical regions, how is it possible to account for their vegetation in our latitude, if we do not admit of a great change of temperature? 1. In the peat-bogs of Northern countries, of Denmark, Sweden, and also in Switzerland, we find sometimes, heaped in very thick strata, much larger trunks of trees than those which have been found in the coal. The following is a description given, in 1846, of a peat-bog which we visited near Waldsmarslund, 30 miles above Copenhagen:*—"These deposits of wood are a true forest heaped upon another, and buried in the peat, which in these marshes (of Denmark) are found everywhere with alternating beds of the same species of trees. At the bottom, upon a bed of peat from 4 to 6 feet thick, are *pine-trees*, lying flat, nearly always in the same direction as the inclination of the basin, viz. the roots against the borders. These pine-trees are ordinarily from 6 to 10 inches in diameter; they have their slightest branches preserved, and are imbedded in a mass of their own leaves, cones, mushrooms, &c., of which the form is not at all altered. Upon these pines is a bed of black peat from 5 to 6 feet thick, overlaid by a forest of prostrated white birches. Upon the birches there is again 6 feet of less-decomposed peat, covered with enormous trunks of oaks, which have no less than 3 feet of diameter, and of which the wood is so well preserved that it is sawed on the place, and used for building-material. The matter or peat in which these trees are buried does not preserve any trace of the leaves of these oaks, but only some acorns. It is evident, nevertheless, that they have grown on the place where they are found, being preserved in their integrity with their smallest branches and their bark. These trees are covered by from 6 to 8 feet of peat, in which, or upon which, is found sometimes a fourth forest of trees, and this time, of beech-trees, the same trees that now form the forest around.† The size of the trunks buried in the peat-bogs is, as is easily seen from the above description, in favour of our present formations. In the Dismal Swamp in Virginia, we have seen in the peat trunks of Magnolia measuring more than 100 feet, without great diminution in their diameter. 2. The trees of the coal, which, like Lepidodendron, Sigillaria, and Stigmaria, are ordinarily ascribed to a genus of plants like the ferns, and so to fern-trees, were not true ferns, but a peculiar species of plants, of which we have no living representatives, and of which the nearest relatives are the Lycopodiaceæ, a genus of plants of which the largest species known are living in the peat-bogs and the forests of our Northern hemisphere. The true fern-trees (Caulopteris) are very scarce in the coal; their diameter does not appear to be large; and if this class of vegetables does truly belong now to the tropical regions, it is well to remember that they are especially found in a very wet atmosphere, either on the small islands or on the highest mountains of Java, either on large marshes or on the borders of shallow and muddy lakes, where the temperature is certainly not the cause of their presence. 3. It is generally known how great is the influence of the dryness of the atmosphere on its temperature. We have only to compare the climate of the evergreen Ireland with that of the central part of Europe under the same latitude, to ascertain what difference this atmospheric agent makes on the vegetation. The best proof we could afford of it is the presence of large trunks of oak-trees at the bottom of the peat-bogs of Switzerland, in valleys many hundred feet above the oak region, and consequently where now there are only some forests of pines. Since the clearing of these valleys, and the draining of the land, the climate has perhaps not become colder, generally speaking, but the extremities of temperature are more distant; colder in the winter, with a stronger heat in the summer. Every one knows, that it is precisely the degree of this difference which regulates the vegetation of a country."

It is, then, sufficient to give us the reason of the difference in the type of vegetation between the coal period and our own, to admit that the continents were less extended, and only low islands entirely covered with marshes.

But all the physical phenomena of our time were then in activity. We find upon the red shales of the Umbral series the evident marks of drops of rain and of hail; the cracks also caused by dryness under the action of the sun upon the mud. We have in the small horizontal layers of the coal, of which the thickness scarcely attains the twelfth part of an inch, the proof of an annual decay, and of an annual heaping of the plants exactly as we find it in the peat. What more is wanted to authorise the conclusion, that our world has not changed its course since the formation of the coal—that the hypotheses of a displacement of the axis of the earth, of great and sudden commotion, of extraordinary temperature, of nebulous atmosphere, and the like, have not any basis on known facts? Our human race is young, but the world lived long before it, and has not changed its revolutions expressly for our purpose. Truly nature has prepared our home. It has heaped, for the future welfare of our race, those inexhaustible beds of combustibles that afford us so much comfort; but it has done this without any miracle, without any of those sudden transitions which we are so prone to discover for the satisfaction of our own pride.

As it is, nevertheless, this coal-formation is an admirable one; and we can look to it only with wonder and with faith to an overruling and provident Director. For this heaping of combustible matter was by itself nothing

* Vide *Explorations dans le Nord de l'Europe, pour l'étude des Dépôts de Combustibles mineraux.* LEO LESQUEREUX; Neuchatel, 1846; p. 68.

† It is well to remember that in Europe the forests have not so many species of trees as in America, and are ordinarily composed of a single species, or seldom of two or three.

but a useless proceeding. The bed to put it in was to be prepared, a long time in advance, by a thick layer of clay, to prevent the egress and the dispersion of the bitumen after its separation from the woody matter. It required also an impermeable covering to prevent too strong an action of the oxygen, and the mingling of sand and other strange matters, which would have entirely changed its combustible property. This, as well as the formation of iron, which is also ordinarily in progress with the formation of the peat-bogs, has been obtained by the simplest laws and the slow progress of nature. The places where these formations were progressing have been subjected to some slow and periodical upheavals and depressions, which are remarked even at our time on the sea-shores of some countries—of Holland and of Sweden. By these slow depressions, the water, saturated with iron, has first covered the beds of combustible matter, and deposited these particles for the formation of the shales; a greater depression has given access to a strong current of water, which has heaped the sand upon the shales, and so, by a repetition of the movement, the woody matter has been formed, then enclosed, then heaped in different beds one upon another; preserved from decomposition, or from the influence of the atmosphere; transformed into coal by the slow disengagement of the gas, and the high temperature of the earth.*

To close the few observations that we are entitled to make here, it is necessary to give an explanation of some local phenomena, of which the causes are still in discussion.

The appearance of the trunks preserved in the coal-shales and in the sandstone is very different. In the sandstone the trees have left an impression of their whole external surface in its primitive form; but they have not left anything else except this impression, and the whole primitive substance has been destroyed, or transformed either into silex or into limestone. In the shales, on the contrary, and immediately above the coal, the woody matter of the trees is preserved, transformed into coal; but the primitive form is entirely changed, the trees having been flattened, and having left only the impression of this flattened surface, as if the bark alone had been preserved and pressed together. We have seen that the wood exposed to the action of the oxygen of the air is slowly but entirely rotted and destroyed. The air, having access through the particles of sand, produces by-and-by this result on all the wood buried in it. Nevertheless the sand around the wood is by-and-by hardened, and the stony substances — either sand, or carbonate of lime, or silex — penetrate all the destroyed part of the wood in such a manner, that, following the circumstance, the vegetable is mouldered into some of these substances. At Carbondale and Greensburg the trees in the sandstone are transformed into sandstone, and their tissues entirely destroyed. At Gallipolis and Athens they are silicified or transformed into limestone, and the silex only has preserved the form of the vessels of the wood. We cannot give any explanation of the petrification of organic substances; it is still an unexplained mystery. Who could tell how it happens that, in the same bed of sandstone, and exactly in contact with each other, we find, as at Gallipolis, two trees, one of which is transformed into limestone, the other crystallised, or entirely silicified? We have seen also that when the action of the oxygen of the atmosphere is nearly prevented, the woody matter is slowly burned into coal. This proceeding does not come to its end without a great many changes. One of these modifications is the transformation of the woody matter into a soft black mud, most easily flattened by the compression of the superior strata. Sometimes, when water is abundant, this black mud becomes nearly fluid; and as the bark of the trees is preserved by its *tannin*, it is not only flattened, but folded into a very thin space. We have seen some beautiful illustrations of these changes in Germany and Denmark. Near Leipsic there is a bed of lignite, formed of large trunks heaped about 15 feet thick. The matter is entirely soft, and all the trunks flattened, measuring in one direction scarcely half the diameter that they have crosswise. It is also entirely black, and yields an excellent fuel. It is extracted with shovels, like the peat, after its surface has been laid bare, from 20 feet of sand and gravel lying upon it. In Denmark, about 20 miles below Copenhagen, near the sea-shore, there is an extensive plain covered with the finest grass, and affording excellent pasture to large herds of cattle. By digging there they find, under 1 foot of humus, a bed of *peat* (?), entirely composed of bark of birches. This bark is heaped 6 feet thick, and closely packed and flattened. It is first dug or cut out, and dried in long rollers, entirely void of earthy matter. The woody matter, nearly fluid, or transformed into a very soft yellow mud, is at the bottom of these beds, and is then taken out of the excavations with buckets, then put on layers of straw, through which the water percolates; and when thickened, it is beaten hard, dried, and burnt like coal.

It happens sometimes, as we have seen at Carbondale, that standing petrified trees are found in the sandstone of the Coal-measures. This accident is easily accounted for, as soon as we admit it only in the sandstone or in the shales of the coal. For if the sand carried by water has been quickly deposited in great thickness, all the trees growing on the marshes have been imbedded in it, and preserved in a standing position. But when this occurrence is reported, of trees having *their roots below a bed of coal, crossing the coal, and penetrating the sandstone above*, we can but pronounce this fact an impossibility, for it is against the laws of nature. It requires very little acquaintance with botanical physiology to understand that trees can never grow when their roots are covered with standing water, or with a stratum of matter impenetrable to the atmosphere. Hence it happens that all the trees—pines, firs, cedars, willows, &c.—living on a marsh, or on a cedar swamp, have their roots horizontally expanded, and as near the surface as possible. Hence also the necessity for the coal trees being supported by such creeping roots as the *Stigmariæ*. When a tree is covered by a bed of decayed woody matter and by water, it soon dies, and rots immediately above the water, where the humidity and the oxygen of the atmosphere have free access. From this cause, all the trees decaying or dead on the peat-bogs are very soon prostrated.

* Liebig has given the history of the chemical process of the formation of coal in his *Chemical Physiology*.

It is also, we think, a very false idea of the growth of the vegetable matter of the coal-beds, to believe that a tree, even in the most favourable conditions, could stand as long a time as it was needed for the formation of even a thin bed of coal. It is not a century, but thousands of years, that have been required to heap a bed of coal of a few feet of thickness. In the bituminous coal of Ohio the annual growth of the coal is well marked by the thin layers, which are about 1-12th of an inch in thickness: so, such beds of coal as the Pittsburg Seam would have required for their formation a period of time of about 1500 years.

A peculiar phenomenon has been observed in England, and may also attract the observation of the naturalists of America. Sometimes, in the internal part of the petrified trees of the Coal-measures, one finds an abundance of fruits and leaves of the same species—viz. *Lepidostrobi*—in the trunks of *Lepidodendra*. We have had a striking explanation of this in our last visit to the Dismal Swamp, on the shores of Drummond Lake. We went there to compare the formation of the peat in its Southern latitude, and found it entirely identical with the same formation in the cedar swamps of the North. The only difference consists in other species of sphagna, and other species of trees, and in the undergrowth of canes, which form there an impenetrable thicket. In the middle of this marsh there has been a depression filled with water, and which has formed Drummond Lake. Its depth is about 15 feet only, and its bottom is covered with prostrated trees—a fact that proves that it has been formed by depression of a surface primitively extending over a sheet of water, and covering it. This formation is of very frequent occurrence in the North of Europe and of America. Around the lake grows the bald cypress (*Taxodium distichum*), and sometimes the trees are half-covered with water, and decaying in such a manner that their standing trunks are entirely hollow. The fruits and leaves of the trees around, falling into the water of the lake, and drifted here and there, are arrested by the hollows of these trees, and fill them almost entirely. If these trees were imbedded in sand, and by-and-by petrified, they would exhibit exactly a repetition of the phenomenon alluded to, of fruits and leaves found in the trunks of their own trees. There are many other similar phenomena of the Coal-measures, which would find an easy explanation from detailed description of the formation of our actual peat-bogs. But we have already exceeded the limits assigned to us in this paper, and shall refer for further details to the books mentioned above.*

Leo Lesquereux.

DESCRIPTION OF THE FOSSIL PLANTS FOUND IN THE ANTHRACITIC AND BITUMINOUS COAL-MEASURES OF PENNSYLVANIA.

BY LEO LESQUEREUX.

Among the plants here described, only a very small number have been found beyond the limits of Pennsylvania. They are mentioned for the peculiar interest they present, either in their form, or in their geological position. The greater number of these fossils were collected by ourselves. A few of them, nevertheless, were studied in the rich and beautiful cabinets of Mr Clarkson at Carbondale, and the Rev. W. Moore of Greensburg. Both these gentlemen gave us, with the greatest kindness, the liberty of copying and describing all the new plants in their possession. With great pleasure we take this opportunity of returning them our thanks. Though there is much to say upon the classification of fossil plants, we are not at liberty, in such a work as this, to enter into long scientific discussions upon the value of the genera as they are now established. We have followed the classification adopted by the best European authors, especially by Brongniart. Nevertheless, as no general description of these fossil plants of America has appeared till now, and as many of our naturalists may look to this enumeration for a direction of their researches, we have thought it necessary to append some general remarks as often as our views do not correspond with the opinions of the high authorities mentioned.

First Class.—*Fungineæ.*

Except *Polyporites Bowmanni*, Lindl., no discernible trace of any kind of mushroom has been found in the coal. Very often the stems of the ferns are covered with elevated points of different size, which closely resemble the small *Thyponileæ* of our time, especially the *Spheriæ*. But it is not possible to ascertain if such marks left on the stems have anything organic in their nature, or are only accidental. That they are very often produced by accident, is proved by their presence on different plants, and on different parts of the vegetables—even on some slates, where there is not any trace of vegetable impressions. The points are especially observable in the coal-basin of Trevorton, where coal-slates—even the slates which do not appear to have contained any bituminous matter—are full of *vesicles*, from the size of a needle's head to the size of a pea. They are filled with a brown powder, which to the naked eye has exactly the same appearance as the spores of the *Spheriæ*, but which, when looked at with a strong microscope, does not present any trace of organisation. It is only a very inflammable bituminous matter. The appearance of those small cells may show the operation of transformation of coal to anthracite. In the half-anthracite coal, the ebullition did not proceed far enough to accomplish the ejection of the gas. A great part of the vesicles were only formed, but did not burst before the cooling of the matter; hence, perhaps, these cells.

As for *Polyporites Bowmanni*, we have found it exactly as described by Lindley, and cannot but admit it to

* Though I do not assent to some of the theoretical views maintained in this ingenious Essay, nor accept some of the statements, as that the Palæozoic coal-formation does not extend beyond the latitudes embracing the existing peat-bogs, I must thank the author for the amount of accurate and curious information which it contains. H. D. Rogers.

be a true fungus. It is easily discernible by its concentric zones or lines, and its surface thickly perforated with small points. It is, however, very different from *Carpolithes umbonatus*, Sternb., to which M. Brongniart has compared it.

Second Class.—*Algæ.*

After a careful examination of all the specimens reported to belong to this class of plants, we do not find a single sea-weed in the Coal-measures of Pennsylvania. Many species of *Algæ* are found below the coal, especially, in the Clinton group, where they are accompanied by marine shells—*Brachiopodes*, *Crinoides*, and some *Acephales*—but in higher formations they by-and-by disappear altogether, and all the so-called *Fucoides* of the Ponent and of the Vespertine formations are either roots or stems of other plants. Certainly many of these roots closely resemble those of *Fucoides*. The branches are short, obtuse, very numerous, without order, either simple or branching again, without any perceptible diminution in their thickness, from one end to the other. But we find exactly the same appearance at present in many roots dipping in water, where they extend and branch in every direction, in shape sometimes like a thick bunch of twine. The best proof of our opinion being right is, that we have found many of the so-called *Fucoides* attached to the stem. We have made drawings of the most interesting of them (see *Pinnularia*, Plate XVII.), only to show how carefully we have to proceed in the study of these fossil remains.

The same may be said about some thread-like, hard, shining vegetable remains found in great abundance on the slates of the coal around Pottsville, and mentioned also as occurring in the coal-basins of England and France. They were supposed to belong to the *Conferves*, or fresh-water *Fucoides;* but besides their tubular form, there is nothing to sustain this supposition. They vary in thickness from a hair's-breadth to one sixteenth of an inch in diameter, and appear ordinarily piled one upon another, without any general order. As they are never flattened, and do not present any trace of articulation or of ramification, it is not possible to compare them with the *Conferves*, these being very weak and brittle plants, of which there could not exist any trace in the vicinity of the coal where the materials were for a long time exposed to decomposition. They are found sometimes even in the coal itself. They are without doubt the true roots or fibrous appendages attached either to the subterraneous or creeping stems of the ferns, and generally named Rootstocks. Their description belongs to the genus *Pinnularia* (which see). *Fucoides dentatus* and *Fucoides serra* (Brongt., *Hist. des Veg. Foss.*, p. 70, t. 6, fig. 9), found in the older Palæozoic limestone of Canada, evidently belong to the genus *Graptolites*, and so are out of the vegetable kingdom. We have found a single specimen of these fossils in the greenish sandstone of the *Ponent* rocks near Trevorton. But they have been found in great abundance in the State of New York, and have been closely described by Professor Hall in his Geological Report.

The only true *Fucoides* that we have to describe belong to the following genus:—

I. Chondrites, Sternb.—Frond cartilaginous, thread-form, dichotomous; branches cylindrical, but flattened in the impressions.

1. *Chondrites antiquus*, Sternb.; *Buthotrephis? flexuosa*, Hall (*Paleont. of New York*).—Frond bipinnately forking; branches and branchlets diverging, inflated at the forks, branchlets linear, obtuse. Very abundant in the Surgent group at Bloomsburg, and at the base of the Alleghany Mountain, below Portage Summit.

2. *Chondrites Fargionis*, Sternb., Vers. II., p. 25.—Frond bipinnately branching; branches elongated, linear, obtuse, entire or scarcely branching. Var. *α*, *fastigiatus;* frond straight, erect, irregularly pinnately divided; branches linear, simple, or branching. Var. *β*, *divaricatus;* frond irregularly pinnate; branches diverging, unequal. Var. *γ*, *confertus;* frond erect, densely pinnately branching; branches filiform, unequal.—Brongt., *Hist. des Veg. Foss.*, i. p. 56. Same locality as the first.

This plant, as described by Sternberg and Brongniart, was found at different places in the cretaceous formations of Europe. Such a difference in the stations would lead us to suppose that our American plant is a different one. Nevertheless, as we find not only the typical form, but also the varieties as they are figured and described, we are not at liberty to change the name, and to admit it as a new plant. We have figured our specimens to give opportunity for a close comparison (Plate XVII., figs. 13, 14, 15, 16, 17).

II. Fucoides, Harlan.—We cannot point out any characteristic marks to describe this genus. It has been preserved for the classification of some organic remains of which the indefinite forms do not clearly indicate an affinity with any known genus of sea-weeds. The two American species generally admitted in this genus have more the general appearance of some corals than that of *Fucoides*. We had an opportunity of studying them in great number, and in as good a state of preservation as it is possible to find them. They are very numerous in the sandstone of the Levant white sandstone series of the Juniata River, below Lewistown and above Huntingdon, where they cover some rocks of very large size. Ordinarily palmately branching, their branches, 1 to 3 inches in thickness, are transversely undulated, cylindrical, or nearly square, and incurved on one side like a half-closed hand. As their substance is completely transformed into coarse sandstone, their form is generally obscure, and it is not possible to ascertain their true nature.

Though we do not admit these *Fucoides* as vegetable remains, we give the description of the two species as indicated by Harlan.

1. *Fucoides Alleghaniensis*, Harl., *Medic. Physic. Res.*, p. 392.—Frond compressed, wrinkled, recurved, obtuse; branches unequal, digitate or fastigiate, without nerves, canaliculate in the middle.

2. *F. Brongniarti*, Harl.—Frond large; branches nearly square, wrinkled across, compressed, and recurved. Probably this species is only a variety of the first.

THIRD CLASS.—*Muscites*.

In the introduction to this memoir, we mentioned our views about the distribution of the plants of this class, their mode of growing, and their participation in the present formation of the mineral combustibles. We can neither describe nor indicate a single species of moss found in the coal; but nevertheless we think that those plants were living with the ferns at the time of the coal-formation, and that we have found specimens belonging to the genus *Sphagnum*. They are in thin, yellow, very light slates, from the roof of the Gate Vein at Pottsville, looking exactly like pasteboard, entirely covered with faintly discernible, very small impressions, and crossed in every direction by flattened thread-like stems. The peat formed by the decomposition of the *Sphagnum* presents exactly the same appearance.

FOURTH CLASS.—*Calamariæ*.

The plants of this class, though found in great abundance in the Coal-measures, present a great difficulty in their examination; not only because they are always found in broken fragments, but because these fragments have never hitherto been found in such a state of preservation that their internal structure can be closely observed. These fragments also, though often belonging to the same species, present the greatest difference in their forms. We shall unite in this class, as M. Unger did, the *Calamites*, *Equisetites*, *Wolkmannia*, *Asterophyllites*, *Sphenophyllum*, and *Annularia*, without being certain, either that this place is the true one to which they belong, or that all the genera above mentioned belong to the same class.

That the *Asterophyllites*, as Messrs Lindley and Hutton supposed, are the branches of some species of *Calamites*, appears without a doubt. The external form, the leaves, the mode of branching, and the fructification, are perfectly visible in the small branches (*vide* Plate I., fig. 1, 1*a*, 2, 3), and may be sometimes followed in larger specimens. But these plants did not bear leaves, fruit, and branches, except when they began unfolding, or at their summits. Branches and leaves falling easily, the stumps were left entirely naked except at their summits, and, growing up, they enlarged themselves with the scars of the branches, and of the fruit, as is the case in indigenous plants. They may be compared in their mode of growing to some kinds of canes or bamboo. They were probably annual stems, with a very rapid growth; they became very high—from 30 to 60 feet—but not very broad, from 3 to 6 inches in diameter—and could consequently stand very near each other, and give, by their annual decay, a very large amount of material for the coal.

We have said that their place in the series of plants is undetermined. By their external form, they are evidently near the *Equisetaceæ;* but the fructification would indicate, as M. Brongniart has thought, that they belong to some kind of conifers related to the genus *Tanus* or Yew. As is apparent in our figure (Plate I., figs. 1, 2, 4), these plants were either diæcious or monæcious. The male flowers were terminal, and composed of an ear of appressed scales or united leaves, enclosing or supporting above them, small round cells, containing a pulverulent matter, probably the pollen (Brongniart, *Tableau*, p. 49). The true fruits—small, round, or obovate capsules—were born around the stems on the axils of the leaves, as indicated (Plate I., figs. 1, 2), and, by falling off, they left the scars ordinarily apparent around the stems of the calamites on the articulations—an organisation which is truly like that of some conifers.

Annularia and *Sphenophyllum* certainly belong to plants of quite another mode of growth. By the disposition of their leaves, which are always seen on a horizontal plane, they appear to have lived either on the water or on the mud, like our *Ayolla Caroliniana*, or more like the *Callitriche*, branching from the axil of the leaves, and extending in every direction. They have been compared to a phanogamous plant, the *Gallium*, but without any reason at all. The fructification of the *Sphenophyllum* much resembles that of the Asterophyllites, the ears only being smaller. It has been examined and described by M. Gutbier; but it is questionable if the ears represent the true fruit, or only the male flowers of these plants. The fructification of the *Annularia* has never been observed, but we think that it is attached under and around the leaves, as in the ferns. In the specimen represented, Plate I., fig. 5, the leaves are emarginate, slightly revolute on the margins, and perhaps this form is the fertile frond; the sterile one, with flat and pointed leaves, being figured in Fig. 5, a.

Many authors have supposed that *Asterophyllites* were the same plants as *Sphenophyllum*, floating partly immersed in water, becoming *Sphenophyllum* and enlarging the leaves when coming out of the liquid element. We cannot admit this opinion; but nevertheless we believe that *Sphenophyllum*, like all the plants which are living in water, have had different modifications of their leaves, without losing their general appearance. Our *Sphenophyllum trifoliatum*, Plate I., Fig. 7, is probably one of those abnormal forms which approach to an *Asterophyllites*.

I.—*Calamites*, Sûck.

Stems cylindrical, furrowed lengthwise, articulated, furrows either alternating or converging at the articulations; leaves encircling the stem like an open sheath; ramification either regular or irregular from the articulation scars of tubercles? marked above or below the point of attachment of the leaves.

1. *Calamites decoratus*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 123, t. 14, Fig. 1-5.—Stem cylindrical; articu-

lations distant above (1 to 2 inches); approached below; ribs convex and thick; tubercles globose. South Salem coal, Pottsville.

2. *Calamites Suckovii*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 124, t. 15, Figs. 1–6.—Stem cylindrical, thick; articulations variable in length; ribs one-eighth of an inch broad, either convex, obtuse, or reeled; tubercles small ovate. Of this species we have two varieties: Var. A has the articulations distant, and the tubercles round. It is very abundant around Carbondale, where it forms a true forest of standing Calamites; the diameter of the stumps varies from 3 to 4 inches. Var. B has the ribs nearly plane, and the tubercles placed below and above the articulations. We found one specimen at the Gate Vein of Pottsville.

3. *Calamites ramosus*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 127, t. 17, Figs. 5, 6.—Stems cylindrical, with distant articulations, bearing a half-spherical tumour at the base of solitary branches, with a hemispherical cavity on the articulation; ribs plane, one-eighth of an inch broad. Gate Vein at Pottsville in coal-slate.

4. *Calamites cruciatus*, Sternb., *Vers.* 1-4, p. 27, tab. 49, Fig. 5.—Stem cylindrical, with the articulations at the same distance, and a little convex; ribs plane and narrow; scars of branches on the articulations, either alone or verticulate; hemispherical, concave. Same locality as above.

5. *Calamites undulatus*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 127, t. 17, Fig. 1.—Stem cylindrical, with distant articulations and plain flexuous broad ribs alternating in the articulations. A single specimen was found at the South Salem Vein, near Pottsville, in the coal-slate.

6. *Calamites Cistii*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 129, t. 20.—Stem thick, cylindrical, with articulations at the same distance; furrows very narrow; ribs half-round; tubercles globose. This species has been found at Wilkesbarre, and has been described by Brongniart, from a specimen sent to him; but we did not see this species anywhere, and all the specimens that we have seen around Wilkesbarre and Carbondale belong to *Calamites Suckovii.*

7. *Calamites dubius*—*Artis Antedil. Phitol.*, Fig. 13.—Stem cylindrical, with distant articulations; ribs parallel, about 1 line broad; furrows bistriate; tubercles ovate.

We refer to this species our No. 405 from Gate Vein, Pottsville, because of the bistriate furrows; but though our specimen is more than half a foot long, it has not any visible articulation. Perhaps it may belong to *Calamites remotissimus*, an undescribed species of Göppert.

8. *Calamites Cannæformis*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 131, tab. 21, Fig. 4.—Stem inflated above; upper articulations 2 to 3 inches distant, the lower ones scarcely 1 inch apart; ribs plane, slightly convex, a little flexuous, converging at the articulations.

Specimens of this species are in the collection of Mr Clarkson at Carbondale.

9. *Calamites pachyderma*, Brongt., *Hist. des Veg. Foss.* vol. 1, p. 132, t. 22.—Stem thick, with distant cylindrical articulations; ribs very broad, nearly plane, or slightly convex, unequal; tubercles obsolete.

The specimens referred to this species were found in the Conglomerates below the coal at Trevorton, and are not in as good a state of preservation as is wanted for an accurate determination. They agree at least in the broad nearly flattened ribs; but the articulations are very obsolete. This species is very large. We have seen, imbedded in the conglomerate sandstone, many of them nearly one foot broad.

10. *Calamites bistriatus*, Lesq.—Pl. II., f. 1.—Stems 3 inches broad, cylindrical; articulations equal, about 2 inches distant; ribs broad, nearly plane, narrowly ribbed again, converging at the articulations; tubercles very small and obsolete, inverted on the articulations.

A single specimen of this fine species was found at the Gate Vein, New Philadelphia. It is well marked by its striated ribs. These striæ are visible only on the barked part of the stem, the bark itself being nearly smooth.

11. *Calamites disjunctus*, Lesq.; Pl. II., f. 5.—Stem cylindrical; articulations distant about 2 inches, inflated and separated by a depressed furrow; ribs elevated, half cylindrical, exactly parallel, narrow surface, covered with very small elevated points which look like a powder; tubercles very small, round. This is also a very distinct species; found at the Gate Vein of Pottsville.

12. *Calamites approximatus*, Brongt., *Hist. des Veg. Foss.*, vol. 1. p. 134, t. 24, f. 7, 8.—Stem cylindrical; joints very near each other, slightly marked; ribs convex; tubercles either numerous and globose, or wanting.

This species is common in the coal-fields of Pennsylvania. We have found it at the Gate Vein, Pottsville, and at Tremont, and have seen beautiful and numerous specimens of it in the collection of Mr Clarkson, at Carbondale.

II.—*Equisetites*, Sternb.

Ear terminal and globose, superior sheaths, nearly immersed, and at length free, with pentagonal or concave scales very near each other; stem cylindrical, striated lengthwise, articulated, simple, branching below the articulations, and bearing erect-toothed sheaths, inserted below the articulations.

1. *Equisetites stellifolius*, Unger, *Gen. et Spec.—Pl. Foss.*, p. 60.

Equisetum stellifolium, Harlan.—Stem erect, simple, smooth, cylindrical, 1 to 8 inches in diameter; branches 10 to 12, emerging from the stem at the joints, like the rays of a star; articulations rather distinct near the base, approached above; sheaths indistinct.

We have mentioned this genus and this species only on account of the description of Harlan, which has been copied by the European authors without any criticism. The plant alluded to, and named by Harlan *Equisetum stellifolium*, is merely an Annularia—probably *Annularia fertilis*, Brongt. The error of those who have not had an opportunity to see the specimens is easily accounted for by the indication of the diameter of the stem, and of the mode of branching. What Harlan has named *branches* are the leaves, and his indication of the breadth of the stem, 1-8 *pal.*, which means the eighth part of an inch or a *line*, in French measure, has been translated 1 *to* 8 inches in diameter. Harlan remarks *that the articular sheaths which exist in all the recent species of this genus are barely visible in this fossil specimen; they may possibly have been destroyed by pressure; remnants of the sheaths are, however, visible.* There is not any trace of these sheaths in the fossil, and probably the author has taken some part of the leaves for them. The place where this species is indicated as found, is the Schuylkill anthracite. As we have had an opportunity of exploring carefully the anthracite basin of the Schuylkill, we have found there a great abundance of the *Asterophyllites* and *Annularia*, but never any trace of an Equisetites, and we have no doubt that Dr Harlan was mistaken in his observation. This conclusion is of great importance concerning the geological distribution of fossil plants; for it removes at once the *Equisetaceæ* from the Palæozoic coal, and shows their true place to be much higher in the geological series. *Equisetites mirabilis*, Sternb., is a stem of which nothing can be said, except that the class of plants to which it belongs is unknown.

III. *Asterophyllites*, Brongt.

Stems articulate, branching at the joints; leaves placed around the stems like the rays of a star (verticillate), open at the base, but often incurved above; equal, linear acute, single nerved, free or slightly joined together at the base. Fruit, axillary, monospermous (?) compressed nutlet, either naked or encircled by a narrow wing, which is pointed or acute at the summit. (For the male inflorescence, *vide* above, p. 849)*.——We have put together both the genera *Wolkmannia* and *Asterophyllites*, being unable to point out any peculiar marks to separate them.

1. *Asterophyllites gracilis*, Brongt., *Wolkmannia gracilis*, Sternb., *Vers.* 2, p. 53, Pl. 15, fig. 1–3.—Stem cylindrical, branching, leafy (articulations 2 to 6 lines distant), strongly furrowed in its length. Leaves verticillate, linear, obtuse, half an inch long, open on the stem, but straight, appressed together, short, and crowded near the summit of the branches, which terminate like an ear.——We have not found any specimen of this species in the coal-fields of Pennsylvania; but we have seen a beautiful one from Zanesville, Ohio, in the cabinet of D. Howart at Columbus.

2. *Asterophyllites equisetiformis*, Brongt., *Prod.* 159; *Hyppurites equisetiformis*, Lindl. and Hutt., vol. 2, tab. 192; *Bornia equisetiformis*, Sternb.—Stem a foot high and more, articulate, branching branches opposite, simple, articulated; leaves linear, lanceolate, single nerved; verticillate, inserted on the joints.——This species abounds in the anthracite basins. We have found stems of this plant, one inch thick and more, bearing leaves and branches. There is no difference between the American and the European specimens. Near the summit of the branches the articulations become shorter, and the leaves straight and appressed, and are longer than the space between the joints. In this state it is, we think, *Asterophyllites regida*, Brongt. *Prod.* p. 154.

3. *Asterophyllites foliosa*, Lindl. and Hutt., *Foss. Flor.* 1, t. 25.—Stem slender, striate, articulated, inflated at the joints; branches simple, either opposite or verticillate; leaves 8 to 10 in a whorl, linear, lanceolate, arched, single nerved, shorter than the distance between the joints.——This species is perhaps also a variety of the former; it scarcely differs, except by the leaves being a little broader and less numerous. Found at the Salem Vein at Pottsville, often mixed with the former. On the same slates we have also seen specimens agreeing exactly with *Asterophyllites tenuifolia*, Brongt., *Prod.* 159, and we think that this species belongs also to *Asterophyllites equisetiformis.*

4. *Asterophyllites crassicaulis*, Lesq.; *Annularia Longifolia* (?) Gutb., Pl. I., fig. 1—1*a*.—Stems thick, articulated, deeply striate; leaves verticillate on the joints, linear, lanceolate, acute, single nerved; fruit obcordate, acute, attached to the stems in the axils of the leaves.

We have found only two very small and broken specimens of this plant at the Gate Vein, New Philadelphia. It differs from all the species yet described, not only by its fruit, but by the thickness and the deep furrows of the stem. The fruits, or compressed nutlets, appear to be attached above the joints of the stems: they fill the whole space between the whorls of the leaves; but our specimens being too small and imperfect, we could not see the point of attachment of the fruits.

5. *Asterophyllites ovalis*, Lesq., Plate I., fig. 2. Differs from the former by its slender stem and slender furrows, the more numerous leaves, and the oval nutlets. Our small specimen is from the same locality as the former.

6. *Asterophyllites sublævis*, Lesq., Plate I., fig 3.—Stem thick, nearly smooth, or slightly undulate below and above the inflated joints, branching at the articulations. Leaves verticillate, half open, shorter than the distance between the joints; branches short, and thick with very short leaves.

The difference in the length of the leaves in this species may show how easily one may be misled in the determination of the species, in plants of which we have only the leaves to rely on as specific and distinctive marks. Taken alone, the branches with their short leaves would agree with *Asterophyllites delicatula*, Brongt., except for the thickness of the stems. The root (Plate I., fig. 9), which is on the same slate, appears to be the root of this Asterophyllites, and is very remarkable for its cuticle. The epidermis is covered with small undulate furrows, crossing each other nearly at right angles, and having the same appearance as the vessels in the internal

* M. Unger, who has not observed the fruits attached to the stem, says that they are encircled by an *emarginate* wing. He has seen them upturned. They are ordinarily pointed above, obcordate or emarginated below, and often bearing a short stem, in which case they belong to *Carpolithes bicuspidatus* of Sternb.

structure of the wood of some coniferæ (Plate I., fig. 9, *a*). Sometimes the epidermis is found detached from the root, and an irregular surface remains; and in this case the resemblance to the vessels of wood is such that it may easily mislead the observer.

7. *Asterophyllites tuberculata*, Brongt., *Prod.*, 159; Lindley and Hutt., *Foss. Flora*, 1, t. 14, p. 45; 2, t. 180, p. 82; *Huttonia carinata* (?), Gutb.—Stem striate, distance between the joints very short; leaves short, obtuse, united together nearly to the summit, forming a thick ear, and enclosing small cells containing the pollen (?). Gate Vein of New Philadelphia, where it is abundant.

8. *Asterophyllites lanceolata*, Lesq.; *Wolkmannia major*, Gutb., Plate VII., fig. 32 (?)—This species differs from the former only by the leaves being united half their length, and terminated in a lanceolate point. In the same locality as the former, we have had opportunities for examining many specimens, and found this species a different one from any others.

9. *Asterophyllites aperta*, Lesq., Plate I., fig. 4.—This species, found also in the slate of the same vein of coal, has the ear more slender and longer than both No. 7 and No. 8. The leaves, though short, and united in their whole length, as in No. 7, are half open, and not appressed. When divested of its leaves it is deeply furrowed, and the joints, not inflated at all, are scarcely visible.

10. *Asterophyllites Brardii*, Brongt., *Prod.*, p. 159; *Annularia reflexa*, Sternb., 1 4, p. 31, t. 19, Fig. 5.—Stem striate, articulated; leaves in whorls turned backwards. We have seen some specimens of this species on slates covered with *Asterophyllites equisetiformis*, and think it the same species, the turning back of the leaves being probably accidental.

IV.—*Annularia*, Brongt.

Stems slender, articulated; branches opposite from below the base of the leaves; leaves verticillate, plain, often obtuse, single-nerved, of unequal length; fruit unknown.

Against the opinion of M. Unger, whose description of the fructification answers exactly to what we take for the male catkins of Asterophyllites, we persist in our opinion that these plants are not only different from the former, but belong to another class. For this reason we think that *Annularia longifolia*, described with the fruit, is a true Asterophyllites, and probably the same as *Asterophyllites equisetiformis*.

1. *Annularia minuta*, Brongt., *Prod.*, 155.—Stem striate, branching in whorls; branches branching again; leaves short, lanceolate. Gate Vein at Pottsville. Our species agrees with the description of Brongniart and the figures of Sternberg, except that in our specimen the leaves are slightly obtuse.

2. *Annularia fertilis*, Sternb., *Vers.*, 1 4, p. 31, t. 51, Fig. 2.—Stem (?); branches bearing about sixteen whorls, lanceolate, linear, slightly obtuse; leaves unequal in length, the lateral ones sometimes $1\frac{1}{2}$ inches in length, and more. This species is commonly found in the highest and lowest veins of the anthracite basin—viz. in the South Salem coal at Pottsville, and the Mammoth Vein at Minersville, &c. We have received it also from many places in the coal-basin of Pennsylvania and Ohio.

3. *Annularia longifolia*, Brongt.—Stem thick; leaves verticillate, single-nerved, linear, lanceolate, numerous in the whorls. The thickness of the stems alone would be sufficient to detach this species from this genus. Gate Vein at Pottsville.

4. *Annularia sphenophylloides*, Unger, *Gen. et Spec.*, p. 68.—Stem diffuse, articulated, marked with deep but very narrow furrows; leaves verticillate, ten to sixteen; obovate, oblong, very entire, either slightly emarginated or pointed (Plate I., fig. 5 and 5 *a*). Very abundant in the slates of the upper coal-beds of the Pottsville anthracite basin.

The whorls of leaves are often found separate from the stem, and have been first mentioned as the corolla of some flowering plant. We have some doubt about the identity of the two forms, though they are ordinarily found together. As there is no other difference than the point of the leaves, we have thought it better to unite them, until it may be perhaps ascertained if the emarginate form is not the fruit-bearing plant, and the other the sterile one.

V.—*Sphenophyllum*, Brongt.

Stems simple, branching, articulated; leaves cuneate, verticillate by six to twelve, truncate at the apex, either serrulate, or bilobate, or laciniate, with linear narrow divisions. Fruit unknown. Messrs Presl and Germar have described the fruit as an axillar or terminal ear, composed of numerous bracteal leaves covering small nutlets, approached or united in four. Their drawings and description are truly remarkable, but the likeness of such ears to the male catkins of Asterophyllites (as said before) leaves a doubt upon this point. Perhaps these ears, which we have described as the male catkins of Asterophyllites, are the fruit of Sphenophyllum; but in this case Sphenophyllum would be the immersed part of an Asterophyllites, for we have seen those ears attached to the stems of these plants, and contrary to nature, the immersed leaves would be enlarged and many-nerved, and the aerial ones narrow, linear, and single-nerved. We cannot admit this conclusion. We have tried without result to solve satisfactorily this question. It is true that Asterophyllites and Sphenophyllum are ordinarily found together, and on the same slates, and often in such confusion that one of the plants looks as if it were the branches of the other; but a careful examination has always shown us both plants truly distinct and separate.

1. *Sphenophyllum Schlotheimii*, Brongt., *Prod.*, p. 68.—Stems 1 to 2 feet long, flexuous, striate, inflated at the

articulations; leaves in whorls of six, cuneate, nearly truncate or very obtuse at the summit; very finely crenate, open or reflexed; nerves furcate, terminating in the sinuses of the minute teeth.—Plate I., fig. 8, 8 *a*, 8 *b*.

At the South Salem Vein (new breaker), near Pottsville, the slates are entirely covered with this species, but we have never found there anything like the fructification described by Messrs Presl and Germar. The slates are often covered with small, round, deep, and hollow impressions, which look like the impression of a hard small nutlet; but they are obsolete, and their true nature cannot be ascertained. Our American species differs only from the European one by shorter, broader leaves, and by the stems being more inflated at the joints. In our Fig. 8 *b*, which represents the upper part of a stem, the leaves are nearly straight, and only three to four in a whorl.

2. *Sphenophyllum emarginatum*, Brongt., *Prod.*, p. 61.—Stem branching; leaves cuneate, crenulate, deeply emarginate, in whorls of six. Gate Vein at Pottsville.

3. *Sphenophyllum filiculmis*, Lesq.; *Sphenophyllites oblongifolia*, Gutbier; Plate I., fig. 6.—Stem very slender, thread-like; leaves in whorls of six, the lateral ones long, cuneate, deeply emarginate, and crenulate; inferior leaves much shorter, and a little broader, of the same form. This species, of peculiar appearance, and easily distinguished by the difference in the length of the leaves, and the slender stem, is the same, I think, that has been figured by Parkinson (*Organic Remains*) without any name. Its slender stem, the leaves expanded horizontally, and of unequal length, gives to it the appearance of a true Annularia.

4. *Sphenophyllum trifoliatum*, Lesq., Plate I., fig. 7.—Stem thick, inflated at the joints, striate; leaves in whorls of three, deeply cut in three linear acute divisions. The small specimen found and represented here does not give any hint about the general appearance of this plant. We think that we have in it a malformation of a Sphenophyllum caused by immersion.

5. *Sphenophyllum oblongifolium*, Unger, *Gen. et Spec.*, p. 70.—Leaves in whorls of six, oblong or ovate; denticulate at the apex, longer than the distance between the joints. We report with doubt of this species, of which we have not seen any figure. No. 127 and 129 of the Collection. Salem Vein at Pottsville.

Fifth Class.—*Filices* (*Ferns*).

This class of plants, as every one knows, is the one of which the remains are most abundantly found in the Coal-measures. In the Palæozoic coal the number of ferns is such, that it was long an established opinion that all the plants of that epoch belonged either to this class of plants, or to the Equisetaceæ and Lycopodiaceæ, the two classes of vegetables nearest the ferns. We have already said what we think of this doctrine (see Introduction). This uniformity of vegetation is worth recollecting when we have a doubt about the classification of any peculiar genera of which there have never been found any specimens perfect enough to show its true place in the vegetable kingdom. Such is the genus *Noeggerathia*, admitted by Göppert, Unger, and the German authors to be a fern, and transferred by M. Brongniart to the class of the *Cycadeæ*. The presence of the plants of this genus in the Palæozoic formations below the coal, would of itself induce us to admit them as ferns. But, notwithstanding the scarcity of these plants, we have found many specimens of which the best part (figured, Plate I. fig. 10) shows evidently the same mode of branching as the ferns. The only difference that can authorise a separation of these vegetables from that class of plants, is the insertion of the leaves. But many species of *Sphenopteris* have the leaflets decurrent on the branches, and apparently slightly clasping, as in the Noeggerathia. This conformation is especially visible in our *Noeggerathia Bockschiana*, Plate III. fig. 1 *b*, 1 *c*, a plant related to the *Noeggerathia* by the disposition of the nerves, and to the *Adiantites* or *Sphenopteris* by the form of the leaves and the ramification.

To direct us in the study of the fossil ferns, there are very few characters on which we can rely with certainty. Though we have found many specimens of fossil ferns with fructifications (spore-cases or sporanges), the position of these fruits is the only character observable in them. Their form is always absolute; and the position itself, in connection with the veinlets, is mostly undefined, these veinlets being ordinarily obscured by the sporanges. Such being the case, we cannot admit the new classification of the fossil ferns as it has been attempted by M. Göppert, taking for its basis the form and the position of the fructifications. Relying only on what we can see on nearly all the leaves of ferns found in the coal, we take our marks or characters from the general form of the leaves and leaflets, and from the direction and the ramification of the veins and veinlets. The form of the leaves is so variable, not only on the same plant, but often on the same branch of a fern, that a classification with such a basis necessarily leads us into many mistakes. But the adoption of another method would not only expose us to as many errors, but especially lead to such a confusion of genera, by the obscurity and even the impossibility of description, that it is far better to adhere to the old method.

We have used the only means in our power of obviating the inconvenience of this method—viz. the study of the fossil ferns on the spot where they are found. We have never found any part of an interesting plant without looking carefully for other portions of the same, at the same locality, and very often have been enabled, by so doing, to rebuild a whole plant, the remains of which, found separately, would have certainly authorised the establishing of many species. It is by such researches that we were able to ascertain the identity of the genera *Cyclopteris* and *Neuropteris*, by following our *Neuropteris hirsuta* in all its transformations from the normal part attached to the stem, Plate III., to all the variations indicated on Plate IV. We have no doubt that all the stemless *Cyclopteris* with arched nerves belong to some described species of *Neuropteris*, and that all the stemless *Cyclopteris* with straight and diverging nerves belong to some species of *Odontopteris*. This opinion is elucidated in the description of the different species. From this point of view, if we had to make a general description of the fossil plants of America, we would necessarily unite under the name of *Cyclopteris*, all the species of *Neuropteris* and *Odontopteris*, of which the veins are slender and narrow, and the form of the leaves variable, from oval or lanceolate to circular. The following are, for the coal of Pennsylvania, all the species of *Neuropteris* which we have described, except *N. Cistii*, *N. Grangeri*, *N. heterophylla*, *N. minor*, *N. rarinervis;* all the stemless *Cyclopteris*, our *Odontopteris squamosa*, and perhaps *O. crenulata*, Bt. We would have naturally to make two divisions of this genus, one having the leaves with arcuate nerves, the other leaves with straight and diverging nerves. The *Cyclopteris*, with stem, belongs to another genus. Preserving, as we do, the classification generally admitted, we recognise only the three following sections in the fossil ferns—viz.:

1. *Neuropterideæ*, to which belong the genera *Noeggerathia*, *Odontopteris*, *Cyclopteris*, *Neuropteris*, and *Dyctiopteris*. 2. *Sphenopterideæ*, with the genera *Sphenopteris*, *Hymenophyllites*, *Pachyphyllum*, and *Scolopendrites*, two genera of which the true place is yet undetermined. 3. *Pecopterideæ*, containing the genera *Callipteris*, *Alethopteris*, *Pecopteris* and *Asplenites*. This last genus only is established on the form of the elongated sporangia.

1. *Neuropterideæ.**—Frond pinnate or bi-pinnate. Secondary veins, either rising from a medial nerve, vanishing above, or all emerging and branching from the base without any distinct medial nerve. Fruits unknown.——It is truly remarkable that hitherto there has not been found any relic of the fruit of these *Neuropterideæ*, though the remains of ferns are very abundant in the coal. The impressions indicated by M. Brongniart, as being possibly the marks of the sporanges, on the leaves of *Neuropteris undulata*, have long since been acknowledged as accidental swellings of the epidermis. They are easily observed on many kinds of ferns belonging to this class, and even on the ferns of the other divisions. Possibly the *Neuropterideæ* had a fertile and a sterile frond like *Onoclea* or *Osmunda*, and perhaps also the fertile frond appeared and decayed before the complete maturity of the sterile ones, as it happens with our *Osmunda Cinnamomea.* Whatever it may be, the total absence of fructification in the plants of this class, both in America and in Europe, is a remarkable occurrence. In many places, especially at Pomroy, Ohio, we have seen the roof of the bed of coal entirely covered with the remains of *Neuropteris undulata;* in other places we have found the roof-slates so thickly covered with the leaves of *Neuropteris hirsuta*, or with those of *Dyctiopteris obliqua*, that the slates seemed like a mass of these leaves heaped upon one another; nevertheless we have not been able to detect any form that could be ascertained to be a fertile leaf.

I. Noeggerathia, Sternb.—Frond bi-pinnately or tri-pinnately branching; branches elongated, obliquely attached to the stems; pinnules obovate, obcordate, or wedge-form, clasping or decurring on the rachis by their base, sometimes narrowed in a short petiole; nerves very numerous, equal, either simple or forking from the base up, parallel.

1. *Noeggerathia obliqua*, Göpp., *Gatt. Foss.*, Plates V. VI., tab. 12, fig. 2.—Frond bi-pinnate, pinnæ half open, attached to the stem in an acute angle, like the pinnules or the rachis; pinnules wedge-form or obconical, long, narrowed at the base, obliquely truncate at the summit; nerves dichotomous, distinct.——This species was found below Pottsville, in the Vergent strata. We cannot decide whether this species is the same as the one described and figured by Professor Hall in his geological report of the survey of New York, and named *Sphenopteris laxus;* or if the plant found by him belongs to the next species. We have also some doubt whether our American form is perfectly identical with the European plant of which the pinnæ have never been found, and the pinnules only been described. In our species the pinnæ are very long, we have only broken parts of them; the leaflets are from 1½ to 2 inches long, very obliquely attached to the rachis, and narrowed into a short and broad clasping petiole; the nerves flabelliform and dichotomous, distinct.

2. *Noeggerathia obtusa*, Lesq., Plate I. fig. 11.—Frond bi-pinnately branching; pinnæ elongated, slightly undulate; pinnules attached to the rachis in a very acute angle, broad and long, obovate, rounded or lobed above, narrowed below in a short broad petiole; nerves dichotomous and simple, parallel, distinct. Red sandstone of the Ponent group, Lehigh, below the Mauch Chunk Gap.——We have found this species only in small fragments on the same slates as the following; perhaps both belong to the same species. The nervation being alike in all our *Noeggerathia*, if we cannot rely on the form of the leaves for a specific character, we must have only one species of these plants. It differs from the following especially by its larger size, and the nearly round form of its leaflets.

3. *Noeggerathia minor*, Lesq., Plate I. fig. 10.—Frond bi-pinnately branching; pinnæ long and straight, half open; pinnules distant, small, obliquely attached to the rachis and slightly recurved, cuneate, very obtuse above, narrowed below; nerves very slender, scarcely distinct, dichotomous or simple and parallel. Same locality as the former.

4. *Noeggerathia Bockschiana*, Lesq., Plate III. fig. 1, 1 *a*, 1 *b*, 1 *c*, 1 *d*; *Cyclopteris Bockschiana*, Göpp. Uebers, p. 209; *Adiantites Bockschii*, Göpp., *Syst. Fil. Foss.*, p. 384, t. 36, fig. 6.—Frond bi-tripinnately branching; pinnæ nearly trifoliate or pinnated; pinnules obliquely attached to the rachis, varying from the obovate and obcordate to a broadly-cuneate form, narrowed into a short broad petiole, the upper leaflet larger and broadly obovate, and narrowed into a longer petiole. Nerves dichotomous and simple, very distinct; primary stem thick, channeled and slightly margined like the branches. In the Vespertine strata opposite Mauch Chunk this species affords the

* The definition of all the botanical terms used in our descriptions may be found in Gray's *Manual of Botany.* The word *frond* indicates the whole outline of a fern leaf. The frond is pinnate, or bi-pinnate, or tri-pinnate. The first division is the pinna, the last ones are the pinnules or leaflets.

best proof of the difficulty of a classification in the fossil ferns of this division. M. Göppert has seen only a leaflet of this plant, exactly like the one figured, Plate III. fig. 1 *a*. He placed it first in the genus *Adiantites*, and afterwards in the genus *Cyclopteris*. Considering the mode of nervation, the first place was the proper one for this plant; but by the nearly round form of the leaflet, it is a *Cyclopteris*. But the other parts of this plant which we have found and figured, would necessarily recall it to its former place. It is a true *Adiantites*, if we admit the genus as it has been fixed by M. Brongniart—viz. frond bi-pinnate or tri-pinnate, pinnules narrowed to the base, flabelliform, entire, with the veins diverging from the base without medial nerve. But as our plant has exactly the same nervation as the *Noeggerathia*, as the leaflets appear to have been joined to the rachis in the same manner as in the former species, and as the general form has nothing that departs from the other *Nöeggerathiæ*, we have preferred to let it remain in this genus, the more so because our plant was found in the same strata as the other species. M. Göppert's plant, evidently the same as ours, was found also in the transition (Devonian) sandstone of Bohemia. This species has a great affinity with *Sphenopteris adianthoides*, Lindl. and Hutton, *Foss. Fl.*, 2, p. 115, t. 91 and 92; placed by M. Göppert among the *Cyclopteris*, it differs only in having equal nerves and enlarged petioles of the leaves.

II. Cyclopteris, Brongt.—Frond pinnate, leaflets sessile, flabelliform, half orbicular, sometimes round, sometimes also lobate, with a cordate and often unequal base: nerves numerous, flabellate, dichotomous from the base, nearly parallel; fructifications unknown. We shall separate this genus into three sections:—

α *Adianthoides*, with leaflets petioled, and nerves parallel and straight; a section which should be united with the genus *Adiantites*. β *Odontopteroides*, with round or cuneate leaves without petioles, the nerves diverging fan-like, dichotomous, and straight. The plants of this section are connected with some species of *Odontopteris*.

γ *Neuropteroides*, with the leaflets without petioles, the nerves furcate or dichotomous from the base, diverging fan-like and arched; a section which, as we have said above, should be united with the genus *Neuropteris*.

α Adianthoides.—1. *Cyclopteris flabellata*, Brongt.—Leaflets very entire, fan-like, round and undulate in outline, cuneate below; nerves very thin and close, straight, dichotomous, distinct. Tremont, New Vein. Our American species does not differ in any way from the one described by Brongniart, except that the nerves do not unite near the base in a thick fascicule. The leaves appear to have been borne on a short petiole. Related to this plant, we have a beautiful species of fern, found in abundance at Cuyahoga Falls, Ohio, and described by Prof. Newberry in the *Annals of Science*, No. X. p. 116, and named *Whittleseya elegans*, Newberry. It is a fan-like leaf, borne on a long petiole, cuneate, ovate below, equally cut, and serrate at the truncated summit. The very fine nerves, parallel and scarcely branching, if at all, are united in a fascicule at the point of the teeth, and diverging from the sinuses. These leaves plicate, fan-like in their length, had their surface deeply and equally undulate. This undulation, we think, has caused the obliteration of the nerves placed in the furrows, and the nerves of the elevated ribs alone are visible. This would account for the strange and abnormal appearance of these nerves, as indicated in the figure. We do not see on what ground it can be separated from the ferns, its likeness with some living *Adianthum*, especially with *Adianthum membranaceum*, being evident. We have never seen this species in the coal-basins of Pennsylvania.

β Odontopteroides.—2. *Cyclopteris fimbriata*, Lesq., Plate IV. figs. 17, 18.—Leaves nearly round or truncate at the base, where they are often unequally cordate or symmetrical; margins, especially above, fringed with long thread-like, linear, acute, flexuous, and nearly equal divisions; nerves flabelliform, dichotomous from the base, nearly straight, distant though very thin, parallel, ascending to the points of the divisions. Salem Vein, Pottsville. We have found many fragments of this beautiful species in the upper veins of the Southern anthracite basin; but we had an opportunity to study its general form in a beautiful specimen preserved by Mr Lawton at Barlow, Ohio, and also in another less perfect one in the cabinet of the Rev. Mr Brown, at Charlestown, Kenawha, Virginia. The species is remarkable not only for its regular fringe, but also for its nerves, which, branching from the base and from the middle, are parallel and simple above, and as distant as the divisions of the fringe. Except *Neuropteris crenulate*, Brongt., to which this plant has some affinity by the distance, the thinness, and the distinctness of the nerves, there is not any known *Neuropteris* with which it may be compared. Though we have many species of living ferns with fimbricate margins, it is the first time that a species of this form has been found in a petrified state, and from the old formations. But every day the study of fossil remains shows us something new, and teaches us that the primitive organic structures of this world were much more perfect than is generally believed. Truly each form of being was perfect from the first.

3. *Cyclopteris laciniate*, Lesq., Plate XIX. fig. 3.—Leaves orbicular quadrate, with the base equal and slightly cordate, irregularly fringed around by long, flexuous, acute divisions, somewhat unequal in length, and united in fascicules; nerves flabelliform, dichotomous, straight, very close and distinct. The surface is covered with a scaly coating, which entirely obliterates the nerves, but it falls easily into pieces, and beneath it the nerves appear perfectly distinct. We have found a single specimen of this plant at the vein of Muddy Creek, between Pottsville and Tremont, in connection with *Odontopteris squamosa*. The nervation of both plants is exactly alike, and also the scaly coating which covers them. This common character not observed on any other species, and the presence of these plants on the same slates, are, we think, sufficient proof that they belong to the same species of plants. And here already we have the first confirmation of our views about the identity of some species of *Odontopteris* and of *Neuropteris* with the genus *Cyclopteris*.

γ Neuropteroides.—4. *Cyclopteris undans*, Lesq., Plate IV. figs. 19, 20, 21, 22; and Plate V. figs. 1, 2.—

Leaves broadly oval or nearly round, emarginate at the base or irregularly cordate; margins undulate and irregularly serrate; nerves flabelliform, dichotomous, very slender and close, distinct, united in fascicules, and thickened at and near the base, arched. Gate Vein at Middleport. Following the transitions of forms between our figures 3 to 7, Plate V., there can be no doubt that all these leaves belong to the same species, and that our *Neuropteris undans* is the same as this *Cyclopteris*. All these leaves were found on the same slates, and all are identical, not only by their undulated outline, but especially by their thin close nerves, inflated at and near the base.

5. *Cyclopteris elegans*, Lesq., Plate V. fig. 4.—Leaves nearly orbicular, the lobes of the base converging and embracing the stem, and the point of attachment being nearly central; entire or slightly undulate in outline; nerves very distinct, deeply marked; radiate and dichotomous from the base, where they are thickened; arched. A beautiful species, easily distinguished by the thinness of the leaves, ordinarily slightly folded along the nerves, and especially by the sharpness of these nerves, ordinarily more arched to one side than in any other species. Found in the vein West of Shamokin, in connection with *Neuropteris tenuifolia*, Brongt., with which species it agrees in the thinness of the leaves and the sharpness of the nerves.

6. *Cyclopteris trichomanoides*, Brongt. — Leaves kidney-shaped or nearly round, either symmetrically or unequally cordate at the base; nerves very slender, distant, radiate, dichotomous, becoming very thin and close at the margins. We find in this species the same variety of forms as in the following, from which it differs only by the total absence of the hairs on the surface, and the nerves slightly thinner and closer on the margins. Found always in connection with *Neuropteris undulata*, especially at the Gate and Salem veins, Pottsville.

7. *Cyclopteris hirsuta*, Lesq., Plate IV., figs. 1 to 16; *Cyclopteris trichomanoides*, Brongt., in part; *Cyclopteris obliqua*, Brongt., *Hist. des Veg. Foss.*, i. 221, t. 61, fig. 3.—Leaves oval or round in outline, either symmetrical or unequally cordate, sometimes kidney-shaped, enlarged at the base with equal or unequal, either converging or diverging lobes; nerves very thin, radiate from the base, very close and slender near the margin; surface covered with short straight hairs about a line long. The monography of *Neuropteris hirsuta* gives a satisfactory reason for the new name adopted for this species. It is most commonly found in all the coal-basins of Pennsylvania, especially in the upper veins, as at Salem Vein, Gate Vein, at Pottsville, &c. We think that a few of the species examined and described by authors belong to this species, an accurate discrimination of them becoming impossible when the hairs, which appear to be very brittle, have disappeared.

8. *Cyclopteris orbicularis*, Brongt., *Hist. des Veg. Foss.*, i., p. 220, t. 61. fig. 12.—Leaves nearly round, slightly cordate, either symmetrical or oblique at the base; nerves very distant and strongly marked, dichotomous. Room Run Mines, above Mauch Chunk, in the lowest veins of anthracite. It appears to be the true species described by M. Brongniart, but does not resemble at all its synonyme *Adiantites cyclopteris* of M. Göppert, of which the nerves are numerous and close. In our specimen the nerves are fully one line apart, and many of them more distant, a little turned to one side. Mr Sternberg has described the rachis *thick and round.* We do not know any *Neuropteris* which might be related to this species, except perhaps our *Neuropteris fissa*, Plate III. fig. 2, of which the nerves are very distant, but thinner, and which has the leaflets concave, like this *Cyclopteris.*

9. *Cyclopteris Germari*, Göpp., *Syst. Fol. Foss.*, p. 218, Plate VII. fig. 1.—Leaves enlarged at the base, sessile on the rachis by the whole base, about round in outline, divided into two parts, the upper one lobate, with the lobes divided in from three to five lanceolate linear acute teeth; the lower part entire, with nerves emerging from the base along the rachis; dichotomous, distant, thin but well marked. A small specimen only of this remarkable species was found at the Salem Vein, Pottsville. The form of the leaves is as peculiar as the manner in which they are attached to the rachis, which is thick and narrowly striate. It is not possible to say anything more about this plant until we find some better specimens. By the form of the leaves it has some analogy with our *Neuropteris Desorii.*

III. Neuropteris, Brongt.—Frond pinnately or bi-pinnately divided; pinnules or leaflets cordate or nearly so at the base, scarcely narrowed, entire or cut-toothed, free or scarcely joined to the rachis by their whole base, and decurrent; nerves oblique, thinner above, either dichotomous from a medial nerve which disappears above the middle, or flabellate and dichotomous from the base. The definition of this genus somewhat differs from the one adopted by authors. The description of our species will show the reason of the difference. By limiting the genus *Neuropteris* to the species having a medial nerve, Messrs Göppert and Unger have been compelled to make different genera with different leaves of the same plant; and M. Brongniart himself necessarily admits in the genus *Neuropteris* many species which have no traces of a medial nerve.

1. *Neuropteris Rogeri*, Lesq., Plate VII., fig. 2.—Frond? leaves oval-lanceolate, cordate at the base, margin entire; nervules flabelliform and dichotomous from a scarcely-inflated medial nerve, distant, very slender and distinct, very arched downwards, and then turned upwards at the margin. Gate Vein, near Port-Carbon. Considering the leaves, the only part of this plant that we have been able to find, this species is the largest and the most beautiful of all. The leaves were of thin texture; the nerves, diverging fan-like and very arched at the base, are forking or dichotomous in ascending from a medial nerve scarcely more thick than its divisions. The nervules, though thin, are nevertheless strongly marked, and twice as distant from each other as in the following species. They approach only at and near the margin, where, changing abruptly their direction, they are curved upwards. We have found many specimens of this species, all at the same place, without any stem; they preserve well their specific characters. We have dedicated this species to Professor Henry D. Rogers, State Geologist of Pennsylvania.

2. *Neuropteris hirsuta*, Lesq., Plate III. fig. 6, and Plate IV. figs. 1 to 16; *N. cordate*, Brongt., *Hist. des Veg. Foss.*, p. 229, tab. 64, f. 5; Lind. and Hutt. *Foss. Fl.* p. 119, tab. 41; *N. angustifolia*, Brongt., *loco cit.*, i. p. 231, tab. 64, f. 8; *N. Scheuchxeri*, Hoffm.; *N. acutifolia*, Brongt., *loco cit.* i. p. 231, tab. 64, figs. 3, 4.—Frond bipinnate; pinnules trifoliate or simple; upper leaflets cordate at the base, lanceolate, acute or obtuse, sometimes irregularly lobed; all with a strong medial nerve disappearing above the middle; nervules furcate, very arched; pinnules of the base kidney-shaped, or round, or oval, much smaller, with the nerves fan-like and dichotomous from the base, without any medial nerve; surface of the leaves more or less hairy. The essential character of this variable species was first observed by Mr Bunbury, and mentioned in his description of the fossil plants of Nova Scotia,—viz., the short hairs scattered on the surface of the leaves. We have scarcely seen a well-preserved specimen on which these hairs were not observable with a lens. They appear, nevertheless, to have been brittle, and easily falling off; for sometimes there are only a few of them left on some part of a leaf, and sometimes they are numerous on the whole surface. This species is the most common of all in the coal-fields of Pennsylvania, from the lowest veins to the highest; and we have frequently had an opportunity of studying it where its remains were the only ones preserved. The short petioles, by which the leaflets are attached to the common rachis, have a peculiar structure. Being enlarged on the stem and pointed above, they stand on the rachis, ordinarily deprived of its leaves, exactly like thorns—Plate IV., figs. 15 and 16. The point of attachment of the leaves was so slender and brittle that we very seldom find any of the pinnules attached to the stem. We have seen them in this state only once or twice, among many thousand specimens that have come under examination. It is easy to follow the mutations of the form of the leaves and leaflets in our Fourth Plate; the basilar leaflets being indicated from N. fig. 6 to the *Cyclopteris*, figs. 13, 14. But the most remarkable of these transformations occurs in some of the upper leaflets, Plate IV., figs. 1 to 5. Near the summit of the pinnæ, the pinnules become simple, narrowly lanceolate (in which case they belong to *Neuropteris angustifolia*, Brongt.), and there they are sometimes cut in many lobes, either to the base or to the middle, preserving ordinarily a medial nerve in each division. The basilar leaflets, also, are sometimes diversely lobed, but they preserve always the flabelliform nerves diverging from the base, without any trace of a medial nerve. By following the series of transformations figured on Plate IV., it is easy to identify the genus *Neuropteris* with *Cyclopteris*, as we have indicated above. We have observed an analogy of form in the leaflets and some of the varieties above mentioned in *Angiopteris erectus*, Hoffm., of which we have seen beautiful specimens in the collection of Professor Asa Gray of Cambridge. *Neuropteris Scheuchxeri*, Hoffm., sent to M. Brongniart from Wilkesbarre, belongs probably to this species also; nevertheless, we have never seen a leaflet with the petiole attached to it as it is figured by this eminent author. The stems of this fern, narrowly ribbed but smooth, are sometimes very large; the one figured, Plate IV., fig. 16, was 3 feet long, and 3 inches broad; we saw it in the roof of an upper vein at Johnstown. We have seen still larger ones in the roof of the coal-seam mined at Pomroy.

3. *Neuropteris Clarksoni*, Lesq., Plate VI., fig. 1.—Stems irregularly bipinnately branching; pinnules simple, broadly lanceolate above, cordate or irregularly auriculated and hastate at the base, by the inferior lobe being more or less elongated; terminal pinnule lance-shaped, equally bilobed in the middle; nervules dichotomous, distinct, strongly marked from a thick medial nerve which ascends nearly to the summit. Collection of Mr Clarkson at Carbondale, where beautiful specimens of this species are preserved. This species, named in honour of Mr Clarkson, is somewhat related to *Neuropteris auriculata*, Brongt.; but it differs much from it by its thick and nearly continuous medial nerve, and by the outline of the upper leaflet, which has exactly the same form in all the specimens that we have seen. We would have admitted *Neuropteris acutifolia*, Brongt., as being probably a synonym of this species; but the author describes it *with nerves very thin and close*,—a character better agreeing with *Neuropteris hirsuta*, this species having the nerves thicker and more distant.*

4. *Neuropteris fissa*, Lesq., Plate III., fig. 2.—Frond (?) Pinnule oval, truncate at the base or cordate, with undulate margins; nerves dichotomous from a medial nerve, very distant and slender. Gate Vein at Pottsville. We have only the broken leaflet figured on Plate III. But this species is very peculiar and distinct by the distance of its undulate and scarcely-arched nerves obliterate above. The leaflet is concave, and the medial nerve appears to have been split by pressure. Its general outline is like *Neuropteris ingens*, Lind.; but in this species the nervules are thin and close, and in one species they are more than one line apart. Its affinity to *Cyclopteris orbicularis* is indicated, p. 856.

5. *Neuropteris smilacifolia*, Sternb., *Vers.*, i. pp. 29, 35; *N. acuminate*, Brongt.—Frond pinnate, pinnules alternate, opposite, petiolate, oblong acuminate, entire, from a slightly cordate base; nerves very thin and close, scarcely discernible. A single leaf of this species was found at an old shaft S.W. of Shamokin.

6. *Neuropteris plicata*, Sternb., *Vers.*, i. p. 16; ii. tab. 19, figs. 1, 3.—Frond pinnate or bipinnate; pinnules alternate, close to each other, ovate-acute, with a cordate base, the inferior lobe longer or extended, the margins undulate-plaited; stem round; medial nerves very slender; nervules numerous, arched, dichotomous. Salem Vein, Pottsville. We would have admitted this species as a variety of *Neuropteris undulata*, but for the nervules, which are finer and closer than in any other species of this division. We have figured Plate XX., fig. 4, the only specimen that we have found. We do not see any difference between this species and *Neuropteris obovata* of the same author.

* The analogy of this species with our living fern *Cassebiera hastate*, from Cape of Good Hope, is truly remarkable. The leaflets, both basilar and terminal, have the same variety of form and the nervation is alike.

7. *Neuropteris flexuosa*, Brongt., *Hist. des Veg. Foss.*, i. p. 239, tab. 65, figs. 2, 3; and tab. 68, fig. 2.—Frond bipinnate, with long lanceolate-linear pinnæ; pinnules closely placed on the rachis, and their margins either continuous or imbricated, oblong, obtuse, very entire; the slightly cordate base parallel to the rachis, and the inferior lobe more or less dilated; terminal pinnule oval, angular, narrowed at the base; nervules very slender, arched, dichotomous from a medial nerve vanishing above the middle. Found everywhere in the whole extent of the coal-basin, especially in the upper veins. This species is very variable in the outline of its leaves; but it has always the inferior lobe of the pinnules more or less dilated. It is, in many of its parts, so very like *Neuropteris Loschii* that we much doubt if the species are not identical, this last one being the upper part of the frond of *Neuropteris undulata*.

8. *Neuropteris Loschii*, Brongt., *Hist. des Veg. Foss.*, i. p. 242, tab. 73.—Frond bipinnate; pinnæ sessile, nearly opposite or alternate, open, linear, lanceolate; pinnules alternate, close, or distant, cordate-oval, very entire; the terminal leaflet rhomboidal, and angular below the middle, larger than the lateral ones; medial nerve very slender, and nervules like the former species. See fig. 3, Plate XX. Our figure, which represents the upper part of a frond, shows how variable the pinnules are in their form.

9. *Neuropteris rotundifolia*, Brongt., *Hist. des Veg. Foss.*, i. p. 238, t. 70, fig. 1.—Frond bipinnate; pinnules very close to each other, and imbricated on the margins, round, oval, very obtuse above, short; medial nerve and nervules like the former. Gate Vein, Pottsville. Perhaps a variety of *Neuropteris flexuosa*, from which it differs only by the shorter, broader, and more obtuse leaflets, placed closer to each other on the rachis.

10. *Neuropteris tenuifolia*, Brongt., *Hist. des Veg. Foss.*, i. p. 241, t. 72, fig. 3.—Frond bipinnate; pinnæ long and linear; pinnules alternate, sessile, oblong, slightly narrowed and obtuse above, cordate at the base; the terminal one lanceolate, long, nearly pointed, angular near the base; medial nerve well marked, like the arched, dichotomous, and slender nervules. Shamokin, at a coal-bed west of the village. The terminal leaflet, by its lanceolate form, is characteristic of this species. The nervation is also peculiar. Vide *Cyclopteris elegans*, p. 856.

11. *Neuropteris gigantea*, Brongt., *Hist. des Veg. Foss.*, i. p. 240, t. 69.—Frond bipinnate; pinnæ nearly opposite, distant; pinnules alternate, sessile, oblong-obtuse, very entire, with a cordate, equal base; medial nerve thin; nervules numerous and thin, arched, forking. This species has been often mentioned as commonly found in the coal-basins of Pennsylvania. We do not doubt but that it has been confounded with *Neuropteris undulata* and *N. Loschii*. The only specimen of this species that we ever saw in the coal-fields of America is in the possession of Dr Howard of Columbus, and had been found at Zanesville, Ohio.

12. *Neuropteris Grangeri*, Brongt., *Hist. des Veg. Foss.*, i. p. 237, t. 68, fig. 1.—Frond bipinnate; pinnæ alternate, long, open, or slightly recurved; pinnules alternate, scarcely contiguous, ordinarily distant, oval, slightly enlarged at the base; nervules strongly marked, dichotomous, arched. A very fine species, related to *Neuropteris Loschii*, but easily distinguished by its oval leaflets, scarcely enlarged at the base, and by its fine and deeply-marked nervules. By its nervation it differs from the following species, to which Mr Brongniart thinks it might be allied. Very scarce in the anthracite coal-basins. Found once at Gate Vein, Pottsville.

13. *Neuropteris Cistii*, Brongt., *Hist. des Veg. Foss.*, i. p. 238, t. 70, fig. 3.—Frond bipinnate (?); pinnules distant, oval, cordate above the base, and narrowed into a short broad petiole; nervules distant, thin, flattened, forking only twice. Gate Vein at Port Carbon—scarce. A species easily distinguishable by its leaflets borne on a broad base, and enlarged above.

14. *Neuropteris delicatula*, Lesq., Plate XX. fig. 2.—Frond bipinnate; pinnæ lanceolate, short; pinnules oblong, attached to the broad flattened rachis by their whole base, and slightly decurrent; nervules distinct, flabellate, dichotomous, arched, thin, and close; rachis slightly winged, flexuous. Salem Vein at Port Carbon. Though we do not like to increase the number of the species, and to admit any new one without being acquainted with it by the inspection of many specimens, we cannot but notice the small branch figured here; its nervation and the decurrent leaves on a broad nearly winged rachis is totally different from all the other *Neuropteri* of this section.

15. *Neuropteris Willersii*, Brongt., *Hist. des Veg.*, *Foss.* i. p. 233, t. 64, fig. 1. Plate III. fig. 3.—Frond bipinnate; pinnules obliquely placed, oblong, obtuse on one side; nearly perpendicular, longer, oblong, lanceolate, acute on the other; nerves flabelliform, dichotomous, crenate, slender, distinct and distant; rachis round, striate. Gate Vein, Pottsville. By the form of the leaves, longer on one side, shorter on the other, this species agrees with Messrs Brongniart's and Sternberg's figure and descriptions. We have nevertheless some doubt about the identity, on account of the peculiar nervation of this plant. Though very distinct and deeply marked, the nerves are thin and distant, and not at all thickened at the base; neither close on the margins, as these eminent authors have described their plant. The terminal leaflet appears very large; but it is broken through the middle in the only specimen that we have found, and we could not see its form.

16. *Neuropteris gibbosa*, Lesq., Plate V. fig. 3.—Frond bipinnate; pinnules nearly opposite, equally cordate at the base; oblong, obtuse, with the margins deeply and irregularly sinuate; nervules flabellate, dichotomous, very slender, close, and distinct. Salem Vein, Pottsville. A fine species, somewhat relative to *Neuropteris flexuosa*, but differing by its nerves, being thinner, closer, and flabellate, without any medial nerve, by the leaflets opposite, and the rachis round and inflated at the articulations of the leaves. At the base of some leaflets there are, between the nerves and following exactly their direction, some short, narrow depressions or holes, which, by their form and their symmetry, appear to have been of an organic nature. We could not ascertain whether they are not possibly the impressions of the fructification of these plants. These depressions are entirely naked.

17. *Neuropteris undans*, Lesq., Plate V., figs. 1 and 2.—Frond bipinnate; pinnules either large, 2 inches long and more, lanceolate, attenuate at the base, with the margins deeply undulate, plaited; or small, oblong, undulate, with a terminal pinnule, much larger and lance-shaped, obtuse, undulate, lobate, or angular below the middle; nerves flabellate, arched, dichotomous, very thin, and close on the margin, inflated near the base. Gate Vein, Middleport. This species is the same as *Cyclopteris undans*. *Vide* p. 855. The pinnules of fig. 9 are very small; but as the general outline is the same, and the nervation alike, we had no reason to separate it, the less so as this species offers us so many changes of form.

18. *Neuropteris crenulata*, Brongt., *Hist. des Veg. Foss.*, i., p. 234, t. 64, fig. 2.—Frond pinnate; pinnules alternate, sessile, oval-obtuse, denticulate, with an unequally truncate obtuse base; nervules furcate, slightly arched, distant and slender, from a slender medial nerve. We have found a single leaf of this species at the Salem Vein, Pottsville; but it is so well characterised by its distant, slightly-arched nerves, and its very small round teeth around the leaf, that we have no doubt about the identity of this species with the European one. —*Vide* Plate V., fig. 6.

19. *Neuropteris tenuinervis*, Lesq., Plate V., figs. 7 and 8.—Frond bipinnate; pinnules oval or oblong, with undulate margins, sometimes irregularly toothed at the summit, either regularly cordate at the base, or attenuate in a short broad petiole; nerves very thin, flabellate, dichotomous from the base, slightly arched, equal, not inflated below; rachis round, and narrowly striate. Gate Vein, Pottsville. There are in this species two characters which separate it from every other of this class; the form of the leaflets, which is very irregular and abnormal; and a very slender, deep, straight medial nerve, which looks nearly like a cleft along the pinnules, dividing them in two. This character enables us to identify both parts of this plant, figs. 7 and 8, which at first would appear as belonging to different species. This medial nerve is perfectly equal in its whole length, and ascends nearly to the summit. This species has some analogy of form with *Odontopteris subcuneata*, Bunb. (*Description of the Fossil Plants of Nova Scotia*); but our species has the nervules evidently arched, and is a true *Neuropteris*.

20. *Neuropteris dentata*, Lesq., Plate V., figs. 9 and 10.—Frond pinnate; pinnules slightly cordate, or irregularly truncate at the base; oval-lanceolate in outline, with the margins irregularly cut-toothed and lobed; nerves flabellate, dichotomous, arched, deeply marked, but very thin and close. Very scarce: found at Salem Vein, Port Carbon. This fine species has the most slender and narrow nerves of all. We have only a small part of a pinnæ, fig. 9, and probably a terminal leaflet, fig. 10.

21. *Neuropteris Desorii*, Lesq., Plate V., figs. 11 and 12, and Plate XX., figs. 5, 6, 7, 8.—Frond bipinnate; pinnules opposite, either oblong, oval, or obovate; entire, or irregularly laciniate and lobate, with the lobes sometimes pinnately divided in long and linear teeth; nerves flabellate, dichotomous, very thin above, thickened at the base. Salem or Gate Vein, West Wood. This species is certainly the most polymorphous in the whole class of *Neuropteris*. Though we have seen only the fragments figured, we do not doubt that all belong to the same species. Not only the nervation is alike, and all the varieties have been found on the same slates, but the analogy of form, and the transitions between them, are easily appreciable. As it happens in this section of *Neuropteris*, the leaflets at the upper part of the pinnæ become adherent to the rachis by their whole base, and are nearly decurrent and often contiguous. In this state the plant is very like the following one (*vide* figs. 11 and 12), but it differs always from it by its thinner and less distinct nerves. We have dedicated this beautiful species to our excellent friend Professor Desor, at one time actively engaged in the geological survey of Pennsylvania.

22. *Neuropteris heterophylla*, Brongt., *Hist. des Veg. Foss.*, i. p. 243, t. 71, 72.—Frond large, many times pinnately divided; interior pinnæ linear, sessile, the exterior ones bipinnate, petiolate, much longer; pinnules oval, or nearly round, obtuse, very entire, with a cordate equal base, terminal leaflet oblong, and much larger, medial nerve slender, nervules arched, dichotomous, distinct. It would be useless to enumerate all the forms and varieties of this species commonly found in the upper veins of the Anthracite Coal-basin at Pottsville, Westwood, New Philadelphia, &c. &c. The large frond is ordinarily three times divided; the last divisions or leaflets are either long and pinnately lobed, with the lobes separate nearly to the base, or united in their whole length; either simple, lanceolate, obtuse, or slightly acute, with two small round leaflets at the base. The strongly-marked nerves are characteristic of this species. One of our varieties presents exactly the form of *Neuropteris Brongniarti*, Sternb. It is distinguished by the longer, lanceolate, obtuse leaflets, sometimes slightly acute, either single, or with two small round leaflets at the base. This is the common form of the species in the upper part of the fronds.

23. *Neuropteris minor*, Lesq., Plate III., fig. 4.—Frond bipinnate; pinnæ short, linear, sessile on a thick, striate, round rachis, pinnatifid; pinnules oval, sessile, either separate, or united in the upper part of the pinnæ; terminal leaflet very small, oval; nerves thick, obsolete, bifurcate. Found at Tamaqua by Desor. Except the form of the upper leaflet and its size, this species agrees with *Neuropteris microphylla*, Brongt. The texture of the leaflets appears to have been thick; their surface is undulate and sometimes entirely smooth, the veins being indistinctly traced by the swelling of the parenchyma between them.

24. *Neuropteris rarinervis*, Bunb. *Quart. Jour. Geol. Soc.*, vol. iii.—Frond bipinnate; pinnæ long and linear, sessile, alternate; pinnules alternate, contiguous, oval, obtuse, slightly scythe-shaped, nearly cordate at the base, with the exterior lobe slightly extended; terminal pinnule deltoid, nearly trilobate. Superior pinnæ simple, linear lanceolate, with undulate margins, medial nerve distinct; nervules distant, bifurcate. Collection of Mr Clarkson, Carbondale. As Mr Bunbury observes, this species, in the form of its pinnules, is near *Neuropteris Loschii*

and *Neuropteris undulata;* but differs from both by its round narrow secondary rachis and its distant nerves. The nervules branch once only near their base—and the one division is simple; the other branches a second time near the margin.

25. *Neuropteris Moorii*, Lesq., Plate XIX., fig. 1.—Frond bipinnate; pinnæ nearly opposite, half open; pinnules alternate, ovate, slightly acute, entire, sessile by their whole base, and somewhat contiguous; nervules emerging either from the medial nerve, or from the rachis, furcate; primary rachis thick, smooth, winged by some pinnules of the same form attached to it. Found near Greensburg by the Rev. Mr Moore, in whose cabinet we were permitted to study it. A beautiful species, remarkable, like the following, for the leaflets being attached on the common rachis, and by the nerves emerging from the whole base of the pinnules. This character would be sufficient to separate these species into a peculiar genus, intermediate between *Odontopteris* and *Neuropteris.*

26. *Neuropteris adiantites*, Lesq., Plate XX., fig. 1.—Frond bipinnate; pinnules nearly decurrent on a slender rachis, oval, obtuse; inferior pinnules decurrent on the primary rachis; nerves dichotomous, distinct. We have only the upper part of a pinna found at South Salem Vein, Pottsville. It has a great affinity with the former, differing only by the thin rachis, and the oval form of the leaflets, of which the terminal one is very small. The veinlets are branching from a medial nerve, and dichotomous.

IV. Odontopteris, Brongt.—Frond bi-tripinnately branching, pinnules attached to the rachis by the entire base, oval, acute, or obtuse, thick; medial nerve slightly marked, nervules either simple or furcate, some of them rising from the rachis. The form of the leaves, as well as the nervation of many of the species of *Odontopteris*, evidently relates this genus to the former. Sometimes this relation is so near, that it is difficult to find any generic character to authorise the separation. Sometimes, also, as in the instance of *Odontopteris Schlotheimii*, this affinity totally disappears; hence a sectioning of this genus would be easy, and perhaps opportune. The first section would contain the species of which the nerves are close, flagellate, dichotomous, differing from the *Neuropteris* only by the straight direction of the nervules. To the second division would belong the species with distant and scarcely branching nerves, some of them rising from the base or from the rachis; and in this section, we think, the two last species of *Neuropteris* would take their place, as well as some of the *Adiantites* of M. Göppert.

1. *Odontopteris squamose*, Lesq., Plate XIX., figs. 2 and 2 *b.*—Frond tripinnate; pinnæ long, lanceolate; pinnules oblong, oval, obtuse, the terminal one smaller, oval, lanceolate, acute; nervules thin, but very distinct, flabellate, dichotomous, straight; surface of the leaves ordinarily covered with a coat of scales. At first this species appears identical with *Odontopteris obtusa*, Brongt., but by a close examination it is found to differ in many essential characters. As may be seen by the unfolded stem, the plant is tripinnate; the leaflets are longer and narrower, the layer of scales which covers the surface falls easily, and below it the nervules appear naked or strongly marked, though thinner than in *O. obtusa.* A scarce plant; found at South Salem Vein, Pottsville. Its analogy with *Cyclopteris laciniata*, is indicated, p. 855.

2. *Odontopteris Brardii*, Brongt. (?) *Hist. des Veg. Foss.*, i. p. 252, t. 75 and 76.—Frond bipinnate; pinnæ nearly opposite, and sessile distant; pinnules alternate, united together at the base, oval, oblong, acute, entire, slightly scythe-shaped, nerves very numerous, furcate, rachis round. We refer with doubt to this species a small specimen, No. 149 of the collection, which is very indistinct; it looks like a superior pinna, and has the pinnules slightly obtuse. Gate Vein, Westwood. A very scarce species in America, if present at all.

3. *Odontopteris crenulata*, Brongt., *Hist. des Veg. Foss.*, p. 254, Plate 78; *Neuropteris serrata*, Sternb., *Vers.* 2, p. 76.—Frond pinnate; pinnules alternate, lanceolate, acute, scythe-shaped, lobate, serrate; medial nerve slightly marked, nervules very thin, slightly arched, emerging from the striate rachis. Tremont New Vein. Our specimen, though small, agrees well with M. Brongniart's figure and description. It has a near affinity to our *Neuropteris dentata*, but evidently differs by the thin nervules being nearly straight, and rising from the rachis.

4. *Odontopteris Schlotheimii*, Brongt., *Hist. des Veg. Foss.*, i. p. 256, t. 78, fig. 5.—Frond tripinnately branching; inferior divisions pinnate, with the pinnules alternate, nearly round, or half round, entire, joined at the base; nervules thick and far distant, rising from the rachis, and nearly perpendicular to it; simple or furcate once only; superior divisions simple, with ovate, oblong, obtuse pinnules, twice as large, nerves dichotomous and slightly arched. Upper veins of the Anthracite coal, Salem Vein, at Pottsville, New Vein at Tremont.

This species, we think, is the same as the one described by M. Göppert, in his *Genera*, 5,6, tab. 6, and also the same as M. Brongniart's, though he says the nerves are very narrow and close (*tenuissimi* and *approximati*). This plant is very variable, either in the disposition and the size of the nerves, or in the form of the leaflets. Our fig., Plate VII., shows the upper part of a pinna, of which the superior pinnules have the form of a *Neuropteris.* On the inferior pinnæ, the short, half round, and sessile leaflets, have only a few nervules, thick, distant, straight, and scarcely branching; on the superior pinnules the nerves are flabelliform, dichotomous, slightly arched, and much closer. We have seen on one of our specimens the round, thickened, or inflated leaflets indicated by M. Göppert, as the fructifications of this plant. We think the appreciation of this able palæontologist is correct. As it occurs with the ferns of this class, the fertile plant is separate, and has a different appearance from the sterile one. In this species the primary rachis of what we think the fertile form is much thicker, deeply striate, with the branches attached perpendicularly, and sometimes recurved; some of the leaflets, round and inflated, do not present any trace of nerves, but only concentric lines; others of them are flattened, and have the normal nervation.

5. *Odontopteris dubia*, Lesq.—Frond (?) pinnule oval, lanceolate, entire on one side, pinnately divided on the other in three lobes, which are nearly distinct to the base, and oval; nerves numerous, slender, distinct, dichotomous.

We give under this name the description of a small specimen found at the Gate Vein, Pottsville, which may belong to some *Odontopteris* already described, either *O. obtusa* or *O. Sternbergii*, Göpp. It nevertheless differs apparently from both by the section of the leaflet on one side, the other side being entire and undulate—possibly one of those anomalies so often remarked in this genus, and only accidental.

V. Dyctiopteris, Gutb.—Frond bipinnate, pinnæ linear-oblong; pinnules sessile, oval-oblong, slightly and equally cordate at the base, obtuse and oblique, or a little scythe-shaped upwards; medial nerve disappearing above the middle; nervules much branching and reticulated by their diverging divisions. At first, by the reticulation of the nerves, this genus does not appear to belong to this class, but, by following the ramifications of the nerves, it is easily seen that it is identical with the nervation of a *Neuropteris*, with a difference in the divergence of the nervules. In many cases, especially in the largest leaves of our only species, the nerves are scarcely reticulated, and their divergence from the point of attachment is no greater than it is in a *Neuropteris*, and such leaves may easily be mistaken for those of this genus.

1. *Dyctiopteris obliqua*, Bunb., *Quart. Jour. Geol. Soc.*, vol. iii.—Frond bipinnate, pinnæ linear; pinnules cordate at the base, oblong-obtuse, slightly narrowed and scythe-shaped above; very deciduous, and attached to the rachis by the base of the medial nerve, which ascends only to half its length. This species is very abundant in both the lower and the upper beds of the coal-basins of Pennsylvania and Ohio. We have found it at the South Salem Vein, at Pottsville, and also at Trevorton. The pinnules, as it happens with many species of *Neuropteris*, are so very deciduous that they are scarcely found attached to the rachis. At Trevorton we have seen a thick bed of slates entirely formed of those pinnules, heaped one upon another, nearly without any trace of other fossil plants. We have figured, Plate VIII., fig. 6, a part of a pinna, that, we think, belongs to this species, in spite of the great difference in the form of the pinnules. The nervation is the same; such branches are found mixed with the pinnules of the normal form. There are found also many intermediate forms, and so we cannot admit it as a peculiar species. The medial nerve at the base of the leaflet is the mark by which this species is separated from *Dyctiopteris Brongniarti*, Gutb. Though the leaflets are ordinarily scythe-shaped in the American plant, this form is not without exception; it is also remarkable in the European species: they may prove identical.

II. Sphenopterideæ.—Frond bi-tripinnate or bi-tripinnatifid; pinnules sometimes entire, but mostly lobate, the lobes wedge-form at the base, dentate or diversely divided; nerves pinnate, with a primary nerve more or less distinct and flexuous; secondary nerves obliquely ascending, either simple in each lobe or division, or dichotomous, furcate at the apex; fructifications punctiform or marginal. This definition, nearly translated from Göppert's and Ungers, embraces the characters of this class of ferns, as we have admitted it; but we have never seen on any of our specimens a trace of fructification, and we can assert nothing either as to their position or their form.

I. Sphenopteris, Brongt.—Frond bi-tripinnate, pinnules lobate, wedge-form at the base, the inferior lobe ordinarily larger. Nerves pinnate; primary nerve more or less distinct, and ascending to the margin (decurrent); flexuous, secondary nerves dichotomous, branching two to three times in each lobe.

1. *Sphenopteris Darallia*, Göpp., *Gatt. Foss. Flor.*, i. p. 68, t. 11, fig. 23.—Frond tripinnate; secondary pinnæ alternately placed, linear, close, open; the inferior ones free at the base, the superior sessile and decurrent on the common rachis, six to ten parted; pinnules or lobes cuneate, round, emarginate above, terminal large; nerves two to three times furcate in each lobe. Kenawha Salines, Virginia; presented by Dr Hildreth, from Marietta. The only difference between the American plant and the species described by M. Brongniart is the greater size in all the parts of our plant. The frond is 4 to 6 inches long, the secondary pinna 1½ inch, with six to eight ranges of larger leaflets. As we have specimens of different sizes, this difference is probably accidental.

2. *Sphenopteris tenella*, Brongt., *Hist. des Veg. Foss.*, i. p. 186, t. 49, fig. 1.—Frond tripinnate, pinnæ and pinnules alternate, distant, petiolate, open; pinnules deeply pinnatifid; the inferior ones with two to three pairs of leaflets; the superior ones bi-trifid, with the divisions alternate, linear-lanceolate, acute, nerves pinnately branching, rachis filiform, naked. Gate Vein, Port Carbon.—A small specimen.

3. *Sphenopteris Gravenhorstii*, Brongt., *Hist. des Veg. Foss.*, i. p. 191, t. 55, fig. 3.—Frond tripinnate, with a broad and flattened rachis; primary pinnæ curved downwards; secondary pinnæ lanceolate, nearly equal, oblique on the slightly marginate rachis; pinnules small, oblique, ovate, three to five lobed; lobes short, bi-tri-toothed nerves nearly pinnately forking. Gate Vein, Westwood. A variable species. Sometimes the leaflets are longer, and the divisions broader. It appears to be common in the bituminous coal-basin, especially in Ohio. There are fine specimens of it in the beautiful cabinet of Professor Newberry.

4. *Sphenopteris Dubuissonii*, Brongt., *Hist. des Veg. Foss.*, i. p. 195, t. 54, fig. 4.—Frond bipinnate, pinnæ alternate, open, oblong-lanceolate, deeply pinnatifid; pinnules sessile, and nearly opposite, united at the base, short, nearly round, three to four toothed at the apex. Gate Vein, Port Carbon. In the American form, the secondary pinnæ are closer, a little longer, and the pinnules of the base ordinarily five-lobed. This character, and the scaly rachis, would place it with *Sphenopteris Hoeninghausii*, Brongt. (*Hist. des Veg. Foss.*, i. p. 199, t. 52). But the divisions of the pinnules are enlarged at the base, sessile by their whole base, and united together—(*neither separate nor narrowed*, as in this last species).

5. *Sphenopteris abbreviata*, Lesq., Plate IX, fig. 1, t. 1 *b*.—Frond bipinnate, pinnæ alternate, open, short, linear-lanceolate; pinnules alternate, sessile by the whole base, obliquely ovate in outline, crenulate; nerves pinnately

forked, distinct, rachis broad and smooth. Gate Vein, Port Carbon. The pinnæ are perpendicular to the rachis, as in *Sphenopteris palentissima*, Göpp., which our species resembles.

6. *Sphenopteris intermedia*, Lesq., Plate VIII., fig. 8, 9, 9 *a*. Frond tripinnatifid, rachis smooth and slender, slightly flexuous, secondary pinnæ linear-lanceolate, deeply pinnatifid; pinnules oval, decurrent, joined together by their base, serrulate at the summit; nerves obsolete, pinnately forked; nervules simple. Gate Vein, Westwood, and Tremont New Vein. This species is truly intermediate between *Sphenopteris chærophylloides*, Sternb., from which it differs by its longer secondary pinnæ, and the short pinnules united half their length, and *Pecopteris athyriodes*, Brongt., than which the secondary pinnæ are a little longer. There is also a slight difference in the less flexuous nerves, and in the pinnules, which are not so deeply toothed in our species; nevertheless, the affinity between them is so great that, but for the difference in their geological age, we would have admitted them as identical. It is abundantly found in the anthracite coal-fields of Pennsylvania.

7. *Sphenopteris flagellaris*, Lesq., Plate XVIII., fig. 1.—Frond bipinnatifid, pinnæ long, linear, flexuous, slender, pinnules alternate, oval, with a broad decurrent base, united together, crenulate; nerves bifurcate. South Salem bed, Pottsville. A species related to the former, but distinguished from it by its long flexuous pinnæ. It has also some affinity with *Pecopteris serra*, Lindley and Hutton.

8. *Sphenopteris plicata*, Lesq., Plate IX., fig. 3.—Frond bipinnatifid (?), pinnæ long, linear, pinnules distant, oval-oblong, enlarged below, sessile on the winged rachis, and united together, pinnately lobate, and undulate plaited; lobes short, a little obtuse; medial nerves thick; nervules obliterated or obsolete. Behind New Philadelphia, at an old shaft—probably of the Gate Vein. Though the specimen is imperfect, the species is evidently distinct and peculiar. We do not know of any already described to which it can be referred.

9. *Sphenopteris latifolia*, Brongt., *Hist. des Veg. Foss.*, i. p. 205, t. 57, figs. 1 to 6.—Frond tripinnate; pinnules short, petioled, ovate, pinnately divided; divisions oblique, oval, obtuse, two to three partite; nerves diverging from the bàse, many times forked, well marked, and thick. Salem Vein, Pottsville.

10. *Sphenopteris acuta*, Brongt., *Hist. des Veg. Foss.*, i. p. 205, t. 57, fig. 5.—Frond bipinnate, rachis slender, flexuous; pinnæ lanceolate, acute, oblique; pinnules lanceolate, five to seven lobed; lobes oval-lanceolate; superior acute, nerves very slender, flabellate, dichotomous, scarcely distinct. We have seen a fine specimen of this species in the cabinet of Dr Hildreth, at Marietta; found at Kenawha Salines, Virginia.

11. *Sphenopteris glandulosa*, Lesq., Plate IX., fig. 2.—Frond tripinnately divided, dichotomous, or forking at the top; primary and secondary pinnæ opposite, long, perpendicular, or recurved on the broad striate rachis; inferior pinnules equally three to five lobate, cordate at the base; lobes round, terminal leaflet acute, sometimes long-pointed by the persistence of the broad medial nerve; superior pinnules smaller, round, entire; all thick, convex, glandular-punctulate, rough; nervules entirely obsolete. A beautiful species found at Shamokin, west of the village. It is separated from *Sphenopteris obtusiloba*, Brongt., by its pointed terminal leaflet, and the glandular surface of the pinnules. It would agree by its ramification with *Sphenopteris Linkii*, Göpp., from which it differs however by its rough surface, and its much larger size.

12. *Sphenopteris decipiens*, Lesq., Plate XVIII., fig. 2.—Frond pinnate; pinnules elongated, pinnately lobed; lobes half round, very obtuse, decurrent, and united at the base, the terminal broader; medial nerve undulate, broad; nervules two to three times forked, slender, distinct. Shamokin Gap. At first sight this species is easily mistaken for both *Sphenopteris latifolia* and the upper part of the frond of *Alethopteris nervosa*, Plate XVIII., fig. 3. It differs from them both by its remarkable nervation. The nervules do not branch from the middle, but from the lowest nervule, which runs nearly parallel, and very near to the medial nerve.

13. *Sphenopteris polyphylla*, Lind. and Hutt., *Foss.*, Plate II., p. 185, t. 147.—Frond bipinnate or tripinnate, pinnæ alternate, open; pinnules alternate, petiolate, oval, inferior ones pinnatifid, superior trilobed, divisions round, ovate, entire, the terminal ones twice as large; rachis flexuous; nerves pinnate, forking near the margin. South Salem Vein, Pottsville. Scarce.

14. *Sphenopteris Newberryi*, Lesq., Plate IX., fig. 4.—Frond dichotomous, forking in a very obtuse angle, bipinnate, secondary pinnæ long, lanceolate, linear, acute, pinnately lobed; inferior pinnules sessile by their whole base, but distinct, irregularly undulate, lobate; superior ones confluent, oval lanceolate, entire, or slightly undulate, the terminal small and pointed; nerves obsolete. Found by a miner at Summit Mines, between Tamaqua and Mauch Chunk in the upper vein (red-ash coal; precise locality undetermined). A very remarkable species for its peculiar ramification. The broad rachis is flattened, or slightly marginate; the inferior leaflets are ordinarily larger than the other, and trilobate. It has some resemblance to the following species, and stands in the same division. Dedicated to our friend Professor Newberry, the palæontologist of Georgetown.

15. *Sphenopteris Lesquereuxii*, Newb., *Annals of Science*. *Vide* our Plate X., fig. 1.—Frond bipinnately divided; pinnæ alternate, long, flexuous, lanceolate; inferior pinnules cordate-oval, distant, pinnately three to five lobed or undulate; superior ones oval, or half round, confluent and decurrent, entire; nerves dichotomous, arched, obsolete medial nerve slender and undulate; rachis irregularly and deeply dotted or tuberculate. Room Run Mines, near Mauch Chunk. By its nervation this species resembles a *Neuropteris*, and would take its place in the genus *Adiantites*, as it has been characterised by M. Göppert. By the form of its leaflets only it has some affinity with *Sphenopteris latifolia*. It is common in the coal-fields of Ohio and Pennsylvania.

16. *Sphenopteris squamosa*, Lesq., Plate X., fig. 3.—Frond bipinnatifid; pinnæ linear, short, obtuse; pinnules nearly square, or half round, very entire, sessile; the superior ones confluent or joined together; terminal

leaflet large, lobate, angular, obtuse; nerves entirely obsolete, the surface appearing covered with small shining scales. South Salem Vein, Pottsville. The true place of this species is doubtful, the leaflets being thick and the nerves entirely obliterate, either by a thick parenchyma or something like a mat of scales. It was found in connection with *Dyctiopteris obliqua*, and resembles the upper branch of this species as we have figured it—Plate VIII., fig. 6.

17. *Sphenopteris artemisiæfolia*, Brongt., *Hist. des Veg. Foss.*, i. p. 136.—Frond dichotomous, inferior pinnæ alternate; superior ones opposite, bipinnately divided; pinnules unequal, alternate, petiolate, obtuse, deeply pinnatifid, lobate, or laciniate; divisions linear or cuneate, with obtuse lobes; nerves numerous, flabellate. A small specimen of this species has been found near Pottsville.

II. Hymenophyllites, Göpp.—Frond membraneous, bipinnate or tripinnate, either irregularly cut, lobate, or pinnatifid and dichotomous, decurrent on the rachis. Nerves pinnate, excurrent, solitary in each division.

1. *Hymenophyllites furcatus* (?) Göpp., *Syst. Fil. Foss.*, p. 259; *Sphenopteris furcata*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 179, t. 49, figs. 4, 5.—Frond tripinnatifid, common rachis subulate, with its divisions nearly perpendicular, pinnules oblique, deeply pinnatifid, lobes bitrifid, the inferior ones nearly palmately divided, with the divisions linear-lanceolate, oblique, diverging, plane, and slightly acute or truncate. In the red shale of the Ponent Series south of Pottsville, and in the same formation near Mauch Chunk. In the American form of this plant, which may be a peculiar species, the lobes are scarcely acute, and often truncate. This fern appears to have been a very large one; it is mixed with stems, some of which are 3 inches in diameter, and apparently belong to the same plant.

2. *Hymenophyllites Hildreti*, Lesq., Plate IX., figs. 5, 5 *a*.—Frond bipinnate, secondary pinnæ lanceolate, open, alternate, the inferior bipinnately, the superior pinnately divided; divisions linear acute. Presented by Dr Hildreth, of Marietta, to whom we have dedicated this beautiful species, found at Kenawha Salines, on the lowest beds there exposed. It has some affinity with *Hymenophyllites obtusilobus*, Göpp., but the divisions in our species are evidently acute.

3. *Hymenophyllites capillaris*, Lesq., Plate IX., fig. 6.—The small specimen figured is scarcely worth a description as a peculiar species. It differs from the former by its very narrow and longer divisions. The ramification is not distinct. It looks at first like a branch of a *Sphenophyllum;* but it is a true *Hymenophyllites* by its nervation and its general outline. Found at the same locality as the former, of which perhaps it is only a variety.

III. Pachyphyllum, Lesq.—Frond large, thick, membraneous, oval or lanceolate in outline, either pinnately or irregularly lobed, radical, or borne on a thick rachis (?); divisions short, lanceolate, obtuse, or long, linear, flexuous. Nerves thick or compound, and parallel near the base; separating above, and solitary in each division, or disappearing totally. We have united in this genus a few species, of which the analogy with living ferns is scarcely known. Their affinity with the former genus is indicated only by the solitary nerve of each division; but beyond this these plants have nothing by which they might be related to the class of the *Phenopterideæ*. These plants, at least our *Pachyphyllum hirsutum*, may be compared to the family of the *Parkeriaceæ* in the living ferns—viz., to the inferior and sterile leaves of the *Parkeria pteroides*, Hooker, found in the marshes of Guyana. These inferior or sterile leaves are pinnatifid, with about three divisions, broadly oval in outline, and diversely lobed. The primary nerve is very thick near the base, simply pinnately branching at each division, quickly narrowing, and disappearing, like the secondary nerves, below the summit of the leaves. The divisions of the fertile leaves are narrow, linear, and much longer, and in these the veinlets are reticulated in an irregular, polygonal, oval, or square form, as they are in many of the leaves of the *Hypnaceæ* in the family of the Mosses. By comparison of the figure of Hooker and Greville, *Icones*, tab. 97, the likeness of the living species with our fossil plant is striking, and would evidently prove much more so without the thick coat of hairs with which our plant is covered. The affinity of *Pachyphyllum lactuca* with the other species of this genus is scarcely acceptable. Nevertheless, we think it much more in place in this genus than either in the *Schizopteris*, from which it evidently differs by its single-nerved lobes, or in the *Aphlebia*, which have no nerve at all.

1. *Pachyphyllum fimbriatum*, Lesq., Plate VIII., fig. 2.—Frond large, pinnate, pinnules sessile, distant, oblique, pinnately divided; divisions lanceolate, acute, short-fringed on the slightly-recurved margin; nerves pinnate, simple. Salem Vein, Pottsville.

2. *Pachyphyllum affine*, Lesq., Plate VIII., fig. 1.—Very like the former, differing only by the flattened and entirely smooth margins of the divisions. Perhaps only a variety. Same locality as the former.

3. *Pachyphyllum hirsutum*, Lesq., Plate VIII., fig. 3.—Frond bipinnately divided, dichotomous, pinnæ decurrent; divisions short, oval-acute; nerves obsolete, the whole surface and margins covered with long glandular hairs. Gate Vein, Westwood. A beautiful species, which, without its affinity with *Parkeria*, would scarcely be accepted as a fern. It appears to have had a thick medial nerve, and one nervule for each of the divisions of the leaves. It is a plant of the same kind as the two former. It may be compared with *Dictyophyllum rugosum*, Lind. and Hutt.; but we cannot see how it can be compared with a thistle, and classed among the dicotyledonous plants. It has the ramification of an endogenous plant.

4. *Pachyphyllum laceratum*, Lesq.—A species like the former, but smooth, and with the divisions undulate and unequally toothed. A small indistinct specimen, found at Johnstown, in the lowest vein of coal.

5. *Pachyphyllum lactuca*, Lesq., Plate VIII., figs. 4, 5.; *Schizopteris lactuca*, Sternb.—Frond pinnatifid (?), pinnæ lanceolate or oval in outline; pinnatifid, the lobes lanceolate, pinnately divided, divisions linear-obtuse; primary

nerves obliterate, appearing parallel and fasciculate below; simple in each division. Gate Vein, below New Philadelphia. This species was evidently of thin texture, and, by this character, would be well classed among *Hymenophyllites.* We have seen a broken specimen, three times as large as fig. 4, of which the leaves or pinnæ appeared as being attached to a broad common rachis, and through the impression of which the form of fossil ferns below it was discernible in their outline. The pinnæ were about half a foot long; but the slate was too brittle, and the specimen could not be preserved. This species is not scarce, either in the coal-formation of America or that of Europe.

III. Pecopterideæ.—Frond either simple, pinnate, bi-tripinnate, or bi-tripinnatifid; pinnules attached to the rachis by the whole of an equal or dilated base, ordinarily united together, and very seldom attenuated; medial nerve strongly marked; secondary nerves or nervules ordinarily perpendicular to the medial nerve, or diverging from it, simple, and rarely forking or dichotomous, bi-trifurcate. Fruit-dots marginal, either attached to the nerves, and lengthened or punctiform. We have removed from this section all the genera admitted by Göppert, and characterised by the form and the position of the fructification, except one—*Asplenites.* In this genus only the form of the fruit-dots is evidently lengthened as in the *Asplenium*, and their form is easily discernible. But in every other specimen of fructified fern that we have found, we have been unable to find any reliable characters which authorise a separation from the genus *Pecopteris.* That this genus is overcharged with species that have no near affinity with each other, is evident. But the separation of the genera, determined by the form and the position of the fruit-dots, before the whole of a plant is perfectly known, causes only increased obscurity, and a useless multiplication of species, by compelling the admission of a fructified part of a fern into one genus, whilst the sterile part of the same is classed and described in another.

Asplenites, Göpp.—Fruit-dots linear, attached to the back of secondary nerves; nerves pinnate, nervules simple or dichotomous; frond pinnate or bi-tripinnate.

1. *Asplenites rubra*, Lesq.—Frond bipinnate (or tripinnate?); pinnæ broadly linear, half open, alternate; pinnules oval-oblong, united at the base; nervules forking from the base; fruit-dots linear, placed in two rows between the margins and the medial nerves; rachis thick. The remains or impressions of this fern cover of themselves a bed of red shale of the upper part of the coal-basin near Marietta, Ohio, in a depression of a rock named, from the presence of this fern, the Grotto of Flowers. It has a close affinity with *Asplenites nodosus* (Göpp.), and only differs from it by the stem being not inflated, and knotty at the articulations of the pinnæ, and by the nervules forking from the base.

Alethopteris, Sternb. and Göpp.—Frond bi-tripinnatifid or bi-tripinnate, secondary nerves rising perpendicularly or obliquely from the medial one, simple or dichotomous, and many times forking; margins of the pinnules often revolute (turned back). Fruit unknown.

1. *Alethopteris lonchitidis*, Sternb., *Vers.*, i. p. 21; *Pecopteris lonchitica*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 275, t. 84, figs. 2, 3, 4, t. 128.—Frond bi-tripinnate; pinnæ open, alternate, the inferior ones bipinnatifid; the superior ones pinnatifid; pinnules open, alternate, lanceolate-linear, long, acute, slightly oblique, decurrent at the base, and united or distinct, convex on the margins; medial nerve broad, canaliculate, nearly excurrent; nervules perpendicular, slender, close, simple or dichotomous. Found in abundance in the lower beds of the coal-field of Ohio, especially at Cuyahoga Falls and Kenawha Salines, Virginia; and also in the upper beds of the anthracite coal at Pottsville. Gate and Salem Veins.

2. *Alethopteris Pennsylvanica*, Lesq., Plate XI., figs. 1 and 2.—Inferior pinnæ bipinnatifid, with short, round pinnules, united half their length; superior pinnæ pinnate only, with long lanceolate-linear and undulate pinnules, slightly decurrent on the rachis, and united at the base. Salem Vein, Pottsville. Perhaps this is only a variety of the former species, for it has exactly the same general appearance, and the same nervation. Nevertheless, as we have never seen, in the true *Alethopteris lonchitidis*, any trace of the lower bipinnate frond, and have never seen any undulate-serrulate pinnules, as figured in Plate XI., fig. 1, we could not unite the species. Both parts of the plant of Plate XI., figs. 1 and 2, evidently belong to the same fern; and we have here a confirmation of the analogy of this class of the *Pecopterideæ* with the *Pteris* of our age. In our *Pteris aquilina*, for example, the inferior pinnæ are bipinnatifid below, like our fig. 2, and only pinnate above. And on the same plant also the pinnules are found either entire, or undulate-crenate, like fig. 1.

3. *Alethopteris aquilina*, Göpp., *Syst. Fil. Foss.*, p. 298; *Pecopteris aquilina*, Brongt., *Hist. des Veg. Foss.*, vol. i. p. 248, t. 90.—Frond bipinnatifid; pinnules very open, close, oblong obtuse, united at the slightly-decurrent base, or sometimes separated to the rachis; the terminal leaflet oblong obtuse; secondary nerves perpendicular to the medial one, either bifurcate, or with one of the nervules simple. This species is often mentioned as being commonly found in the coal-basins of America; and we have seen many specimens under this name in Collections. Nevertheless, we could not find any well-characterised specimen of it, and all those which were shown to us under this name belong, we think, without any exception, to *Pecopteris polymorpha;* and so we mention this species with doubt as belonging to the American coal-formation.

4. *Alethopteris urophylla*, Göpp., *Syst. Fil. Foss.*, p. 300; *Pecopteris urophylla*, Brongt., *Hist. des Veg. Foss.*, i. p. 290, t. 86.—Frond bi-tripinnatifid; pinnatifid only above; terminal pinnæ linear, very long, entire, decurrent; inferior pinnæ deeply pinnatifid, terminated in a linear elongated leaflet; lateral pinnules united at the base, oblong linear, slightly obtuse; secondary nerves very thin, simple or dichotomous, slightly oblique. A small specimen found at the Gate Vein, Pottsville.

5. *Alethopteris Serlii*, Göpp., *Syst. Fil. Foss.*, p. 301, t. 21; *Pecopteris Serlii*, Brongt., *Hist. des Veg. Foss.*, i. p. 292, t. 85.—Frond bipinnatifid; pinnules oblong, oblique, enlarged and decurrent at the base, obtuse or slightly acute; terminal leaflet lanceolate; secondary nerves nearly perpendicular to the medial one, very numerous and thin, close, dichotomous. Both varieties of this species are abundant in the lowest veins of the Bituminous coal and anthracite basins of Pennsylvania. The variety α, identical with the European species, with obtuse leaflets, was found at Room Run mines, above Mauch Chunk, and at many other places in the Mammoth Vein; variety β, with the pinnules slightly acute, was found at Wilkesbarre, at Minersville, and also at the Kenawha Salines, Virginia.

6. *Alethopteris marginata*, Göpp., *Syst. Fil. Foss.*, p. 301; *Pecopteris marginata*, Brongt., *Hist. des Veg. Foss.*, i. p. 291, t. 87.—Frond bipinnatifid, pinnæ sessile, open, deeply pinnatifid; pinnules contiguous, oblong, slightly obtuse, decurrent, and united together, undulate-sinuate, and slightly emarginate; terminal leaflet oblong, lanceolate, obtuse; rachis and medial nerves rough; nervules very slender, perpendicular to the medial nerves, nearly simple. Tremont New Vein. In our specimen the pinnules are smaller, but probably represent the upper part of a frond; the leaflets are sessile, scarcely decurrent, and nearly distinct to the base.

7. *Alethopteris distans*, Lesq., Plate XII., fig. 2.—Frond bipinnatifid; pinnæ open, linear lanceolate; pinnules alternate, linear, distant, crenulate, enlarged but distinct at the base; united only in the upper part of the terminal pinnæ, where they become broader, shorter, and obtuse; secondary nerves obsolete. Found at Muddy Creek. We publish this species as a new one with some doubt, though we do not know anything for which it might be taken. It has a distant likeness to *Alethopteris Davrenzii*, differing from it by the crenulate leaflets. It may be also the upper part of the frond either of *Pecopteris abbreviata*, or of *Pecopteris plumosa*. As the nervules are entirely obsolete, and we can rely only on the form of the pinnules—a deceptive character—we cannot assert anything else except the peculiar form of these leaflets.

8. *Alethopteris obscura*, Lesq., Plate I., figs. 13, 14.—Frond bipinnatifid, pinnæ pinnatifid above; pinnules lanceolate, enlarged at the base, united together, and decurrent above, distinct below; deeply undulate on the margins, secondary nerves obsolete, very slender and oblique, bifurcate. Gate Vein, Pottsville. A beautiful species, distinct from all its congeners by the peculiar position of its secondary nerves rising from the narrow undulate medial nerve in a very acute angle. We have found only the specimens figured here, which probably represent the upper part of a frond.

9. *Alethopteris serrula*, Lesq., Plate XII. fig. 1.—Frond pinnatifid, very large; pinnules alternate, sessile, quite open, or inclined backwards; 4 inches long, and more linear, pinnately lobed; lobes alternate, two to three times toothed, sometimes nearly entire, obtuse; secondary nerves dichotomous, forking one or two times. Gate Vein behind Port Carbon. This remarkable species is related to *Pecopteris angustissima* and *Pecopteris similis*, Sternb., but perfectly distinct from both by the long leaflets, the lobes of which are once or twice toothed. The rachis is round and smooth. This fossil fern has so much affinity with *Davallia pinnata*, Der. (*Saccoloma pinnatum*, Presl.), that it is scarcely possible to find any difference between them. The fruit appears to be in the same position, and if this is the case, this plant would necessarily be far removed from the genus Pecopteris.

10. *Alethopteris nervosa*, Göpp., *Syst. Fil. Foss.*, p. 312.—Frond bi-tripinnate; pinnæ and pinnules nearly open; pinnules entire, oblique, oblong, lanceolate or oval, enlarged at the base, decurrent and united together; terminal pinnule oval, or linear oblong, the inferior leaflet of each pinna bilobate; secondary nerves distinct, oblique on the medial nerve, the inferior ones forking, the superior entire, thick. This species is abundant in the anthracite basins of Pennsylvania, at Shamokin, Pottsville, &c., and is very variable. Sometimes the leaflets are large and acute; sometimes near the top of the fronds the pinnæ are only pinnately lobed with round short lobes, entire, oval, obtuse, or slightly undulate. *Vide* Plate XVIII. fig. 3. We have had opportunities for finding it by itself on the same slate in its different varieties, and for ascertaining that the species described by M. Brongniart, and figured Plate XCV., figs. 1 and 2 of his *Hist. des Veg. Foss.*, belong truly to this, and not to *Pecopteris Sauveurei*, as has been asserted by M. Göppert.

11. *Alethopteris lævis*, Lesq.—Under this name, and till it is better known, we mention a form of which we could only obtain small specimens, and which does not appear to differ from the former, except by its entirely smooth surface, on which there cannot be seen any trace, either of secondary nerves or of medial ones. The pinnules are scarcely broader than in the former species, and the inferior leaflet is probably bilobed. Found at Gate Vein, New Philadelphia.

12. *Alethopteris muricata*, Göpp., *Syst. Fil. Foss.*, p. 313; *Pecopteris muricata*, Brongt., *Hist. des Veg. Foss.*, p. 352, t. 97.—Frond bipinnatifid or tripinnatifid, pinnæ or pinnules open, superior leaflets oval-lanceolate, acute, close, slightly decurrent at the base, the inferior ones distant, irregularly, pinnately lobed; lobes oval-acute, secondary nerves dichotomous, oblique on the medial nerve, simple or furcate. South Salem Vein, Pottsville. There is no difference between the American and the European form of this species.

III. Callipteris, Brongt., *Tab. des Veg. Foss.*, p. 24.—Frond bipinnatifid; pinnæ long, decurrent on the common rachis; pinnules contiguous, slightly oblique, united and decurrent at the base; medial nerve arched and oblique; secondary nerves oblique, bifurcate; fruit-dots punctiform, inserted on the divisions of the nerves near their bifurcation. We have adopted this genus as it is established by M. Brongniart, admitting in it only those species which have the nervation of *Neuropteris*, but which, by their general outline, and the punctiform fructification, belong to *Pecopteris*.

Callipteris Sullivantii, Lesq., Plate V., fig. 13.—Frond bipinnate, pinna lanceolate, pinnules alternate, oblique, obovate or oblong, nearly contiguous, slightly decurrent by their base, and united together with a slightly-obtuse sinus. Medial nerve very broad, disappearing above the middle; secondary nerves arched, slender, close, many times forking, or dichotomous. West Vein at Shamokin. A beautiful species, dedicated to our friend W. S. Sullivant, Esq., the well-known American Bryologist. The nearest species described is *Neuropteris conferta*, Sternb., of which M. Göppert has given a good description, with drawings (*Gatt. Foss.*, Plates V. VI., t. 8, 9, fig. 2). In our species the pinnæ are shorter, broader, and lanceolate; the pinnules are never separated to the rachis, and the superior leaflet is very small. The broad flat medial nerve vanishing above the middle is also a point of difference.

IV. PECOPTERIS, Brongt.—Fronds bi-tripinnate or pinnatifid, pinnæ ordinarily enlarged, united together, and decurrent at the base, or sometimes separated, distinct and sessile; secondary nerves rising obliquely from the medial one; dichotomous or simple; fruit-dots round, diversely placed, ordinarily two-ranked.

1. *Pecopteris Cistii*, Brongt., *Hist. des Veg. Foss.*, i. p. 330, t. 106, figs. 1, 2; *Pecopteris pteroides*, Brongt., *Hist. des Veg. Foss.*, i. p. 329 (Tremont, roof New Vein); *Alethopteris Cistii*, Göpp., *Syst. Fil. Foss.*, p. 316.—Frond bipinnate; pinnæ and pinnules open; pinnules entire, oval, oblong, obtuse, free and sessile by the slightly enlarged base; terminal leaflet short, oval, the inferior attached to the common rachis at the base of the pinnæ; secondary nerves dichotomous, slender, the nervules forking. This species appears to be very scarce in the anthracite basins: it was sent to M. Brongniart from Wilkesbarre. All the specimens which we collected there, as related to this species, were, after a closer examination, referred to the following one.

2. *Pecopteris polymorpha*, Brongt., *Hist. des Veg. Foss.*, i. pp. 331, 332, t. 113; *Pecopteris Miltoni*, Brongt., *loc. cit.*, pp. 333, 114; *Cyatheites Miltoni*, Göpp., *Syst. Fil. Foss.*, p. 324.—Frond tripinnatifid; rachis smooth; pinnæ and pinnules open, alternate; pinnules slightly contracted at the base, close to each other, oblong, obtuse, the medial ones sinuate, the inferior pinnatifid; fertile leaflets longer, and somewhat crenulate; secondary nerves dichotomous, nearly perpendicular to the medial nerve; nervules simple or forking. Gate Vein, Pottsville, Muddy Creek, &c. Though we have found many varieties of this species, which is common in the anthracite basin, we could not observe a reliable character to separate it from *Pecopteris Miltoni*. We should even, perhaps, refer to it the following species.

3. *Pecopteris distans*, Lesq., Plate XI., fig. 3.—This differs from the former only by its distant pinnules, oval-lanceolate, narrowed at the base, and sessile only by the base of the thickened medial nerve. Same locality as the former. This species may perhaps be the same as *Pecopteris elliptica*, Bunb. (*Proc. of Geol. Soc.*, vol. ii. p. 84); but it differs by the veins, which are branching from the middle, or from the base; and by the leaflets, which are not decurrent on the stem.

4. *Pecopteris velutina*, Lesq., Plate XII., fig. 3.—Frond bipinnatifid; lower pinnæ very open; pinnate, short, linear-lanceolate; pinnules distinct, enlarged above the base, sessile, united only near the summit of the pinnæ, where they form a large lanceolate oval and lobate terminal leaflet; upper pinnæ simple, pinnately undulate, lobed or entire; nerves obsolete, the surface being covered with a coat of short appressed hairs; fruit-dots placed only at the upper part of the pinnules, few, two-ranked, large, oval. We have found at Johnstown, in one of the lowest beds of the coal, a beautiful and well-preserved specimen of this species. By the form of the leaflets only, it has some likeness with *Pecopteris Defrancii*, but it is a very different plant.

5. *Pecopteris ovata*, Brongt., *Hist. des Veg. Foss.*, i. p. 328, t. 107, fig. 4; *Alethopteris ovata*, Göpp., *Syst. Fil. Foss.*, p. 314.—Frond bipinnatifid; pinnæ linear, lanceolate, acute; superior pinnules oval, the inferior ones oblong, obtuse, convex, enlarged at the base, and united, the lowest leaflet attached to the common rachis at the base of the pinnæ; secondary nerves dichotomous, very thin, two or three times forked, attached to the medial one in an acute angle. New Vein, Tremont. In our American specimens the pinnæ are very long, pointed, and the terminal leaflet lanceolate. If this species is identical with the European one (only to be ascertained by a comparison of specimens), M. Brongniart has only seen or described the upper part of a frond, for in the inferior pinnæ the leaflets are much longer and narrower, resembling those of *Pecopteris Defrancii*. The nervation is perfectly alike in the American species, as described by M. Brongniart.

6. *Pecopteris notata*, Lesq., Plate XVIII., fig. 4.—Frond tripinnate; secondary pinnæ horizontal, short, linear-lanceolate, obtuse, sessile; pinnules short, oval, united nearly to the middle; terminal leaflet large, oval, obtuse; nervules strongly marked, one time forking, attached to the undulate slender medial nerve in an acute angle; rachis striate; fruit-dots very small, punctiform, irregularly placed along the nervules between the branches. The Gate Vein, Pottsville. The short and broad leaflets, and especially the strongly-marked though slender nervules, separate this species from the following. It is covered with small dots, pointing in relief on the surface of the leaflets, and irregularly placed between the nervules. We think that they are the impressions of fruit-dots. If we are right, this species would belong to the genus *Hemitelites* of Göppert.

7. *Pecopteris oreopteridis*, Brongt., *Hist. des Veg. Foss.*, i. p. 317, t. 104, fig. 2, and 105, figs. 1–3.—Frond bi-tripinnatifid; pinnæ and pinnules open, close, alternate; pinnules distinct, sessile, elliptical, obtuse; nervules forking from the base or the middle, oblique; fertile leaflets distant, longer, oval-lanceolate, with the margins recurved. The Gate Vein and Salem Vein, Pottsville.

8. *Pecopteris pusilla*, Lesq., Plate XI. fig. 4.—Frond bipinnate; pinnæ oblique, linear, nearly decurrent on a broad, flexuous, and winged smooth rachis; pinnules very small, united above the middle, oval, hairy, the lowest a little larger; nervules simple, obsolete. Salem Vein, Pottsville. It much resembles the smallest forms of the

following species, but differs in the hairiness of the leaves. It differs also from *Pecopteris villosa* by the smooth rachis and the small size of all its parts.

9, 10. *Pecopteris arborescens*, Brongt., *Hist. des Veg. Foss.*, i. p. 310, t. 101, 103, fig. 1.—Frond bipinnate or tripinnate, with a smooth-winged rachis; pinnæ long, close to each other, open; pinnules imbricated, but free to the base, equal, oblong, oval, short, and very obtuse; terminal leaflet larger; secondary nerves simple, oblique. It is commonly found in the upper beds of the anthracite coal, as at the Gate and Salem veins, at Pottsville, with both its varieties, *Pecopteris platyrachis*, Brongt. (*loc. cit.*, p. 312, t. 103, figs. 4, 5), which only differs from the normal form in the thickness of the rachis, and *Pecopteris dubia*, Lesq., which has the rachis covered with long glandular hairs.

11. *Pecopteris cyathea*, Brongt., *Hist. des Veg. Foss.*, i. p. 307, t. 101.—Frond bipinnate or tripinnate (?); rachis smooth; pinnæ and pinnules very open; pinnules unequal, very close to each other, linear-oval, obtuse, separated to the base; secondary nerves simple or forked once only, perpendicular to the medial nerve; fruit-dots two-ranked, small in the divisions of the nervules; fertile pinnules, with the margins curved backwards. A species commonly found in the upper beds of the anthracite basin, at the Gate Vein of Port Carbon, and scarcely distinguishable from the former.

12. *Pecopteris arguta*, Brongt., *Hist. des Veg. Foss.*, i. p. 303, t. 108, fig. 3; *Polypodites elegans*, Göpp., *Syst. Fil. Foss.*, p. 344, t. 15, fig. 10.—Frond pinnate; pinnæ open, straight, very long, close to each other; pinnules equal, contiguous, united at the base, linear, oblong, obtuse, undulate-plicate on the margins; secondary nerves simple, oblique, well marked, straight. The South Salem Vein, Pottsville; commonly found in the upper beds of the coal-basins.

13. *Pecopteris abbreviata*, Brongt., *Hist. des Veg. Foss.*, i. p. 337, t. 115, figs. 1–4.—Frond bi-tripinnatifid; pinnules oblong, obtuse, crenate, or slightly pinnately lobed; lobes round, convex, very short or longer, like pinnules; nerves pinnately forking in each division, ordinarily forking again from the middle. Found in the low beds of coal at Trevorton. A variable species. In our specimen the nervules are obsolete.

14. *Pecopteris unita*, Brongt., *Hist. des Veg. Foss.*, i. p. 342, t. 116, figs. 1, 5.—Frond bipinnatifid; pinnæ oblong, pinnatifid; pinnules united to the middle, sometimes in their whole length, so that the pinnæ are only crenulate on the margins; medial nerve of each pinnule oblique; nervules pinnate, simple, very oblique; fruit-dots simple two-ranked, attached on the simple nervules; fertile leaflets, with the margins recurved. Var. *α.*, pinnæ entire, and only crenulate on the margins. *Pecopteris unita*, Brongt. (*Prod.*, p. 58); var. *β. majus*, pinnæ pinnatifid, the pinnules united only to the middle. *Pecopteris pectinata*, Brongt. (*loc. cit.*), var. *α.*, at the South Salem Vein, Pottsville; var. *β.* Muddy Creek. In each of these varieties the fruit-dots preserve the same position.

15. *Pecopteris concinna*, Lesq., Plate XI. fig. 5.—Frond bipinnate; pinnæ open, with an undulate rachis; pinnules oval, lanceolate, sessile by a narrowed base, distant and perpendicular to the rachis; pinnately undulate, lobed; secondary nerves pinnate in each lobe; nervules simple. Gate Vein, Pottsville. A fine species, differing from *Pecopteris abbreviata* by the form of the pinnules, and from *Pecopteris angustissima* by its nervation.

16. *Pecopteris pennæformis*, Brongt., *Hist. des Veg. Foss.*, i. p. 345, t. 118, figs. 3, 4.—Frond tripinnatifid; pinnæ long, linear; rachis covered with small glandular points; pinnules slightly united at the base, elliptical, oblong, obtuse, perpendicular to the rachis; the lowest slightly longer; secondary nerves pinnately forked; nervules ordinarily forking again from the middle. Tremont New Vein.

17. *Pecopteris plumosa*, Brongt., *Hist. des Veg. Foss.*, i. p. 348, t. 121, 122.—Frond tripinnatifid; pinnæ long, acute; superior pinnules united, triangular, acute, with the secondary nerves simple; medial pinnules oblong-triangular, more obtuse, enlarged, and united at the base, with the secondary nerves ordinarily forking; inferior pinnules oblong-obtuse, scarcely enlarged, and united at the base, very entire, the lowest oblong-linear, crenulate on the margins, distant, with all the nervules forked. Scarce in Pennsylvania; found only at the South Salem Vein, Pottsville.

18. *Pecopteris Sillimanni*, Brongt., *Hist. des Veg. Foss.*, i. p. 353, t. 96, fig. 5.—Frond bipinnatifid; pinnæ short, the superior entire, the inferior ones pinnatifid, seven to nine lobed; pinnules or lobes nearly round, obtuse, nearly contiguous; the lower distant, the upper ones united at the base; terminal lobe short, oval, entire, or three crenate; nervules very slender, forking one or two times; medial nerve scarcely more distinct than the lateral ones. Specimens of this species were sent to M. Brongniart from Zanesville, Ohio. We could not find any specimen of this species either in the field or in the cabinets which we have examined.

19. *Pecopteris Loschii*, Brongt., *Hist. des Veg. Foss.*, i. p. 355, t. 96, fig. 6.—Frond bi-tripinnate; pinnæ and pinnules shortening; inferior pinnæ bipinnate, with the upper pinnules united together; the medial ones separated to the narrowed base, and distant, ovate, acute; the lowest two five-lobed, nearly pinnatifid; nervules very slender, arched, forking from the middle. The Salem Vein, Pottsville. The American specimens of this species do not differ from the European.

20. *Pecopteris decurrens*, Lesq., Plate XI. fig. 5 *a.*—Frond bipinnatifid; pinnæ opposite, the superior ones terminal by the forking of the rachis; pinnules distant, oval-oblong, obtuse, entire, contracted at the base on the upper side; dilated on the lower, and decurrent on the rachis, which is broadly winged; medial nerve undulate, scarcely thicker than the lateral ones, which are simple, or sometimes forked and arched; primary rachis flattened and broad, enlarged at the articulations of the pinnæ, striate; and roughened by very small glandular points. The Gate Vein, Pottsville. A remarkable species, which does not well agree with *Pecopteris*, and should be taken as the type of a peculiar genus.

21. *Pecopteris incompleta*, Lesq., Plate I. fig. 12.—Frond bipinnatifid; pinnæ oblique, scarcely open, lanceolate; pinnules oval, or nearly round, decurrent, united at the base, very oblique; the superior ones very small, and the terminal wanting, its place being taken by the lengthened secondary rachis pointing above the leaflets; nerves dichotomous. The small specimen figured here was found at the Gate Vein, Pottsville. It is so imperfect that we cannot ascertain whether it represents only a part of a fern before its complete unfolding, or if this peculiarity of form belongs to a species in its state of perfection.

FERNS OF UNDETERMINED AFFINITY.

Crematopteris, V. P. Schimper.—Frond simply pinnate, rachis broad; pinnules vertical, oblique, oval-oblong, entire; nervation obsolete. Fruit-dots placed on the inferior pinnules, which are turned backwards, and are smaller than the upper ones. This genus has been established for a single species found in the red sandstone of the Vosges, *Crematopteris typica*, Schp. and Mouzeot, *Monog. of Fossil Pl.*, p. 73; *Filicites scolopendrioides*, Brongt., *Hist. des Veg. Foss.*, i. p. 388, t. 137, figs. 2, 3. Its relation with *Pecopteridiæ* is not ascertained, as there has not been found any trace of nervation in these plants.

1. *Crematopteris Pennsylvanica*, Lesq., Plate III. fig. 5.—Rachis very thick, round, nearly smooth, or irregularly striate; pinnules short, linear-oval, distant, sessile on the broad rachis, slightly attenuated at the base; nerves entirely obsolete. The specimen figured here is in the collection of Rev. Mr Moore of Greensburg, and was found by himself near this place in black shale, covered with marine shells, a little above the fourth vein of coal, and at the base of the Barren measures. This plant is not in as good a state of preservation as would be desirable for a satisfactory description; nevertheless it appears to belong to this genus. Its presence on a shale covered with marine shells would perhaps lead to the supposition that the plant is some *fucoide*, or sea-weed. We have examined closely the locality, and have been able to find there many other vegetable remains, all of them belonging to ferns and to calamites, especially a *Sphenopteris*.

Scolopendrites, Lesq.—Frond simple, lanceolate, large, deeply irregularly toothed; medial nerves very slender; nervules thin, pinnately forking from the medial nerve in a very acute angle, nearly straight and scarcely arched, undulate, very distant, one to two lines; forking one time in the middle, and each nervule forking again near the margin. This genus has no affinity with any of the other genera of fossil ferns. In the form of the leaves it would resemble the living *Scolopendria* of our time, but its nervation is different, the medial nerve being much more slender, and the nervules much more erect, or not so divergent from the medial nerve. Nevertheless the divergence of the nervules is less marked in some species of the genus *Scolopendrium*, as in *S. hastatum*, Duby; and also *S. hemionitis*. The general outline of the leaves of *Halypteris scolopendrina*, Hooker, and *Vittaria isoctifolia*, is also much alike; but the veins are simple in both these species, and more diverging. This plant, by its nervation, resembles perhaps some species of *Osmundæ* with large leaves—the largest leaflets of *Osmunda regalis*, for example. But its affinity with this genus is not so close as with the former ones, and as we cannot compare it with any other, we have preferred to name it after the living genus, which it resembles in the form of its leaves.

1. *Scolopendrites grosse dentata*, Lesq., Plate VIII. fig. 7.—The species corresponds to the description of the genus of which it is the type. The texture of the leaves was very thin, entirely smooth and shining, and its size probably large. We found a few specimens of it at the Gate Vein, New Philadelphia; but the shale being very brittle, we could not preserve a better specimen than the one figured here. Many of these leaves, of which the outline was obliterated, appeared wrinkled, as if they had been crushed in no one given direction.

STEMS.

The true relation of some of the stems found in the coal, with their branches and leaves, is indicated either by their form or by the situation in which they have been found, and also by the branches attached to them. This is the case, for example, with the *Calamites*. But when we come to the examination of most of the large trunks or stumps found in the coal of transition, we are only able to assert, by the impressions of their bark, either that they belonged to the bark of some fern tree, or to some genus of plants resembling the *Lycopodiaceæ* of our time. The study of those trees which are sometimes found well preserved in a petrified state is now satisfactorily progressing, by the examination of the internal structure of the wood. But this examination is possible only with the aid of a strong microscope, or very thin polished plates of the matter. As we have not until now had the facility for preparing these plates, and as all the petrified wood which we have seen in the coal-basins of Pennsylvania has been transformed into sandstone, and its vessels entirely obliterated, we can only rely for our descriptions on the prints left by the base of the leaves on the bark of those trees, and not attempt a classification fixed on other characters.

For the facility of our descriptions we shall separate all the vegetable remains which have not been mentioned above, into three classes,—1st, *Stems;* 2d, *Fruits;* 3d, *Roots.*

1st, Stems.—In the slates covering or supporting the coal, nothing remains of the trees which have been heaped for the formation of the coal except the impressions of their bark. We have given in the introduction such reasons as we could for the explanation of this remarkable phenomenon. Sometimes, it is true, the form of a tree is preserved entire, but this is seldom the case; and when it happens in the sandstone, the woody matter has entirely disappeared, and been transformed into sandstone, and the mould only of the external form remains marked upon the stone. Many of those trees became very large, and the impressions of their leaves, very small at first, but growing up and enlarging with them, and undergoing some modifications, may lead the observer into some unavoidable mistakes. As soon after as it was possible, we have compared specimens of different ages, and our descriptions of new species are exclusively in accordance with the form, but never with the size, of the impressions.

I. Caulopteris, Lind. and Hutt.—Stem very thick, tree-like, round, marked without with large scars left by the insertion of the petioles of leaves; scars disposed spirally, oblong, oval, with a broad double or simple margin (annulus), marked in the middle by a fascicule of vessels—simple, oval, or curved above, horn-like. In the species belonging to this genus, which, as we have asserted, contains the *Ptychopteris*, *Stemmatopteris*, and *Caulopteris* of Corda, the scars are ordinarily obsolete, and sometimes covered with the rootlets attached to the stem. The true form of the fascicule of vessels is visible only on one scar of our fig. 1, Plate XIII., in *a*, and it is easy to see how it has been overlooked till now, this form becoming entirely changed by the obliteration of the horns. Following the observations of Mr Lindley, and other authors, the scars in this genus are identical with those left on the stems of the tree-ferns by the falling of their leaves.

1. *Caulopteris punctata*, Lesq., Plate XIII., fig. 1.—Scars oval, obtuse, about 2 inches long, distant, with a broad smooth margin; fascicule of vessels simple, oval, forming the margin, and curved above in two horns. Interval between the scars thickly dotted with round elevated points resembling glands, but probably the base of small rootlets. A beautiful species found at the Gate Vein, New Philadelphia.

2. *Caulopteris gigantea*, Lesq., Plate XIII., fig. 2.—The difference between this species and the former is not only in the larger size of the scars, but in the entirely smooth surface, and the divergence between the horns of the vascular fascicule. The small specimen figured here is preserved in the beautiful collection of Mr Clarkson at Carbondale.

3. *Caulopteris Cistii*, Brongt., *Hist. des Veg. Foss.*, i. p. 418, t. 140, fig. 2.—In this species the form of the vascular fascicule is entirely obliterated; but it differs evidently from the two former by the intervals furrowed in the length—the scars being more distant, with a broader margin. It has been found at Wilkesbarre, sent to Europe, and described by M. Brongniart. We have not seen any specimens of it.

II. Psaronius, Corda.—Stem thick and tree-like, cylindrical or angular, externally marked with scars, the form of which is obliterated by a thick coat of rootlets covering nearly the whole stem; bark thick and hard. The internal structure of these trees is beautifully illustrated and described by M. Corda in his *Beytrage*. These fossil remains represent, we think, the petrified root-stalk of some large ferns, and do not belong, as M. Brongniart supposes, to the *Lepidodendron*. They are found in great abundance in some places, always in short thick stumps, which, either by the rootlets with which they are covered, or by their form and their internal structure, resemble the short trunks of large ferns as they are found in the tropical islands, especially on the mountains of Java. We cannot describe any species of this genus for the reason mentioned above—viz., the impossibility of polishing thin plates of them for microscopical investigation. But it is necessary for us to mention this genus, for the abundance of the specimens found in the coal-basins, and for their peculiar situation. Their place, wherever they have been found, is at the base of the Barren measures, a little above the fourth vein of coal, and very near the slates covered with marine shells and impressions of fern. There are a great many specimens at Greensburg, in the cabinets of the Rev. Mr Moore, and of Dr King, and especially at Marietta, in the beautiful cabinet of Dr Hildreth. These latter have been found near Athens, Ohio, but the others were collected around Greensburg, Pennsylvania. The specimens of Ohio are entirely silicified; and those which Mr Hildreth has had polished in Europe present as fine an appearance as the most beautiful agate. We have seen *Psaronius* also at Charlestown, Virginia, on the Great Kenawha Saline, and at Gallipolis, Ohio.

III. Diplostegium, Corda, *Beytrage*, p. 112.—Stem thick, tree-like, equal, round, marked with elevated scars, very near each other, and spirally; top of the elevated scars abruptly cut, rhomboidal.

1. *Diplostegium Brownianum*, Corda, *Beyt.*, p. 112, tab. 59.—This species is the only one of the genus described. It much resembles a *Knorria*, except that the elevated scars are abruptly cut and transversely broken, and not rounded at the top. We have found a specimen of this species at Summit Portage, below the Ponent, in a bank of sandstone, containing also large bivalve shells. Our species agrees well with the one described by M. Corda.

IV. Stigmaria, Brongt.—Stems creeping, 2 or 3 inches in diameter; dichotomous, covered with leaf-like round appendages, either simple or forking; slightly contracted at the base, with a single central vascular fascicule; scars round, with a double ring and a single elevated point (mamilla) in the middle. Every author who has studied the fossil plants has had a peculiar opinion about these fossil remains, the most abundant of any in the Coal-measures. It has been asserted, on the observations of Mr Joseph Hooker especially, that they were the roots of a peculiar genus of trees—probably the Sigillaria. We have had many good opportunities of examining large specimens of these vegetable remains in the coal-basins of Pennsylvania, and we have come nearly to the same conclusion. Near Minersville there is a flattened rock, entirely covered with *Stigmaria ficoides* on a surface of about 70 feet long and 25 broad. All the branches are nearly equal in diameter, and all dichotomous or forking, and, forking again, extending themselves in every direction, and evidently creeping on the mud or on a soft ground, where their rootlets or leaves supported them. We cannot say, with Messrs Lindley and Hutton, that they are coming out from a common axis; but that, at their point of union, they support a trunk of *Sigillaria*, or of another species of tree. At Minersville there is no trace of such an axis, but it has been observed many times; and we have ourselves seen, in the collection of Mr Moore, a beautiful specimen, illustrating the manner of branching of the roots from the tree. The stump is about 6 inches in diameter, with pretty large scars, and divided below into three diverging branches, of which the diameters are about a third of the diameter of the trunk, and of which the scars are slightly smaller, and of nearly the same form. As the specimen is a mould in the sandstone, the scars, which appear triangular, are not very distinct. This disposition of long creeping root-stalks is in perfect accordance with the places which the vegetables forming the coal occupied. It was the only one which could be devised to sustain large trees on a soft and ordinarily inundated ground. It explains the disproportion in the scarcity of trees with the great abundance of *Stigmaria;* for these plants having a growth by themselves, and probably nearly independent of the aerial plant or the tree, as is the case in some creeping and running plants, were extended in every direction, covering the ground by a network of their branches, and thrusting an aerial branch or a tree in some favourable condition. We cannot record here the observations made by different authors to prove that the internal structure of the *Stigmaria* is the same as the structure of the roots, but only eliminate, by a common observation, the opinion that the Stigmariæ and their *leaves* were fleshy plants, somewhat like the *Cacti* of our time, or like some *Euphorbiæ.* That they were hard plants is established by this fact—that they are found sometimes preserved in their outline, and scarcely flattened, in circumstances where all other vegetable remains have been entirely flattened or destroyed; and also that they are the only ones of which the impressions are preserved in the coal: the same may be said of their rootlets, generally named leaves. And as the coal is sometimes a compound of their remains only, it is not possible to deny that their texture was essentially woody, like the texture of ferns. Of their relation to *Sigillaria* we will assert nothing; but we think that their relation is as near to *Lepidodendron* as to *Sigillaria.* We have seen some impressions of *Stigmaria* possessing the form of *Sigillaria*, but the transition was not very distinct. As the number of trees, especially of *Sigillaria*, is large, and there are a great many different species of them, we think that it would be right to admit many species of *Stigmaria*, instead of classifying them in two or three species with a quantity of varieties.

1. *Stigmaria ficoides*, Brongt.—Stems creeping, branches alternate, dichotomous; rootlets long and round; intervals between the scars smooth or plaited, ribbed or wrinkled. It is the most common plant found in the coal-basins of Pennsylvania, especially in the lower veins. It has been many times asserted that these *Stigmaria* are commonly found in the shale of the bottom of the veins, and that they are scarcely present in the shales of the roof. We have carefully examined the general position of these plants, and have found them evenly distributed in the whole extent of the coal-basin, but generally in greater abundance in the low beds of coal. Sometimes this abundance at a particular locality is astonishing, either at the roof or at the bottom of the seams—so much so, that there are no traces of any other vegetables; but this predominance is nowhere so general a fact that we can draw any conclusions as to their distribution. In the bottom and also in the roof shales of the Mammoth Vein at Minersville, they are so plentiful that they entirely cover the slates; but one finds them nearly as abundant on the roof of the South Salem Vein at Pottsville—a vein generally considered as the uppermost of the anthracite series. Perhaps it may be asked why we admit these plants as creeping ones. It is easy to answer. On all the large surfaces covered with *Stigmaria* that we have examined, we have seen them horizontally placed, though they had preserved their cylindrical form in many instances; and in such cases their rootlets were descending in the shale in every direction, varying from a very oblique position to a perpendicular one.

2. *Stigmaria anabathra*, Corda, *Beytr.*, Plate XXXVI., p. 14.—Stem thick, forking, creeping; intervals between the scars either plated-ribbed or stellate. A very variable species, if we adopt the diagnosis established on the internal structure of the wood, without taking into account its external character. But we think that these internal characters—viz. the thickness of the woody cylinder, and the breadth of the vessels—may belong to many species. Commonly found with the former.

3. *Stigmaria costata*, Lesq., Plate II., fig. 3.—Differs from the former by the nearly regular, strong, and elevated ribs which separate the rows of scars placed in regular order, resembling the spiral position of the scars of *Sigillaria.* Perhaps our specimen, found at Salem Vein, Pottsville, was broken from the base of a *Sigillaria.* Perhaps this species is *Stigmaria regularis*, Brongt. (*Prod.*, p. 88), a species mentioned but not yet described by this author.

4. *Stigmaria umbonata*, Lesq.—Differs from *Stigmaria ficoides* by the scars being at least twice as broad and elevated, and having a single ring at the border. It may be *Stigmaria tuberculosa*, Brongt. (*Prod.*, p. 88), an undescribed species.

5. *Stigmaria irregularis*, Lesq., Plate II., No. 4.—Stem deeply and narrowly ribbed; scars distant and scarce, oval, sometimes acute at both ends, sometimes round, placed without order. As we have only the small specimen figured here, found at the Gate Vein, Pottsville, it would have been perhaps as well to omit mentioning it. Its appearance is very peculiar, resembling a calamites, with the marks of rootlets, and so evidently a *Stigmaria.*

6. *Stigmaria radicans*, Lesq., Plate II., No. 2.—Stem about two inches broad, narrowly striate in its length; scars irregular, and irregularly placed; rootlets apparently round and attenuated at the base. The Salem Vein, Pottsville. Scarcely a true *Stigmaria*, looking much more like a root.

7. *Stigmaria minuta*, Lesq., Plate XVI., figs. 1, 2.—Stem thick; lower scars very small, and near each other, placed in a spiral line, round; the superior ones more distant, oval, pointed, or open in their inferior part; central scars elongated, like a deep narrow line dividing the general scars. Both specimens figured here belong to the same species, found in the Vespertine below Pottsville. We have followed the transitions between both forms—the first evidently a *Stigmaria*, the second one belonging to a *Sigillaria*, or perhaps to a *Lepidodendron*.

V. Sigillaria, Brongt., *Hist. des Veg. Foss.*, i. p. 422.—Stems large, tree-like, ordinarily marked with parallel or reticulated ribs; scars of the leaves placed spirally in the middle of those ribs; scars disciform, oblong, round, scarcely lanceolate crosswise, with the sides mostly angular, marked in the middle by the vascular scars, ordinarily placed by three or by two, but seldom single. M. Brongniart, taking into consideration the internal structure of the plants of this class, has admitted them as probably belonging to the phanerogamous dicotyledonous plants, and so has removed them far from the *Lepidodendra*. We cannot admit this opinion. The leaves of the *Sigillaria*, their position on the stem, and the scars left by them, have so great an affinity with those of the *Lepidodendron* that we cannot but conclude that these classes of plants are closely related to each other. We have no plants now living which can be compared with the *Sigillariæ*—the nearest ones are the *Lycopodiaceæ*—and so we think that their true place, far removed from the dicotyledonous plants, is between the *Lycopodiaceæ* and the ferns, differing from the former in the manner in which the leaves are attached to the stem, and from the ferns especially by the form of their long, linear, grass-like leaves. Like the *Lepidodendra*, these *Sigillariæ* bore their leaves on their young shoots, or on the summits of their branches, and the leaves falling, easily left small scars, which were enlarged as the trees were growing up. We have never seen as large trunks of *Sigillariæ* as those of *Lepidodendra;* nevertheless, there are many standing around Carbondale, and visible in the bed of the river, of which the diameter is from 8 inches to 1 foot.

1. *Sigillaria lepidodendrifolia*, Brongt., *Hist. des Veg. Foss.*, i. p. 426, t. 161.—Stem without ribs, undulate, transversely wrinkled below the scars, the wrinkles parallel to the base of the scars; scars nearly rhomboidal; lateral angles acute, the inferior and the superior rounded; vascular scars, three well marked, the medial one punctiform, the lateral ones linear, arched; leaves long, keeled, three-nerved, enlarged at the base. Seen at the Lehigh Summit. The scars, though nearly obliterated, are visible enough to indicate that our species is the same as M. Brongniart's. It has also the leaves attached to it.

2. *Sigillaria sculpta*, Lesq., Plate XIII., fig. 3.—Stem irregularly and narrowly striate in its length, without ribs; wrinkles undulate; scars elevated, smooth, quadrangular, rhomboidal oblique, emarginate cordate above, with the other angles acute; vascular scars three, the medial one oval, placed crosswise, the lateral ones linear, arched. A fine species, somewhat resembling the following, but differing by the elevated scars, emarginated above, and pointed below. In its corticated state the scars are square and ribbed, as figured in *a*. The Gate Vein, New Philadelphia.

3. *Sigillaria obliqua*, Brongt.—Surface of the stem undulate, striate, or scarcely ribbed, the ribs indicated by undulate lines; scars oblique, half round at the base, angular, trapeziform above; vascular scars three, oblong. We have found it at the same vein as the former, but very scarce.

4. *Sigillaria fissa*, Lesq., Plate XIII., fig. 4.—Surface undulate, marked in its length by narrow, undulate, smooth lines; scars distant, elevated, cordate, obtuse in outline, deeply emarginate above, round, obtuse below, with two acute angles at both sides, and a single oval vascular scar, attached in the middle of a semilunar or arched ring. A beautiful species, found at Muddy Creek.

5. *Sigillaria dilatata*, Lesq., Plate XIII., fig. 5.—Surface marked with thin, undulate, and smooth, very narrow lines; scars near each other, plane, enlarged on the sides, and nearly twice as broad as high; emarginate cordate above, very obtuse below, lateral angles very acute; vascular scars three, the medial one broadly oval crosswise, the lateral ones, linear, arched. In its corticated state it is narrowly undulated on the whole surface, with the lines only diverging above the vascular scars, which are oval, the two exterior lengthwise, the central one crosswise. Preserved in the collection of Carbondale.

6. *Sigillaria Schimperi*, Lesq., Plate XIV., fig. 1.—Surface undulated, narrowly plaited, and striate crosswise; scars slightly undulated, striate in the same direction, nearly round in outline; the upper marginal line well marked, and extending horizontally on both sides, the inferior one slightly marked, rounded; vascular scars two, oval, placed below an arched linear depression. Muddy Creek. A beautiful and remarkable species, dedicated to our friend Professor W. P. Schimper, the eminent European Bryologist, and author of the *Fossil Flora of the Red Sandstone of the Vosges.*

7. *Sigillaria stellata*, Lesq., Plate XIV., fig. 2.—Surface deeply marked with undulated branching lines or wrinkles, diverging in every direction from the scars and around them; scars nearly plane, hexagonal, the upper side obtusely emarginate, the under side obtuse, the others straight, equal; vascular scars three, the medial one semilunar, the lateral ones placed a little higher, oval, pointed downwards, and diverging to the sides. Large specimens of this beautiful species are preserved in the cabinet of Mr Clarkson, at Carbondale.

8. *Sigillaria Menardi*, Brongt., *Hist. des Veg. Foss.*, i. p. 430, t. 158, figs. 5, 6.—Stem mamillate, furrows distinct, reticulated, joined crosswise; scars close, nearly as large as the mamillæ, equal, nearly round, slightly enlarged, and obtuse on the sides, emarginate above; leaves very long, linear, keeled, many-nerved; nerves parallel, equal, thin, obsolete. Muddy Creek and Gate Vein, New Philadelphia. Common in the superior beds of the anthracite basins of Pennsylvania. Our species is evidently the same as the one described by M. Brongniart;

it differs only by the very narrow furrows between the scars; but this is only accidental. We have seen also specimens with broader furrows.

9. *Sigillaria Brardii*, Brongt., *Hist. des Veg. Foss.*, i. pp. 65, 431, t. 158, fig. 4.—Stem undulate, mamillate; mamillæ nearly plane; furrows obtuse, distinct, reticulated crosswise; surface corticated, smooth, decorticated, striate in its length; scars nearly round, smaller than the mamillæ, with the angles acute on the sides, emarginate above; vascular scars three, oblong, the medial one transversal. Gate Vein of New Philadelphia.

10. *Sigillaria Defrancii*, Brongt., *Hist. des Veg. Foss.*, i. p. 432, t. 159, fig. 1.—Stems mamillate; mamillæ transversely lanceolate; furrows deep, acute, reticulate, distinct, smooth; scars discoid, with the lateral angle acutely keeled; inferior margin slightly convex, superior very arched and slightly emarginate; vascular scars three, the medial one like a point, the lateral ones linear, arched. Muddy Creek—scarce.

11. *Sigillaria Serlii*, Brongt., *Hist. des Veg. Foss.*, i. p. 433, t. 158, fig. 9.—Stem mamillate, with the mamillæ elevated, nearly rhomboidal, broader transversely; furrows deep and distinct; scars placed in the upper part of the mamillæ, transversely lanceolate, with the lateral angles very acute, decurrent in the mamillæ; vascular scars three points. Seen in the Trevorton low coal. The specimen is not very distinct.

12. *Sigillaria tessellata*, Brongt., *Hist. des Veg. Foss.*, i. p. 436, t. 157, fig. 1, t. 162, figs. 1-4.—Surface marked with longitudinal undulated narrow ribs; scars discoid, as broad as the ribs, about square; hexagonal, with the sides obtuse, and slightly emarginate above. Trevorton coal; specimen indistinct. It has been sent to M. Brongniart from Wilkesbarre.

13. *Sigillaria elegans*, Brongt., *Hist. des Veg. Foss.*, i. p. 438, t. 146, fig. 1; t. 155 and 158, fig. 1.—Surface ribbed; ribs and furrows deeply marked, alternately enlarged and narrowed, and so undulated; ribs slightly mamillate; mamillæ nearly hexagonal, convex, laterally broader; scars discoid, near each other, and nearly as large as the mamillæ; vascular scars three, the lateral ones arched, the central linear, horizontal. Lehigh Summit, and also New Philadelphia.

14. *Sigillaria Brochantii*, Brongt., *Hist. des Veg. Foss.*, i. p. 442, t. 159, fig. 2.—Stems marked with deep undulated furrows, slightly mamillate, smooth; scars oblique, rhomboidal, transversely lanceolate, with the lateral angle very acute; superior and inferior ones arched, obtuse; vascular scar, a single central point. Found at Lehigh Summit; a broken but distinct specimen.

15. *Sigillaria alveolaria*, Brongt., *Hist. des Veg. Foss.*, i. p. 443, t. 162, fig. 5.—Stem ribbed; ribs equal, narrow; scars discoid, nearly contiguous, oval, without angles; vascular scars, three points placed in the upper part of the disc. Shamokin.

16. *Sigillaria scutellata*, Brongt., *Hist. des Veg. Foss.*, i. p. 455, t. 150, fig. 23, t. 163, fig. 3.—Stems ribbed; ribs convex, equal, or alternately contracted and enlarged at the scars; furrows deep, straight, or sinuous, distinct; scars discoid, round, oval, about as large as the ribs; longer than broad, slightly angular on the sides, and round, keeled at the base; vascular scars three, punctiform. Found at Muddy Creek,—a poor specimen.

17. *Sigillaria Sillimanni*, Brongt., *Hist. des Veg. Foss.*, i. p. 460, t. 147, fig. 1.—Stem ribbed; ribs alternately and slightly contracted and enlarged; transversely wrinkled above the scars, and obliquely below; scars discoid, twice as far from each other as their length, a little narrower than the ribs, oval, oblong, rounded on each side; vascular scars three—the medial one punctiform, the lateral ones linear, arched. A species described by M. Brongniart, on specimens sent from Wilkesbarre. We have not seen any specimens of it.

18. *Sigillaria oculata*, Brongt., *Hist. des Veg. Foss.*, i. p. 461.—Stem ribbed; ribs narrow, with straight distinct furrows; bark smooth; scars discoid, oval-rounded, emarginate above, more distant from each other than the diameter of the ribs; vascular scars, three—the medial one punctiform, the lateral ones oblong, arched. Found at Trevorton in its decorticated state, as figured by Sternberg (*Vers.* 1-3, p. 40, t. 31, fig. 1), and described under the name of *Syrigodendron complanatum*.

19. *Sigillaria polita*, Lesq., Plate XIV., fig. 3.—Stem ribbed; ribs nearly plane, very smooth, as broad as the distance between the scars; separated by narrow, deep, and very straight furrows; scars discoid, enlarged both sides, round above, the lower margin convex, with two lateral angles very obtuse; vascular scars three—the medial one transverse, linear, straight in the middle, and convex at both ends; the lateral ones linear, arched. This fine species from Carbondale has some affinity with both *Sigillaria Saullii*, Brongt., and *Sigillaria hyppocrepis*, Brongt., different from the first by its straight and larger ribs—from the second by the round base of the scars and the flattened ribs.

20. *Sigillaria dubia*, Lesq.—Stems ribbed; ribs well marked, narrow, half an inch broad, with the furrows obtuse, deeply marked; very narrowly striate or wrinkled in its length; scars about twice as distant from each other as they are long; obovate, with the lateral angles scarcely marked; vascular scars three, placed above—the medial one semilunar, with the horns turned upwards, and nearly converging; the lateral ones linear, straight, parallel; bark thick, striate. Trevorton low coal. It is very near *Sigillaria Cortes*, Brongt. (*Hist. des Veg. Foss.*, i. p. 167, t. 147, figs. 3, 4); differing only in the greater distance of the scars, being broader at the base, and by the wrinkles more deeply marked on the ribs. Perhaps a variety.

21. *Sigillaria obovata*, Lesq., Plate XIV., fig. 4.—Stem ribbed; ribs broad, a little more than one inch, nearly flat and smooth, or obsoletely striate; furrows deep and narrow; scars a little less distant from each other than the breadth of the ribs; obovate; inferior margin very obtuse; vascular scars three—the medial one linear, short;

the lateral ones linear, slightly arched. Trevorton Coal, low beds. This species is related to the former by the obovate form of the scars, evidently differing by its broad, flat, smooth ribs, and the form of the vascular scars. The bark is striated lengthwise, as in the former; but the scars on the bark are semilunar in this species, and squarish-oval in the former.

22. *Sigillaria reniformis*, Brongt., *Hist. des Veg. Foss.*, i. p. 470, t. 142.—Ribs very broad, flattened, scarcely striate in their length; scars reniform, rounded, a little broader than long, emarginate above; furrows faintly marked; bark thick; vascular scars of the decorticated stem geminate, oval, oblong. The Gate Vein at Pottsville and New Philadelphia; common in the superior beds of the anthracite basins, but always found in its decorticated state.

23. *Sigillaria lævigata*, Brongt., *Hist. des Veg. Foss.*, i. p. 471, t. 143.—Stem ribbed; ribs very broad, flattened, with deep acute furrows; bark thick, thinly striated, or wrinkled in its length; scars discoid, hexagonal, rounded, with the lateral angles obtuse; vascular scars three—the medial one very small, the lateral ones oval-lanceolate, larger. In the decorticated state, the vascular scars are geminate, contiguous, very large. New Philadelphia, Gate Vein; found only decorticated.

24. *Sigillaria elongata*, Brongt., *Hist. des Veg. Foss.*, i. p. 473, t. 145 and 146, fig. 2.—Stem ribbed; ribs straight, equal, with deep angular furrows; scars discoid, oblong, lanceolate; truncate at the base and at the summit, or slightly emarginate above; vascular scars three, placed above—the medial one very small, the lateral ones oblong; bark thick; decorticated stem deeply striate; scars oblong. Lehigh Summit; a specimen scarcely distinct.

25. *Sigillaria rugosa*, Brongt., *Hist. des Veg. Foss.*, i. p. 476, t. 144, fig. 2.—Stem ribbed; ribs plane, equal; furrows straight, narrow, distinct; ribs marked, with very slender points in the middle, between the scars; scars discoid, oval, distant twice their length; vascular scars three, placed above—the medial one like a point, the lateral ones oblong, parallel. Sent to M. Brongniart from Wilkesbarre; known to us only by his description.

26. *Sigillaria alternans*, Lind. & Hutt., *Foss. Fl.*, i. p. 159, t. 6.—Stem ribbed; ribs broad, equal; scars two, approximate, elliptical, with a small vascular scar in the middle. Pittsburg Seam at Greensburg.

27. *Sigillaria catenulata*, Lind. & Hutt., *Foss. Fl.*, i. p. 159, t. 56.—Stem ribbed; ribs broad; scars elliptical, long, or lanceolate, acute at both ends, joined together by a continuous line without any vascular scar, except a point in the middle. Trevorton Low Coal. These two last species are evidently the decorticated state of species either already published with other names, or unknown in their perfect form.

28. *Sigillaria discoidea*, Lesq., Plate XIV., fig. 5.—Stems furrowed; furrows distant, irregular, deeply marked and wrinkled; distance between them large—two or three inches; flattened; irregularly dotted; scars discoid or round, elevated, half globular, diminishing in size, slightly emarginate below, very near each other, marked in the middle with a deep irregular point. We have given a true copy of this vegetable relic; we have it from a sandstone rock at Lehigh Summit. Its place in the family of the *Sigillariæ* is scarcely acceptable. But as we could not obtain any good specimens for further examination, we have nothing else to say about its other characters; we mention it here till some better opportunity to study it is afforded.

VI. Syrigodendron, Sternb. & Brongt.—Stems furrowed, ribs equal, parallel, covered with a bark ordinarily transformed into coal, bearing, on the exterior surface of the ribs, small scars which are not discoid, and have no impressions of vascular scars.

1. *Syrigodendron pachyderma*, Brongt., *Hist. des Veg. Foss.*, i. p. 479, t. 166, fig. 1.—Bark thick; ribs and furrows obtuse, distinct, striate on their external surface; wrinkles (striæ) arched, and converging to the scars, which are small, nearly square, bitoothed above: in the decorticated state the scars are linear and simple. Common at Trevorton Low Coal.

2. *Syrigodendron cyclostegium*, Brongt., *Hist. des Veg. Foss.*, i. pp. 480 and 166, figs. 2, 3.—Bark thin; ribs convex, with broad, obtuse, distinct furrows; striate; scars marked on an elevation of the ribs; nearly round, forming a small depressed circle. Same locality as the former. A large perpendicular wall of roof-slate at Trevorton is covered with the stems or bark of these *Syrigodendron*. (See Sketch.)

VII. Lepidodendron, Sternb.—Stems large, tree-like, sometimes as long as one hundred feet or longer; dichotomous, bearing leaves on the young branches or shoots; branches ordinarily fastigiate. Leaves linear, sometimes linear-lanceolate; bark covered with the scars left by the falling of the leaves at their point of attachment; oval-lanceolate or acute at both ends, marked on the middle or above it by a triangular or rhomboidal vascular impression, ordinarily transversely three-pointed; below the inferior angle of the vascular scar there are ordinarily two oval slightly diverging impressions which we name tubercles, and a medial line from the base of the vascular scar to the tail of the general scar; this line sometimes follows the direction of the scars, descending from one to the other, and nearly dividing them into two longitudinal parts. In this case it is ordinarily stopped above the vascular scar by a diverging furrow, forming a lid or a crown, either triangular or trapezoidal, above the vascular scars. We name the distance between the scars *a margin;* it is ordinarily a good character. It is truly astonishing to see how well these impressions of the scars of the *Lepidodendron* have been preserved. We have seen many specimens at Mr Clarkson's, and one also at Mr Moore's, of which the impressions were as distinct as if they had been carved in the stone by the best engraver. We have had good opportunity for studying the remarkable fossil-remains of this family in the cabinet of Mr Clarkson at Carbondale, where, during more than fifteen years, that gentleman has collected the largest and most beautiful specimens. The roof of the vein of coal worked at Carbondale, under the direction of Mr Clarkson, is almost entirely covered with impressions of trunks of *Lepidodendra*, sometimes of an immense size. There are some of them seventy feet long and about two feet broad, which are not at all narrowed at the upper end, where they are broken, and which consequently must have been much longer than the preserved part. The affinity of these trees with the *Lycopodiaceæ* of our time has been fully established by Mr Hooker from his observations on the internal structure of the fruits, the *Lepidostrobi*. But we know nothing about the mode of growth of these enormous vegetables, nor how they were sustained on the soft ground where they were living. We cannot assert anything satisfactory in this matter; but we think that for this genus, as for the *Sigillariæ*, the roots were nothing but the long creeping *Stigmariæ*, making by their ramification a true network to support the tree, and drawing, by their long and innumerable rootlets, the vegetable sap in sufficient abundance to promote the rapid growth of those trees bearing only small leaves at the upper part of their branches. We find in many *Lycopodiaceæ* the same disposition of roots and branches.

1. *Lepidodendron aculeatum*, Sternb., *Vers.*, i. p. 10, and 2 3, t. 6, fig. 2, and t. 8, fig. 1.—General scars oboval, elliptical, narrowed and acute at both ends; tail pointed and curved below; vascular scars obtuse, regularly rhomboidal; medial line deeply transversely short-wrinkled; tubercles oval. A variable species commonly found in the low beds of the coal-basins. Minersville, Lehigh Summit, Carbondale, &c.

2. *Lepidodendron rugosum*, Sternb., ii. p. 178, t. 68, fig. 4.—Scars oval, narrowed, acuminate at both ends; vascular scars trapezoidal, transversely marked with three points united by an elevated line; tubercles two, one of them sometimes obliterated; medial line furrowed broadly, transversely wrinkled. Carbondale and Zanesville, Ohio.

3. *Lepidodendron crenatum*, Sternb., *Vers.*, i. p. 10, figs. 20, 23, t. 8, fig. 2.—Scars elliptical, narrowly pointed at both ends, slightly curved below; vascular scars large, acute, rhomboidal, three-pointed; medial line transversely wrinkled in its inferior part only; transverse points, and turbercles obsolete. Found at Carbondale. In our specimens the vascular impression is acute at both sides.

4. *Lepidodendron obovatum*, Sternb., *Vers.*, i. p. 10, t. 6, fig. i. t. 8, fig. 1.—General scars obovate, pointed above, narrowed and acuminate below, vascular scars rhomboidal obtuse, with three somewhat obliterated points. Common in the low beds of the coal-basins.

5. *Lepidodendron modulatum*, Lesq., Plate XV., fig. 1.—Scars oval, narrowed acuminate at both ends, curved at the base, separated by a broad, half round, elevated, and deeply-wrinkled margin; wrinkles undulated, and parallel to the scars; vascular scars rhomboidal, obtuse arched above, narrowed at the base in a long point, acute at both sides, marked with three transverse points united by a depressed line; tubercles narrow; medial line deeply marked and transversely furrowed by deep short wrinkles; appendage double. A beautiful species preserved at Carbondale somewhat resembling *Lepidodendron rugosum*.

6. *Lepidodendron giganteum*, Lesq., Plate XV., fig. 2.—General scars oval, trapezoidal, elongated, acute both ends; vascular scars nearly in the middle; rhomboidal, quadrangular, with three points in the middle; appendages irregular, longer on one side; tubercles very small, short, oval; medial line marked from the summit to the lower end of the scars; smooth. Common at Carbondale, and found also at Lehigh Summit. This species may be the same as the *Lepidodendron undulatum*, Sternb., this being in a decorticated state.

7. *Lepidodendron vestitum*, Lesq., Plate XVI., fig. 3.—General scars oval, trapezoidal, acute at both ends, separated by an irregular smooth margin, covering the borders of the scars; vascular scars quadrangular, trapezoidal, placed at the summit of the general scars, with three points in the middle; no appendages; tubercles large, oval; medial line deep, smooth, curved. A peculiar and well-characterised species, found at Wilkesbarre. The margins of the scars are sometimes very broad, covering the borders of the scars, but detached from them like a frame, and easily broken and falling off.

8. *Lepidodendron conicum*, Lesq., Plate XV., fig. 3.—General scars oval, acute, and narrowed at both ends; vascular scars triangular, conical, with a single oval point in the middle, and two broad oval tubercles below; appendages none; medial line marked only by a row of long, undulate, transverse wrinkles; margins flat, broad, deeply wrinkled; wrinkles parallel to the scars, or marked in the same direction. Carbondale, where we have found many specimens. Though well marked and distinct, it may be a decorticated impression.

9. *Lepidodendron oculatum*, Lesq., Plate XVI., fig. 4.—Scars oval, acuminate at both ends; vascular scars marked only in the superior outline by a linear line, curved like a bow, and transversed by another narrow perpendicular line, at the base of which there are marked two large oval tubercles; medial line deeply wrinkled, obsolete; margin of the scars very broad (half an inch), flat, undulately wrinkled or striate. A beautiful species, perhaps the same as the following in its decorticated state. Preserved at Carbondale.

10. *Lepidodendron distans*, Lesq., Plate XVI., fig. 5.—Scars oval, lengthened, acute, or acuminate at both ends; vascular scars rhomboidal, square, transversely marked with three points; appendages two on each side; tubercles small, diverging; medial line deep, transversely cut by broad short wrinkles; margin between the scars very broad, striate, or wrinkled in their length with undulate smooth lines, flat; scars very smooth. Same place as the former.

11. *Lepidodendron rimosum*, Sternb., *Vers.*, vol. i. pp. 11, 21, 23, t. 10, fig. 1.—Scars distant, elliptical, acute at both ends; margins irregularly wrinkled in the length; vascular scars rhomboidal, concave, without points; medial line obsolete. Found at Trevorton. It is only a decorticated state of another species.

12. *Lepidodendron obtusum*, Lesq., Plate XVI., fig. 6.—Scars trapezoidal, acutely pointed above, slightly narrowed and abruptly obtuse below; vascular scars nearly placed in the middle, rhomboidal-obtuse above, acute below, angular on both sides, marked transversely with three points; appendage irregular, distinct on one side only; tubercles oval, diverging; medial line wrinkled; margins broad, undulately striate, and furrowed in their length. Collection of Carbondale.

13. *Lepidodendron carinatum*, Lesq., Plate XV., fig. 4.—Scars oval, hexagonal, angular, acute at both ends, with narrow, deep, keeled, smooth margins; vascular scars rhomboidal, obtuse above, triangular below; appendages short, obsolete; tubercles small, oval; medial line obsolete, transversely wrinkled. Found at Carbondale.

14. *Lepidodendron clypeatum*, Lesq., Plate XV., fig. 5, and XVI., fig. 7.—Scars irregularly trapezoidal, acute at both ends, obtuse on the sides, with narrow linear margins; vascular scars large, obtuse on the inferior and the superior borders, enlarged and acute on both sides, transversely three-pointed; appendages obsolete, descending to the very obsolete medial line, where they unite in an acute angle; tubercles obsolete on one side, well marked on the other; oval. Common at Carbondale. Plate XVI., fig. 7, represents the decorticated state of this species.

15. *Lepidodendron sigillarioides*, Lesq., Plate XV., fig. 6.—Scars exactly trapezoidal, with the acute angles at both ends; margins narrow, smooth; vascular scars dilated, acute at both ends, marked with three points; without any appendages, neither medial lines nor tubercles. Lehigh Summit.

16. *Lepidodendron Mieleckii*, Göpp., *Syst. Fil. Foss.*, p. 465, t. 44, figs. 1, 2.—Scars regularly rhomboidal, acute at both ends; vascular scars plain, with five nearly equal angles, the two inferior rounded. Lehigh Summit. Perhaps a decorticated state of another already-described species. At different places in the coal-basin of Pennsylvania, as at Minersville, Trevorton, Carbondale, and Johnstown, and always in the lowest vein, we have found also small branches of *Lepidodendron*, sometimes with the leaves, which we could easily relate to *Lepidodendron Sternbergii*, Brongt., *L. acerosum*, Lind., *L. dilatatum*, Lind., *L. selayinoides*, *L. elegans*, Brongt. But as the only reliable character for the distinction of these plants is the form of the scars, and their relative position, it is useless to describe such small branches or species of which the impressions are not distinct.

VIII. Ulodendron, Rhodes.—Stems simple (?), tree-like, covered with rhomboidal scars of the leaves; branches distechous, strobilaceous, covered with densely-imbricated leaves.

1. *Ulodendron majus*, Lind. and Hutt., *Foss. Flor.*, vol. i. p. 22, t. 5.—Scars of the branches distant, orbicular, eccentrically bossed; scars of the leaves transversely half rhomboidal, rounded on the inferior margin, superior angle acute, the lateral ones acuminate. The single specimen of this species which we have seen belongs to the Rev. Mr Brown of Charlestown, Kenawha, and was found in the lowest vein of coal there.

2. *Ulodendron Lindleyanum*, Sternb., *Vers.*, ii. p. 185, t. 45, fig. 4.—Scars of the branches very large and distant, oval, and eccentrically bossed; scars of the leaves marked only by obsolete points, placed in spiral. In the collection of Mr Clarkson at Carbondale there are two beautiful specimens of this species. The scars of the branches are about 5 inches long, and 3 inches broad. The eccentric lump, which is irregularly oval, and placed in the upper part of the scar, is surrounded by undulated radiating lines, terminating at the margin of the general scars.

FRUITS.

I. Lepidophyllum, Brongt.—Leaflets sessile, simple, entire, lanceolate or linear, one to three nerved. This description of M. Brongniart, copied by M. Unger in his *Gen. et Spec. Plantarum*, mentions only the blade of the fruit of a *Lepidodendron*. These fruits are attached together in catkins (*lepidostrobus*), formed of a scale, attached at a right angle to the axis by a short pedicle, inflated at the top, and supporting a spore-case (sporange) full of spores, and elongated above in a leaflet, the lanceolate or linear blade. These fruits or sporanges are imbricated around the axis: their position is well indicated by the cross section of a catkin in Plate XVII., fig. 1. We do not think the leaves of *Lepidodendron* worth mentioning and describing, these being much alike in all the species which we have been able to examine.

1. *Lepidophyllum acuminatum*, Lesq., Plate XVII., fig. 2.—Blade nearly 1 inch broad, slightly narrowed near the base, 3 inches long, acuminate, binerved. Johnstown, lowest bed of the coal. This species resembles *Lepidophyllum trinerve*, Lind. and Hutt., *Foss. Flor.*, vol. ii. p. 195, t. 152, but differs from it by its two nerves.

2. *Lepidophyllum obtusum*, Lesq., Plate XVII., fig. 3.—Blade three-fourths of an inch broad, more than 4 inches long, linear, abruptly terminated in a short point, marked in the middle by a broad, obsolete, inflated nerve. Same place as the former. We have seen many broken specimens of this species, which would lead us to suppose that it was about twice as long as here figured.

3. *Lepidophyllum lanceolatum*, Brongt., Lind., and Hutt., *Foss. Flor.*, vol. i. t. 7, figs. 3, 4.—Sporange inflated, irregularly five-angular, narrowed and obtuse at the base, enlarged above; blade lanceolate, pointed, entire, one-nerved. Our species is probably the same as that figured by Messrs Lindley and Hutton; but we have seen better specimens. The beautiful one figured, Plate XVII., fig. 1, belongs to Mr Chambers at Carbondale.

4. *Lepidophyllum affine*, Lesq., Plate XVII., fig. 5.—Differs from the former by its obtuse blade and its long pointed sporange. New Philadelphia; very scarce.

5. *Lepidophyllum hastatum*, Lesq., Plate XVII., fig. 7.—Sporange long-pointed, blade enlarged at the base in two diverging auricles; hastate slightly acute, with a strong nerve; sporange lanceolate, acute. Found by the Rev. Mr Moore near Greensburg.

6. *Lepidophyllum brevifolium*, Lesq., Plate XVII., fig. 6.—Sporange narrowed at the base in a long point; blade very short, enlarged at the slightly-obtuse sides. Common at Wilkesbarre Low Coal. In this species the angles of the blade are not diverging at the base, and the blade is much shorter than in the former species. We found it also abundantly in the lowest bed of coal at Johnstown and Wilkesbarre.

7. *Lepidophyllum plicatum*, Lesq., Plate XVII., fig. 4.—Blade linear, lanceolate, obtuse, narrowed at the base, curved (geniculated) in the middle; nerved from the base to half its length, the nerve disappearing. We have not seen the sporange of this species, of which we have a single specimen from the Gate Vein, Pottsville.

8. *Lepidophyllum lineari*, Brongt., is a leaf of *Lepidodendron;* linear, carinate, nerved with parallel nerves. We mention it only for its abundance at Wilkesbarre and Johnstown, in connection with *Lepidophyllum brevifolium.*

II. Lepidostrobus, Brongt.—Catkins cylindrical, composed of winged sporanges, attached to a common axis, and imbricated. It is impossible to give a satisfactory description of these *Lepidostrobi*, when they are found in their perfect or normal state, and when the form of the imbricated sporanges, and of the blade or wing, cannot be exactly ascertained. In the two places above mentioned—viz. at the low beds of coal at Wilkesbarre and at Johnstown—we have seen the three following forms described by Messrs Brongniart and Lindley; but certainly the separate sporanges of them, found together, and described above, were part of some of them.

1. *Lepidostrobus ornatus*, Lind. and Hutt., *Foss. Flor.*, vol. i. p. 163, t. 26.—Catkins cylindrical, about 1 inch broad, with a thick woody axis.

2. *Lepidostrobus variabilis*, Lind. and Hutt., *Foss. Flor.*, vol. i. t. 10, 11.—Catkins cylindrical or ova-lobtuse; scales acute, densely imbricated.

3. *Lepidostrobus pinaster*, Lind. and Hutt., *Foss. Flor.*, vol. iii. t. 198.—Catkins small, cylindrical, 2 inches long, scales rhomboidal.

III. Brachyphyllum, Brongt. (?)—Stem dichotomous; leaves imbricated, conical, obtuse, appressed, placed spirally around the stem.

1. *Brachyphyllum obtusum*, Lesq., Plate XVII., fig. 8.—We have classed under this name, and till it is better known, this remarkable branch, which ought to belong to this genus. The leaves or scales, which appear to be narrowed below, like the sporanges of the *Lepidophylla*, are rounded above, marked in the middle by an elevated line like a nerve. If this plant is a true *Brachyphyllum*, we cannot conceive why it has been generally taken for the branches of some coniferous tree. It looks much more like an elongated and narrow catkin of a *Lepidodendron*, viz. a *Lepidostrobus*, or is perhaps only a branch of some *Lepidodendron.* Our specimens of this plant were found at the South Salem Vein, Pottsville. Before leaving this remarkable class of plants—viz. the stems found in the coal-formation—we shall remark that we have never been able to find in this formation any specimens which would lead us to suppose that they were the fossil remains of dicotyledonous or phanerogamous plants. We have seen at Mr Lawton's of Barlow, near Marietta, Ohio, some specimens of petrified wood with concentric circles, which ought certainly to belong to some coniferous tree. But the geological age of the formation where this fossil wood occurs is far from being exactly ascertained. It is a coarse loose sandstone which reposes in the coal sandstone, but the direction of its beds is not in accordance with the direction of the sandstone below it. This at least is what has been affirmed by Mr Lawton. The bivalve shells found in this formation are also far different from the shells of the coal. Nevertheless, the presence of this formation, placed immediately above the coal sandstone, containing fossil trees of a description entirely different from those of the coal, is a remarkable coincidence. Though this formation is of small extent, and may be a comparatively new fresh-water formation, it merits a closer examination and attention from the geologists of Ohio. Its extent is about three miles long and one or two miles broad.

IV. Cardiocarpon, Brongt.—Capsules lenticular, compressed, obcordate or reniform, acuminate. These fruits and those of the following genus have been differently classed. As they have never been found attached to the branches, all that has been asserted about them, except their form, is hypothetical. We would not dare to express any opinion, as these fruits are very scarce in the anthracite basins of Pennsylvania, and as we have had scarcely an opportunity to examine their internal structure.

1. *Cardiocarpon Trevortoni*, Lesq.—Capsule plane, nearly orbicular, emarginate, cordiform above, pointed at the base, marked in the middle by a sharp elevated line, very smooth. Trevorton upper bed of coal, mixed with *Dyctiopteris obliqua.* It resembles *Cardiocarpon emarginatum*, Göpp. and Berg., *De Fruit*, p. 24, t. 3, fig. 35; but it is pointed at the base. Differs also from *Cardiocarpon latum* (Newberry, *Annals of Science*, p. 153) by its elevated medial line.

2. *Cardiocarpon plicatum*, Lesq., Plate XVII., fig. 9.—Differs from the former by its undulate plaited surface, without medial line. Found at the same locality.

3. *Cardiocarpon punctatum* (?), Göpp. and Berg., *De Fruit*, p. 24, t. 2, fig. 26.—Capsule plane, reniform or round, emarginate, marked with points regularly placed by five. Our specimen from Muddy Creek differs from this species by the surface being slightly concave, and the points irregularly placed.

V. Trigonocarpum, Brongt.—Fruit ovoid, three or six ribbed; ribs thickened at the base, three of them broader, with a broad hexagonal flattened top. We have scarcely found any good specimens of these fruits in the coal-basins of Pennsylvania, where all the fossil remains are ordinarily flattened in the shales; but they appear to be common in the coal sandstone of Ohio, and there are a great many of them preserved in the cabinets of Professor Newberry and of Dr Hildreth at Marietta. We can only indicate with certainty the following ones:—

1. *Trignocarpum Schulzianum*, Göpp. and Berg., *De Fruit*, t. 2, figs. 22, 23.—Fruit oblong, triangular, with the angles five-ribbed. Trevorton Low Coal.

2. *Trigonocarpum Hildreti*, Lesq.—Fruit oval-oblong, narrowly three-ribbed, with the intervals finely striate. From Ohio; preserved in the collection of Dr Hildreth.

3. *Trigonocarpum oblongum*, Lind. and Hutt., *Fos. Flor.*, iii. t. 193.—Fruit oval, pointed, slightly compressed, more than one inch long, and three quarters of an inch broad; marked with three large ribs; intervals smooth. A broken specimen from Trevorton.

VI. Rhabdocarpos, Göpp. and Berg.—Fruit oval or elliptical-oblong, marked in its length with parallel nerves or narrow ribs.

1. *Rhabdocarpos amigdalæformis*, Göpp. and Berg., *De Fruit et Sem.*, p. 21, t. 1, fig. 12.—Fruit oval, marked in the middle by a longitudinal elevated line. Trevorton Low Coal.

2. *Rhabdocarpos venosus*, Lesq.; *Carpolites venosus*, Sternb., *Vers.*, ii. p. 208, t. 58, figs. 16, 17.—Fruit oval, marked lengthwise by small undulated wrinkles. The Gate Vein, Pottsville. This species agrees well with the figure of Sternberg, but it is a true *Rhabdocarpos*.

VII. Carpolithes, Sternb.—This genus contains the fruits, very variable in form, of which the affinity is doubtful.

1. *Carpolithes fraxiniformis*, Göpp. and Berg., *De Fruit et Sem.*, p. 26, Plate III., figs. 33 and 34.—Fruit elliptical, linear, flattened, obtuse, nearly smooth. We have found in the Vespertine, below Pottsville, specimens of a fruit which resembles this one described by M. Göppert. It is not possible to tell anything about it. It looks like a flattened elongated sporange, full of small seeds.

2. *Carpolithes bifidus*, Lesq., Plate XVII., fig. 10.—Fruit apparently pedicellate, oval-oblong, arched; split in two parts above, three-ribbed near the base; pedicle (?) thick, ribbed. Gate Vein, New Philadelphia.

3. *Carpolithes disjunctus*, Lesq., Plate XVII., fig. 11.—Fruit oval, lanceolate, slightly obtuse, divided into two parts, the superior one convex, the inferior concave, diverging from the other. Found also at Trevorton. This remarkable specimen looks as if the oval fruit had been turned aside, or removed from its place (round the base as an axis), and left its impression on it. It is quite smooth.

4. *Carpolithes acuminatus*, Sternb. (?), *Vers.*, 4, t. 7, fig. 15.—Fruit small, about two lines long, one line broad, oval, lanceolate, convex, acute at one end, obtuse at the other, entirely smooth. We have found at Shamokin the species described above, which resembles Sternberg's figure. On the same slate with this fruit there are some other much smaller, scarcely half a line broad, round, flat, or varying much in size and in form. These fruits appear to have been externally of a hard texture, like the fruits of some Gramineæ or Cyperaceæ.

5. *Carpolithes platimarginatus*, Lesq., Plate XVII., fig. 12.—Fruit oval, acute, convex, smooth, broadly margined; margin flat, broader near the point, disappearing below. Trevorton Low Coal.

6. *Carpolithes bicuspidatus*, Sternb., *Vers.*, i. t. 7, fig. 8.—Fruit flattened, round, slightly pointed on one side, scarcely emarginate on the other, with a point on the emargination. Found at Muddy Creek, and at the Gate Vein of Pottsville. It looks like the fruit of a Calamite.

7. *Carpolithes multistriatus*, Sternb., *Vers.*, ii. p. 208, t. 39, figs. 1, 2.—Fruit broadly oval, large, pointed on one side, flattened on the other, marked in its length with equal ribs, separated by obtuse furrows; ribs about one line broad. Shamokin Vein, west of the village.

VIII. *Carpolithes umbonatus*, Sternb., i. tab. 9, fig. 2.—This is scarcely a fruit; it is very irregular in its outline, irregularly bossed and ribbed, and does not look at all like an organic relic, but more like a pebble of iron. It is commonly found in slates of the coal, varying in diameter from half an inch to about half a foot. To the description of the species mentioned above we will subjoin a short enumeration of the genera and species which, in our opinion, shall be eliminated, or of which the place will be changed. These are, *Cordaites*, *Poacites*, *Cyperites*, and *Pinnularia*.

I. Cordaites.—Leaves simple, sessile, placed spirally, half embracing the stems with very narrow parallel nerves.

1. *Cordaites borassifolia*, Ung.—Leaves simple, spathulate, entire, very long, nerves thin, parallel, epidermis formed of striate parallel cells, stomate, simple. These are long leaves or stems, of which many fragments were found in the upper beds of the anthracite coal, near Pottsville. Their place and their nature is undetermined. M. Brongniart has placed them near the *Næggerathia*, supposing them to be some dicotyledonous plant of the Gymnosperma.

2. *Poacites*, Brongt.—Leaves linear, long, with nerves equal and parallel. We have found many of these *Poacites* in the upper beds of the coal, in the same locality as the former; we think that they are the leaves of some *Sigillaria*.

3. *Cyperites*, Lind. and Hutt., *Hist. Foss. Flor.*, i. t. 43, figs. 1, 2.—Leaves linear, with two primary nerves on both

sides, and secondary ones between them. These are also found in the upper beds of the coal at Pottsville, at the Salem and Gate veins. They are also certainly the leaves of some *Sigillariæ*.

4. *Pinnularia*, Lind. and Hutt., *Foss. Flor.*, ii. tab. 3.—These vegetable remains are evidently roots. Though we think their description and nomenclature useless when their connection with the plants to which they belong is not ascertained, we have made a drawing of the most interesting of them. Preserving the nomenclature of this genus, as established by Messrs Lindley and Hutton, we would name those figured, as follows:—

1. *Pinnularia calamitarum*, Lesq., Plate I., fig. 9.
2. *Pinnularia pinnata*, Lesq., Plate XVII., fig. 18.
3. *Pinnularia fucoides*, Lesq., Plate XVII., fig. 19.
4. *Pinnularia horizontalis*, Lesq., Plate XVII., fig. 21.
5. *Pinnularia capillacea*, Lind. and Hutt., l. c., Plate XVII., fig. 22.
6. *Pinnularia confervoides*, Lesq., Plate XVII., fig. 20. The only one of which the name merits preservation, as its identity may be ascertained everywhere, is this last one.

The foregoing Essays by Mr Lesquereux are the results of researches made by him in the years 1852–1854, upon the fossil flora of Pennsylvania, under my direction, at the expense of the Commonwealth. I have been therefore much surprised and chagrined to find their publication partially forestalled by the production of a portion of the same matter in a *Report on the Fossils of the Western Kentucky Coal-Field*, recently issued as a part of the Geological Survey of that State. In a prefatory paragraph to that Report, Mr Lesquereux remarks, "As for the right I may have to quote a few lines of a Report delivered in 1854 to the Director of the Geological State Survey of Pennsylvania, I do not think that it can be denied me. This Report, elaborated with great care, and the arduous labour of two years, was to appear in the *Final Report of the Geological State Survey of Pennsylvania*, but it is a question if it will ever be published." In answer to this feeble attempt at an apology for a breach of literary obligation, I have merely to reply that the action of the Legislature to proceed with the publication of my work was notorious, and that Mr Lesquereux never wrote to me to know if my well-known wish to print had been disappointed.

Since the rendering in of his Report to me on the Fossil Plants of Pennsylvania in 1854, M. Lesquereux has read (February 1858) a catalogue of nearly all the Coal Plants of North America, including the Pennsylvanian ones, to the Pottsville Scientific Association, which that body has published. Embracing, as this does, many species and localities not mentioned in the foregoing Essay, the following synopsis of it, omitting many descriptive details, will, I trust, be acceptable to the palæontological reader.

CATALOGUE OF THE FOSSIL PLANTS WHICH HAVE BEEN NAMED OR DESCRIBED FROM THE COAL-MEASURES OF NORTH AMERICA.

By LEO LESQUEREUX.

FILICES OR FERN LEAVES.

NEUROPTERIDEÆ.

1.—NOEGGERATHIA, Rut.

1. NOEGGERATHIA *obliqua*, Göpp., old red sandstone (Ponent), Pottsville.
2. ——— *obtusa*, Lsqx., old red sandstone (Ponent), Lehigh, below Mauch Chunk.
3. ——— *minor*, Lsqx., same place.
4. ——— *Bockschiana*, Lsqx. (*Cyclopteris Bockschiana*, Göpp.), old red sandstone (Vespertine), opposite Mauch Chunk.
5. ——— *Beinertiana ?* Göpp., Cuyahoga falls (Newb'y).
6. ——— *microphylla*, Newb'y (ined.), Cuyahoga falls.

All the true *Noeggerathia* that I have seen belong to the old red sandstone. *N. Beinertiana ?* Göpp., mentioned with doubt by Dr Newberry, is rather a *Cordaites*, and I am still in doubt if *N. microphylla* truly belongs to this genus.

2.—ODONTOPTERIS, Brgt.

1. ODONTOPTERIS *squamosa*, Lsqx., Shamokin, low coal.
2. ——— *alata*, Lsqx.
3. ——— *Brardii*, Brgt. This species is stated by M. Unger as found at Mauch Chunk. It may be the true one; but I have some doubt about it. It has, perhaps, been mistaken for the former, which it resembles, differing evidently, nevertheless, by its more pointed leaflets, and by the absence of leaflets to the main rachis.
4. ——— *crenulata*, Brgt., Tremont, new vein.
5. ——— *Schlotheimii*, Brgt., same place.
6. ——— *dubia*, Lsqx. A small specimen, no locality mentioned.

7. ODONTOPTERIS *Neuropteroides*, Newb'y (ined.), Cuyahoga falls. The species of this genus appear to belong mostly to the low coal.

3.—DICTYOPTERIS, Gutb.

1. DICTYOPTERIS *obliqua*, Bunb'y. Trevorton, Sharp Mountain Vein, Pottsville, &c.—Salineville, O., Newb'y.

4.—CYCLOPTERIS, Brgt.

1. CYCLOPTERIS *flabellata*, Brgt., Tremont new vein.
2. *Whittleseya elegans*, Newb'y, Annals of Science of Cleveland, No. 10; found abundantly at Cuyahoga falls, O.—low coal.

5.—NEPHROPTERIS, Brgt.

1. NEPHROPTERIS *fimbriata*, Lsqx., Salem v., Pottsville; Pomroy, O.
2. ——— *laciniata*, Lsqx., Muddy Creek, Schuylkill Co.
3. ——— *elegans*, Lsqx., Shamokin.
4. ——— *undans*, Lsqx., Gate v., Middleport.
5. ——— *trichomanoides*, Brgt., Gate and Salem v., Pottsville; Pomroy, O.
6. ——— *hirsuta*, Lsqx., common, especially in the upper coal.
7. ——— *orbicularis*, Brgt., Room-run mines, near Mauch Chunk.
8. ——— *Germari*, Göpp., Salem v., Pottsville.

6.—NEUROPTERIS, Brgt.

1. NEUROPTERIS *speciosa*, Lsqx., Gate v., Port Carbon.
2. ——— *hirsuta*, Lsqx., through the whole extent of the Coal-measures, mostly in the upper coal.
3. ——— *Clarksoni*, Lsqx., Ferris v., near Archibald and Eagle Hill, above Bellmont (grey-ash coal).
4. ——— *fissa*, Lsqx., Gate v., Pottsville.
5. ——— *smilacifolia*, Sternb., Shamokin.
6. ——— *plicata*, Sternb., Salem v., Pottsville.
7. ——— *flexuosa*, Brgt. The most common of all, found through the whole extent of the Coal-measures.
8. ——— *Loschii*, Brgt., Gate and Salem v., Pottsville. It descends to the low coal, and is perhaps only a variety of the former.
9. ——— *rotundifolia*, Brgt., Gate v., &c., with both the former.
10. ——— *tenuifolia*, Brgt., Shamokin.
11. ——— *gigantea*, Brgt., Zanesville, O.
12. ——— *Grangeri*, Brgt., Gate v., Port Carbon.
13. ——— *Cistii*, Brgt., same place.
14. ——— *delicatula*, Lsqx., Sharp Mount v., Pottsville.
15. ——— *Villersii*, Brgt., Gate v., Pottsville; Pomroy, O.
16. ——— *gibbosa*, Lsqx., Salem v., Pottsville.
17. ——— *undans*, Lsqx., Gate v., Middleport.
18. ——— *crenulata*, Brgt., Salem v., Pottsville and Tamaqua.
19. ——— *tenuinervis*, Lsqx., Gate v., Pottsville.
20. ——— *dentata*, Lsqx., Salem v., Pottsville.
21. ——— *Desorii*, Lsqx., West Wood (upper coal).
22. ——— *heterophylla*, Brgt., common. Upper Coal-measures.
23. ——— *minor*, Lsqx., Tamaqua.
24. ——— *rarinervis*, Bunb'y, Room Run mines, near Mauch Chunk.
25. NEUROPTERIS *Moorii*, Lsqx., Greensburg coal, higher than the Pittsburg bed.
26. ——— *adiantites*, Lsqx., locality unknown.
27. ——— *lancifera*, Newb'y (ined.), Cuyahoga falls.

SPHENOPTERIDEÆ.

1.—SPHENOPTERIS.

1. SPHENOPTERIS *Davalliana*, Göpp., ? lowest coal, Kenawha Salines, Va.
2. ——— *tenella*, Brgt., ? Gate v., Port Carbon (a poor specimen).
3. ——— *Gravenhorstii*, Brgt., Black Mine, Westwood.
4. ——— *Dubuissonis*, Brgt., Gate v., Port Carbon.
5. ——— *abbreviata*, Lsqx., same place.
6. ——— *intermedia*, Lsqx., Black Mine, Westwood.
7. ——— *flagellaris*, Lsqx., Sharp Mt. v., Pottsville.
8. ——— *plicata*, Lsqx., New Philadelphia (upper coal).
9. ——— *latifolia*, Brgt., low coal, Pennsylvania and Ohio.
10. ——— *acuta*, Brgt., low coal Kenawha, Salines (in the cabinet of Marietta College).
11. ——— *obtusiloba*, Brgt., Cuyahoga falls, Newb'y.
12. ——— *glandulosa*, Lsqx., Shamokin (low coal).
13. ——— *decipiens*, Lsqx., Salem v., Young's Landing, Pottsville.
14. ——— *polyphylla*, Lind. & Hutt., low coal, Iowa and Kentucky (in D. D. Owen's cabinet).
15. ——— *Newberrii*, Lsqx., Wilkesbarre, low coal.
16. ——— *Lesquereuxii*, Newb'y (ined.) Cuyahoga falls.
17. ——— *squamosa*, Lsqx., probably low coal. Locality unknown.
18. ——— *artemisæfolia*, Brgt. Locality unknown.
19. ——— *parvifolia*, Newb'y (ined.), Cuyahoga falls.
20. ——— *concinna*, Newb'y (ined.), same place.
21. ——— *uncinnate*, Newb'y (ined.), same place.
22. ——— *Kirtlandiana*, Newb'y (ined.), Poland, O.
23. ——— *simplex*, Newb'y (ined.), Poland, O.
24. ——— *subspinosa*, Newb'y (ined.), Cuyahoga falls.
25. ——— *tenuis*, Newb'y (ined.), same place.
26. ——— *foliosa*, Newb'y (ined.), same place.
27. ——— *coriacea*, Newb'y (ined.), Salineville.

2.—HYMENOPHYLLITES, Göpp.

1. HYMENOPHYLLITES *furcatus*, Göpp. (Vespertine), Mauch Chunk and Pottsville. Lowest coal, Cuyahago falls, Newb'y.
2. ——— *Hildreti*, Lsqx., Great Kenawha, Salines, low coal.
3. ——— *capillaris*, Lsqx., same place.
4. ——— *fimbriatus*, Lsqx., Salem v., Pottsville; Pomroy, O.
5. ——— *affinis*, Lsqx., Gate v., New Philadelphia.
6. ——— *hirsutus*, Lsqx., Gate v., Westwood.
7. ——— *laceratus*, Lsqx., Johnstown, Penn., low coal.
8. ——— *giganteus*, Lsqx. (*Shizopteris lactuca*, Sternb.), Gate v., north of Port Carbon.

PECOPTERIDEÆ.

1.—ASPLENITES, Göpp.

Fruit-dots linear, attached to the back of the secondary nerves; secondary nerves simple or dichotomous; frond bi-tripinnate.

1. ASPLENITES *rubra*, Lsqx., barren measures, Marietta, O.

2.—ALETHOPTERIS, Sternb. and Göpp.

Frond bi-tripinnatifid; secondary nerve nearly perpendicular to the medial nerve, either simple or forking.

1. ALETHOPTERIS *lonchitidis*, Sternb. This species is truly characteristic of the lowest coal, or that above the conglomerate, from the Mississippi to the anthracite basins of Pennsylvania.
2. ——— *Pennsylvanica*, Lsqx., Salem v., Pottsville.
3. ——— *Aquilina*, Göpp. Locality uncertain.
4. ——— *urophylla*, Göpp., Gate v., Pottsville.
5. ——— *Serlii*, Göpp., Room Run mines, near Mauch Chunk; Zanesville, O.; Kenawha, Salines, Va.
6. ——— *marginata*, Göpp., Tremont (new vein).
7. ——— *distans*, Lsqx., Muddy Creek, Schuylkill County.
8. ——— *obscura*, Lsqx., Gate v., Pottsville.
9. ——— *serrula*, Lsqx., Gate v., north of Port Carbon.
10. ——— *nervosa*, Göpp., Shamokin, Carbondale. Cuyahoga falls, Newb'y.
11. ——— *lævis*, Lsqx., Shamokin.
12. ALETHOPTERIS *rugosa*, Lsqx., Salem v., Pottsville.
13. ——— *muricata*, Göpp., Sharp Mt. v., Pottsville.
14. ——— *grandifolia*, Newb'y (ined.), Cuyahoga falls.
15. ——— *gracilis*, Newb'y (ined.), Cuyahoga falls.

3.—CALLIPTERIS, Brgt.

Frond bipinnatifid; pinnæ long, decurrent on the common rachis; pinnules continuous, slightly oblique, united, and decurrent at the base; medial nerve oblique, arched; secondary nerves oblique, arched, and bifurcate.

1. CALLIPTERIS *Sullivantii*, Lsqx. Found only at Shamokin.

4.—PECOPTERIS, Brgt.

1. PECOPTERIS *Cistii*, Brgt., Wilkesbarre (from M. Brongniart's indication).
2. ——— *polymorpha*, Brgt., common, upper coal.
3. ——— *distans*, Lsqx., with the former.
4. ——— *velutina*, Lsqx., Johnstown, Pa., low coal.
5. ——— *orata*, Brgt., Tremont (new vein).
6. ——— *Sheaferi*, Lsqx. It was found in M'Kean County.
7. PECOPTERIS *notata*, Lsqx., Salem v., Port Carbon, &c.
8. ——— *oreopteridis*, Brgt., Gate and Salem v., Pottsville.
9. ——— *pusilla*, Lsqx., same place.
10. ——— *arborescens*, Brgt., common in the upper coal, Pa. and Ohio.
11. ——— *dubia*, Lsqx., Gate v., Pottsville.
12. ——— *cyathœa*, Brgt., Gate v., Port Carbon.
13. ——— *arguta*, Brgt., upper Coal-measures. Pottsville and Pomroy, O.
14. ——— *abbreviata*, Brgt., Trevorton.
15. ——— *unita*, Brgt., Sharp Mt. v., Pottsville.
16. ——— *concinna*, Lsqx., Gate v., Pottsville.
17. ——— *pennæformis*, Brgt., Trevorton (new vein).
18. ——— *plumosa*, Brgt., Cuyahoga falls (Dr Newb'y).
19. ——— *Sillimani*, Brgt., Zanesville, O., following M. Brongniart, to whom it was sent.
20. ——— *Loschii*, Brgt., Sam. Ferris v., four miles W. of Archibald.
21. ——— *incompleta*, Lsqx., Gate v., Pottsville.
22. PECOPTERIS *elliptica*, Bunb'y, Zanesville, O. (Dr Newb'y).
23. ——— *inflata*, Newb'y (ined.), Cuyahoga falls, low coal.
24. ——— *pavifolia*, Newb'y (ined.), same place.
25. ——— *latirachis*, Newb'y (ined.), same place.

This genus truly characterises, by most of its species, the upper Coal-measures. I have never yet seen a true *Pecopteris* either in or below the conglomerates.

LEAVES OF DOUBTFUL AFFINITY.

1.—CREMATOPTERIS, W. P. Schp.

Frond simple, pinnate; rachis broad; pinnules vertical or oblique, oval-oblong, entire; nerve obsolete.

1. CREMATOPTERIS *Pennsylvanica*, Lsqx., Greensburg, Pa. (in Rev. Mr Moore's cabinet).

2.—SCOLOPENDRITES, Lsqx.

Frond simple, linear-lanceolate, large, deeply, irregularly toothed; medial nerve very slender; secondary nerves thin, pinnately forking, very oblique, distant.

1. SCOLOPENDRITES *grosse-dentata*, Lsqx., New Philadelphia (upper coal).

3.—SHIZOPTERIS, Brgt.

Frond irregular, pinnately lobate with the lobes elongated, dentate, diversely cut; primary nerves none; secondary nerves parallel, very thin.

1. SHIZOPTERIS *robusta*, Newb'y, (ined.), Cuyahoga falls, O.

4.—CANNOPHYLLITES, Brgt.

Leaves simple, entire, with a strong central nerve; secondary nerve oblique, simple, parallel, equal.

1.—CANNOPHYLLITES *cordata*, Newb'y, (ined.), Cuyahoga falls, O.

5.—CORDAITES, Ung.

Stems erect, annulate by the persistent base of the leaves. Leaves simple, half embracing the stem, long, linear, one or two inches broad; nerves thin, parallel.

1. CORDAITES *borassifolia*, Ung., abounds in the upper coal, Pa. & O.

ASTEROPHYLLITEÆ.

This family of plants is composed of herbaceous plants or of trees, of which the stems are ordinarily striated lengthwise, the branches and stems bearing whorls of leaves at the more or less distant articulations. The following genera, till some of them are better known, may be admitted in it, viz. *Sphenophyllum*, *Annularia*, *Asterophyllites*, and *Calamites*. The genus *Wolkmannia*, admitted by some authors, was formed for the nomenclature of the fruit of *Asterophyllites*; it cannot be separated.

1.—SPHENOPHYLLUM, Brgt.

Stems articulated, branching from the articulations; leaves wedge-shaped, verticillate by six to twelve, truncate at the top, either bi-lobate, or dentate, or laciniate.

1. SPHENOPHYLLUM *Schlotheimii*, Brgt., Salem and Gate v., &c., upper coal, Pa., and Ohio, Pomroy, O.

2. SPHENOPHYLLUM *emarginatum*, Brgt., same places.
3. ——— *filicaule*, Lsqx., same places.
4. ——— *trifoliatum*, Lsqx., Salem v., Pottsville.
5. ——— *oblongifolium*, Ung. ?
6. ——— *erosum*, Lind. & Hutt., Cuyahoga falls, (Newb'y).
7. ——— *peltatum*, Newb'y (ined.), same place.
8. ——— *laciniatum*, Newb'y (ined.), no locality mentioned.
9. ——— *brevifolium*, Newb'y (ined.), Cuyahoga falls, O.

The species of this genus, as well as those of the whole family, are pretty well distributed through the whole extent of the Coal-measures. A few species only appear to characterise a peculiar geological level.

2.—ANNULARIA, Sternb.

Like the former, but differs by the branches opposite from below the base of the verticillate leaves; leaves lanceolate or linear, nerved in the middle.

1. ANNULARIA *minuta*, Brgt., Gate v., Pottsville.
2. ——— *fertilis*, Sternb., upper Coal-measures. Common.
3. ——— *longifolia*, Brgt., Gate v., Pottsville, &c. It descends to the lowest coal.
4. ——— *sphenophylloides*, Ung., ? upper coal, Salem v., Gate v., &c., Pottsville; Pomroy, O.

These species are mostly found in the upper Coal-measures.

3.—ASTEROPHYLLITES, Brongt.

Stems articulated with opposite branches; leaves verticillate, numerous, equal, linear, acute, slightly joined together at the base. Inflorescence diœcious. Male flowers united in leafy catkins at the top of the branches (*Wolkmannia.*) The fruit is a small nutlet at the axil of the leaves.

1. ASTEROPHYLLITES *gracilis*, Brongt., Zanesville, O.
2. ——— *equisetiformis*, Brongt. Abounds in the upper coal.
3. ——— *foliosa*, Lind. & Hutt., same place.
4. ——— *crassicaulis*, Lsqx., Gate v., New Philadelphia.
5. ——— *ovalis*, Lsqx., same place.
6. ——— *sublævis*, Lsqx., Gate v., Westwood.
7. ——— *tuberculata*, Brgt., New Philadelphia, &c., upper coal.
8. ——— *lanceolata*, Lsqx., same place.
9. ——— *aperta*, Lsqx., same place.

These three last species would belong to the genus *Wolkmannia*, Sternb. All the *Asterophyllites* belong to the upper Coal-measures, and scarcely descend to the low coal.

4.—CALAMITES, Suck.

Stems cylindrical, hollow, striated in the length, articulated in the leaves, narrow, encircling the stem like a sheet; ramification from the axil of the leaves.

1. CALAMITES *decoratus*, Brongt., Sharp Mt. v., Pottsville. This species appears to belong only to the upper coal.
2. ——— *Suckowii*, Brgt., common.
3. ——— *ramosus*, Brgt., Gate, Lewis, and Salem v., Pottsville, Cuyahoga falls, Newb'y.
4. ——— *undulatus*, Brgt., Sharp Mt. v., Pottsville. Cuyahoga falls, O., Newb'y.
5. ——— *cruciatus*, Sternb., same places as No. 3.
6. ——— *Cistii*, Brgt., Wilkesbarre and Carbondale, (low coal).
7. CALAMITES *dubius*, Artis., Gate v., Pottsville.
8. ——— *cannæformis*, Brgt., Carbondale, &c.
9. ——— *pachyderma*, Brgt., conglomerate sandstone, Trevorton; Akron, O., Newb'y. Also in the conglomerate.
10. ——— *nodusus*, Schloth., conglomerate, Cuyahoga falls, Newb'y.
11. ——— *bistriatus*, Lsqx., New Philadelphia (upper coal).
12. ——— *disjunctus*, Lsqx., Gate v., Pottsville.
13. ——— *approximatus*, Brongt., common.
14. ——— *Voltzii*, Brgt. Quoted by Dr Newberry without indication of locality.

STEMS OF TREES.

In this division of the stems, with the genus *Psaronius*, we have the following genera: *Caulopteris*, *Diplothegium*, *Stigmaria*, *Sigillaria*, *Syrigodendron*, *Lepidodendron*, *Lepidophloios*, *Ulodendron*, *Megaphytum*, and *Knorria*.

1.—CAULOPTERIS, Lind. & Hutt.

Stem thick, externally marked with scars left by the insertion of the petioles. Scars large, oval, with a broad, double, or simple margin; disposed in spirals around the stem.

1. CAULOPTERIS *punctata*, Lsqx. Locality unknown.
2. ——— *gigas*, Lsqx., Carbondale (Mr Clarkson's cabinet).
?3. ——— *Cistii*, Brgt., Wilkesbarre (quoted by M. Brongniart).

Specimens of this genus are very scarce. The few of which the locality was ascertained, belong to the low coal.

2.—DIPLOTEGIUM, Corda.

Stem round, equal, marked with elevated scars, very near each other, and placed in spirals; the top of the elevated scars being abruptly cut, rhomboidally.

1. DIPLOTEGIUM *Brownianum*, Corda., Portage Summit, Pa., low coal.

3.—STIGMARIA, Brongt.

Stems creeping, from 2 to 6 inches thick, dichotomous, covered with leaf-like fleshy appendages, either simple or forking, long, contracted at the base, with a single vascular fascicle. Scars round, with a double ring and a small elevated point (*mamilla*) in the middle.

1. STIGMARIA, *ficoides*, Brgt. Everywhere from the base to the top of the Coal-measures. In the low coal it abounds, especially in the shales of the roof; elsewhere in those of the bottoms of the coal-beds.
2. ——— *anabathra*, Corda. Scarce.
3. ——— *costata*, Lsqx. Locality unknown.
4. ——— *unbonata*, Lsqx., Gate v., Pottsville.
5. ——— *irregularis*, Lsqx. Same place.
6. ——— *minuta*, Lsqx., old red sandstone (Ponent), Pottsville.
7. ——— *radicans*, Lsqx., Salem v., Pottsville.

All the species of *Stigmaria* have apparently the same range of distribution as No. 1.

4.—SIGILLARIA, Brongt.

Stems large, ribbed, mostly marked with parallel or reticulated furrows. Scars of the leaves placed in spirals, in the middle of the ribs, disciform, oblong, or round, with the sides mostly angular, marked in their middle by the scars of the vessels by three, two, seldom single.

1. SIGILLARIA *lepidodendrifolia*, Brgt., New Philadelphia, upper coal.
2. ——— *sculpta*, Lsqx. Same place.
3. ——— *obliqua*, Brgt., Salem v., Pottsville.
4. ——— *dilatata*, Lsqx., Gate and Salem v., Pottsville.
5. ——— *fissa*, Gate v., New Philadelphia.
6. ——— *Schimperi*, Lsqx., Muddy Creek.
?7. ——— *stellata*, Lsqx., Carbondale (Mr Clarkson's cabinet).
8. ——— *Menardi*, Brgt., Muddy Creek. A common species.
9. ——— *Brardii*, Brgt., New Philadelphia.
10. ——— *Defrancii*, Brgt., Muddy Creek, Pa., and Massillon, O., low coal.
11. ——— *Serlii*, Brgt. ? Trevorton, low coal.
12. ——— *tessellato*, Brgt., same place.
13. ——— *elegans*, Brgt., Summit, Lehigh, Carbondale, &c.—Cuyahoga falls, Newb'y, low coal.
14. ——— *Brochantii*, Brgt., Summit, Lehigh, low coal.
15. ——— *alveolaris* Brgt., same place, low coal.
16. ——— *scutellata*, Brgt., Muddy Creek.
17. ——— *Sillimanni*, Brgt., Wilkesbarre (quoted by M. Brongniart—no specimen seen).
18. ——— *oculata*, Brgt., Trevorton.
19. ——— *polita*, Lsqx., Carbondale (Mr Clarkson's cabinet).
20. ——— *obovata*, Lsqx., Trevorton, low coal.
21. ——— *reniformis*, Brgt. A common species.
22. ——— *lævigata*, Brgt., New Philadelphia, Gate v.
23. ——— *Yardleyi*, Sp. nov.
24. ——— *elongata*, Brgt., Summit, Lehigh.
25. ——— *attenuata*, Sp. nov.
26. ——— *alternans*, Lind. & Hutt., Trevorton, low coal.
27. ——— *catenulata*, Lind. & Hutt., same place.
28. ——— *discoidea*, Lsqx., Summit, Lehigh, low coal.
29. ——— *acuminata*, Newb'y, *Ann. of Science*, p. 164, fig. 1, Cuyahoga falls.
30. ——— *Biercei*, Newb'y, loc. cit., fig. 2, Coshocton, O.
31. ——— *pulchra*, Newb'y, loc. cit., fig. 3, Youngstown, O.
32. ——— *dentata*, Newb'y, loc. cit., fig. 4, Cuyahoga falls, O.
33. ——— *marineria*, Hildreth, Cuyahoga falls and Poland, O.
34. ——— *grandis*, Newb'y (ined.), Cuyahoga falls.
35. ——— *centralis*, Newb'y (ined.), Cuyahoga falls.
36. ——— *minuta*, Newb'y (ined.), Cuyahoga falls.
37. ——— *squamosa*, Newb'y (ined.), Cuyahoga falls.

5.—SYRIGODENDRON, Sternb.

Stems furrowed; ribs equal, parallel, narrow, bearing on the corticated surface of the ribs small round scars, without any vascular marks. The stems belonging to this genus are mostly found ribbed, without any traces of scars.

1. SYRIGODENDRON *pachyderma*, Brgt., low coal. Common.
2. ——— *cyclostegium*, Brgt., same places as the former.
3. ——— *Americanum*, Newb'y (ined.) Cuyahoga falls.

The geological distribution of both the former genera is not yet sufficiently examined. Some of the enumerated species are certainly identical with others. The *Sigillariæ* appear, like the *Stigmariæ*, to have lived during the whole epoch of the coal-formation; but it is not now possible to assert what species belong to a peculiar station.

6.—LEPIDODENDRON, Sternb.

1. LEPIDODENDRON *aculeatum*, Sternb., common, Carbondale, &c.
2. ——— *rugosum*, Sternb., Carbondale, &c., low coal.
3. ——— *crenatum*, Sternb., Lehigh Summit, &c.
4. ——— *obovatum*, Sternb. Common.
5. ——— *modulatum*, Lsqx., Carbondale.
6. ——— *giganteum*, Lsqx., Carbondale.
7. ——— *vestitum*, Lsqx., Wilkesbarre and Carbondale.
8. ——— *conicum*, Lsqx., Carbondale.
9. ——— *oculatum*, Lsqx., Carbondale (Mr Clarkson's cabinet).
10. ——— *distans*, Lsqx., same place.
11. ——— *obtusum*, Lsqx., same place.
12. ——— *carinatum*, Lsqx., same place.
13. ——— *clypeatum*, Lsqx. Common, Archibald, &c.
14. ——— *sigillarioides*, Lsqx., Lehigh Summit.
15. ——— *rimosum*, Sternb., Carbondale.
16. ——— *Mieleckii*, Göpp.,? Lehigh Summit.
17. ——— *elegans*, Brgt., Cuyahoga falls (Newb'y).
18. ——— *gracile*, Brgt., Cuyahoga falls (Newb'y).

All the species of this genus, and of the four following, belong to the low coal. It is very difficult to find a trace of *Lepidodendron* in the grey-ash coal of Pa., and I have never seen any species of this genus above.

7.—LEPIDOPHOLIOS, Sternb.

Stem tree-like, marked by the base of the leaves, which are persistent and forming scales; scars at the top of the scales.

1. LEPIDOPHOLIOS *laricinum*, Sternb., Cuyahoga falls, (Newb'y).
2. ——— *crassicaule*, Brgt., same place (Newb'y).

Fine specimens of *Lepidopholios* have been found in the shales of the low coal in Illinois, Iowa, and Virginia: they are still undescribed. Specimens of this genus, and of the three following, are very scarce.

8.—ULODENDRON, Rhode.

Stems marked with the rhomboidal scars of the leaves, bearing two-ranked coniferous branches covered with imbricate leaves.

1. ULODENDRON *majus*, Lind. & Hutt., Great Kenawha, Va.; Salineville, O. (Newb'y).
2. ——— *Lindleyonum*, Sternb., Carbondale (Mr Clarkson's cabinet).

9.—MEGAPHYTUM, Artis.

Stem tree-like without bark, bearing small point-like scars placed spirally with some larger two-ranked and obicular.

1. MEGAPHYTUM *discretum*, Newb'y (ined.), Cuyahoga falls.

10.—KNORRIA, Sternb.

Stems tree-like, covered with thick short leaves and scars of branches. Leaves round, sessile, disposed in spirals; scars of the branches round.

?1. Knorria *taxina*, Lind. & Hutt., Cuyahoga falls (Newb'y).

2. ——— *Hildrethii*, Newb'y; *Ficoidites scabrosus*, Hild., *Amer. Jour. of Science*, vol. xxxi. p. 31.

3. ——— *distans*, Newb'y (ined.), Summit Co., O.

CONES OR CATKINS AND THEIR SCALES.

1.—Lepidophyllum, Brongt.

Leaflets simple, sessile, entire, lanceolate, or linear, bearing at their base an inflated bag (sporange,) full of spores, and forming, by their union on a common axis, a catkin. (*Lepidostrobus*.)

1. Lepidophyllum *acuminatum*, Lsqx., Johnstown, Pa.
2. ——— *obtusum*, Lsqx. Locality unknown.
3. ——— *lanceolatum*, Brgt., Carbondale (Mr Chambers' cabinet).
4. ——— *affine*, Lsqx., Wilkesbarre.
5. ——— *hastatum*, Lsqx., Greensburg, (Rev. Mr Moore's cabinet.)
6. ——— *brevifolium*, Lsqx., Wilkesbarre.
7. ——— *plicatum*, Lsqx., Wilkesbarre.

2.—Lepidostrobus, Brongt.

Catkin formed by winged sporanges (*Lepidophylla*), perpendicularly attached on a common axis, and imbricated.

1. ——— Lepidostrobus *ornatus*, Lind. & Hutt., Pa. and Ohio, low coal.

?2. ——— *variabilis*, Lind. & Hutt. With the former.

3. ——— *pinaster*, Lind. & Hutt., same places.

4. ——— *macrolepis*, Newb'y (ined.), Cuyahoga falls.

These two genera, being fruits of *Lepidodendron*, have of course the same geological distribution. The leaves of *Lepidodendron*, which are narrowly linear, grass-like, have been sometimes described either as blades of grass or as true *Lepidophyllum*.

3.—Brachyphyllum, Brongt.

Stems? or dichotomous axis covered with imbricated obtuse leaves placed in spirals.

1. Brachyphyllum? *obtusum*, Lsqx., low coal, Massillon, O.

FRUITS OR NUTLETS.

1.—Cardiocarpon, Brongt.

Capsules lenticular, compressed, obcordate or reniform, acuminate.

1. Cardiocarpon *Trevortoni*, Lsqx., Trevorton, low coal.
2. ——— *plicatum*, Lsqx. Same place.
3. ——— *Samaræforme* (Newb'y), *Annals of Science*, p. 152, fig. 1. Cuyahoga falls.
4. ——— *annulatum*, Newb'y, loc. cit., fig. 2. Youngstown, O.
5. ——— *latum*, Newb'y, loc. cit., fig. 3. Cuyahoga falls.
6. ——— *minus*, Newb'y, loc. cit., fig. 4. Same place.
7. Cardiocarpon *orbiculare*, Newb'y, loc. cit., fig. 5. Same place.
8. ——— *elongatum* (Newb'y), loc. cit., fig. 6. Youngstown, O.
9. ——— *punctatum*? Göpp., Muddy Creek.

All the species enumerated above, except perhaps the last, have been found in the low coal.

2.—Rhabdocarpos, Göpp. & Berg.

Fruit oval, ribbed in its length by parallel lines.

1. Rhabdocarpos *amygdalæformis*, Göpp. & Berg. Trevorton.
2. ——— *venosus*, Lsqx., Gate. v., Pottsville.
3. ——— *compressus*, Newb'y (ined.), Cuyahoga falls.

3.—Trigonocarpon, Brongt.

Fruit ovoid, three to six ribbed, with a broad hexagonal, flattened base.

1. Trigonocarpon *Schultzianum*, Göpp., Berg. Trevorton low coal.
2. ——— *Hilrethii*, Lsqx., Poland Co., O. (D. Hildreth).
3. ——— *oblongum*, Lind. & Hutt., Trevorton.
4. ——— *Nœggerathii*? Brgt. Cuyahoga falls (Newb'y).
5. ——— *tricuspidatum* Newb'y (ined.), same place.
6. ——— *magnum*, Newb'y, (ined.) Coshocton, O.
7. ——— *multistriatum*, Newb'y (ined.), Cuyahoga falls.

These fruits, and those of the following genus, have beeu mostly found in the low coal; a few of them are found in the upper Coal-measures, but always scarce.

4.—Carpolithes, Sternb.

Fruits or nutlets of variable forms.

1. Carpolithes *fraxiniformis*, Göpp., old red sandstone, (Ponent), below Pottsville.
2. ——— *bifidus*, Lsqx., Trevorton low coal.
3. ——— *disjunctus*, Lsqx., same place.
4. ——— *platimarginatus*, Lsqx., Trevorton.
5. ——— *acuminatus*, Sternb., same place.
6. ——— *bicuspidatus*, Sternb., common, low coal.
7. ——— *multistriatus*, Sternb., common. It ascends higher in the Coal-measures than the former.
8. ——— *umbonatus*, Sternb. Low coal.
9. ——— *retusus*, Sternb., Cuyahoga falls (Newb'y).
10. ——— *minutus*, Newb'y (ined.), same place.

To this enumeration of the species of fossil plants of our Coal-measures, I could add species of *Cyperites*, Lind. & Hutt., and of *Pinnularia* of the same authors. But the first genus represents only the leaves of some *Sigillariæ*. *Lepidodendron*, or even *Stigmaria*, and the species of the second, are referable to some roots which cannot be described by themselves.

About three hundred species of plants are enumerated in this catalogue. It is not possible to foretell how far the number may be increased by subsequent investigation. But until now the fossil plants of America have not been carefully collected, except by Dr Newberry and by myself; and it is probable that future explorations will at least double the number of these species. There are already about fifty species newly collected, which have not been described, and are not enumerated above.

My friend Prof. J. H. Balfour, Regius Professor of Botany in the University of Edinburgh, has kindly favoured me with the following notes upon the specimens of fossil vegetation figured on Plates XXI., XXII., and XXIII., and upon two other specimens not figured :—

As regards the fossil plants sent for examination, it is not easy to come to any definite conclusion regarding them; I can only, I fear, give very crude conjectures respecting their nature. We may call many of them Algoids, and refer to existing Algæ which they resemble, but it is absolutely impossible to point to any characters which will fix what they are. In speaking of the difficulty of determining such fossil specimens, Professor Harvey says—"I need but remind you of the algoid forms of *Podostemaceæ*—where you have often an external habit so closely resembling that of an alga, that, till you resort to the knife and the microscope, you may be easily deceived." Entertaining similar views, it is with great diffidence that I hazard any conjecture on the drawings sent for my inspection.

No. I. *Filicoid?*—A fern-like frond apparently resembling the primordial or barren frond of a Platycerium. The frond spreads in a radiating manner, with forked striæ not unlike the veins of a fern. At the edge the frond seems to have been folded in one or two places. There are several known species of Platycerium at the present day; viz., *Platycerium alcicorne*, a native of Madagascar and Eastern Asia, and found also in Eastern Peru; *P. grande*, in New Holland and Singapore; *P. stemmaria*, in tropical Western Africa; *P. biforme*, in the Malay islands.

The fossil plant, however, may be an algoid, although the forked venation is adverse to that view. If so, then it may be regarded as allied to Padina.

No. II. *Lepidodendron*, sp.?—A slender species of the genus, with imperfect markings in the form of dots arranged in a circular manner round the stem. The markings want the usual alternate arrangement of Lepidodendron scales.

No. III. *Leaf of a Gymnosperm?*—Resembling that of *Salisburia adiantifolia*. There appears to be a common broad petiole, whence proceeds a lamina divided into cuneate segments. The venation is very marked, and proceeds in a radiating manner.

No. IV. *Algoid?*—Resembling a Desmarestia. The stalk divides in a forked manner, and gives off narrow pinnæ, some of which are again pinnate.

No. V. *Algoid?*—Resembling *Nemastoma comosa*, an Australian alga. There is a central rachis which gives off branches, and then divides into small ramifications, which come off in a pinnate manner.

No. VI. *Algoid?*—Resembling *Halosaccion ramentaceum* of J. Agardh's work, the *Fucus ramentaceus* of Turner's "Icones Fucorum," vol. iii., tab. 149. In some of the fossil specimens there is a swelling whence the stalk seems to proceed.

On the whole subject of such fossil forms, I would take leave to forward to you the following words of Harvey, who, in speaking of a sea-weed called *Ptilota rhodocallis*, says:—"At first sight this beautiful species might almost be taken for *Phacelocarpus Billardieri*, so similar are its ramifications and colour; but the structure of the frond and the fructification are so different, that we are forced to refer these Algæ to widely-separated families. Geologists sometimes complain that botanists refuse definitively to name fossil plants whose impressions are left on sandstone, and, in the geological sense, *well-preserved*; but cases such as the present—and it is one of a thousand—show how uncertain must be the *determination* even of the best stone-printing of a fossil stem. What shall we say, then, of the positive settlement of the affinities and structure of fossil shadows, where there does not remain the faintest trace in stone of the entity that was and is not?"—J. H. Balfour.

The annexed Cuts, excluded for want of room from page 896, illustrate the different degrees of dip of the Levant Grey Sandstone on the Pennsylvania and New Jersey sides of the Delaware River, indicating a transverse fracture. (See page 896.)

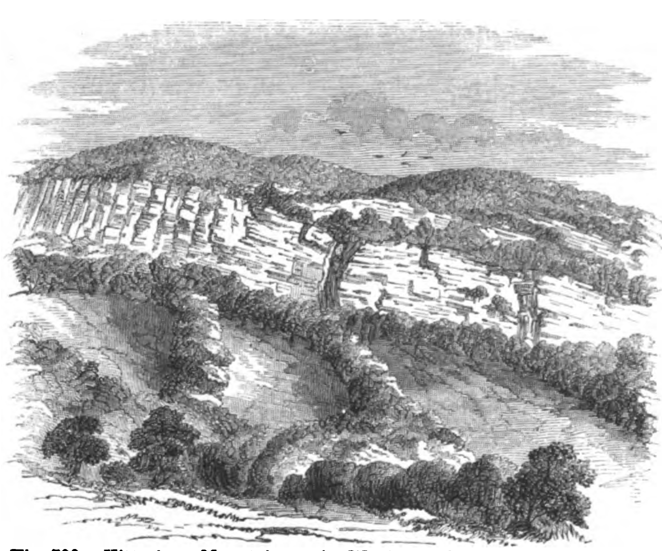


Fig. 700.—Kittatinny Mountain on the W. side of the Delaware Water-Gap.

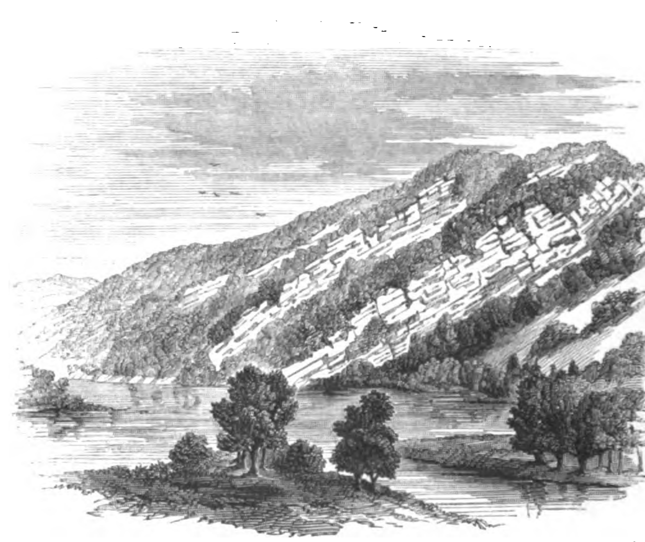


Fig. 700 a.—Kittatinny Mountain on the E. side of the Delaware Water-Gap.

ON THE LAWS OF STRUCTURE OF THE MORE DISTURBED ZONES OF THE EARTH'S CRUST.

Having several years ago, in the course of a prolonged investigation of the geological structure of the Appalachian chain of the United States, conducted partly in co-operation with Professor W. B. Rogers, as a purely scientific inquiry, partly by myself, in connection with the Geological Survey of Pennsylvania, discovered what we deemed important laws, applicable generally to all corrugated tracts of strata, I am prepared, by observations since made in the United States and in Europe, to extend their application, and give them a more general expression.

WAVE-LIKE FORM OF ALL UPRAISED TRACTS OF THE CRUST.

The first or most general fact to be enunciated respecting any portion of the earth's crust that has suffered elevation or depression from the position or level at which its strata were originally deposited, is, that the displaced beds present invariably the form of one or many waves, even when, within limited geographical areas, they may seem to retain an approximate horizontality. This comprehensive statement respecting the wave-like structure of the earth's crust is not invalidated by the instances of disordered dip seen in certain dislocated regions, such as some of the coal-fields of Great Britain; for it will generally be found that the breaks or faults in the strata only separate disarranged portions of what were originally continuous undulations.

In all large stratified areas, where the dip is both gentle and persistent in its direction throughout considerable spaces, and where this dip is genuine—the result, that is to say, of a true displacement of the mass, and not a consequence of the original obliquity of deposition called false bedding—the crust-waves will be found to be of an amplitude proportioned to their flatness; but in those districts where the prevailing inclinations are steep, and where they are directed to opposite points, it will be found invariably that the inclined masses are but the parts of successive arches or waves, the denuded or broken crests of which approach each other the closer as the dips are steeper.

EXEMPLIFIED IN PENNSYLVANIA AND IN THE UNITED STATES GENERALLY.

This cardinal fact of undulation in the structure of the earth's crust is admirably exemplified in the Palæozoic Basin of the United States, especially along its S. border, the Appalachian chain, and nowhere, perhaps, so well as in Pennsylvania. It is only necessary to appeal to any geological map and general section of the strata between the Atlantic and the Rocky Mountains—such, for example, as the Author has contributed to *Johnston's Physical Atlas*—to prove that every tract of inclined or dipping strata is but a segment of a great wave or waves of wider or narrower amplitude, and of gentler or steeper curvature. Even in those broad tracts of the central basin of the continent, where the strata, to a careless eye, seem to be absolutely horizontal, they possess an appreciable dip, which, continuously traced, changes its angle, and reverses its direction, until it discloses a very broad low wave. One such gentle yet majestic swell of the rocks extends from Lake Erie to Alabama, and fills the wide interval occupied by Ohio, Indiana, Middle Kentucky, and Middle Tennessee, between the great Appalachian coal-field and that of Illinois. Another divides the Illinois coal-field from that of Iowa and Missouri ; and similar flat undulations, on a scale of the grandest amplitude, heave the apparently level strata throughout the vast horizontal planes and steppes of Texas, Kansas, and Nebraska. For numerous and most striking instances of this law of wave-structure in districts of steeply-inclined strata, we need look no farther than the mountains of Pennsylvania, where, among the older rocks, almost every dipping mass is but a part of one or other flank of a more or less compressed high-crested wave, and where every gradation of form, from the most contracted to the most dilated, is discernible, as well in the N.E. half of the chain, within and round its coal-fields, as in the S.W., amid its alternating smooth valleys and steep rocky ridges. A mere glance at any of the numerous sections, general or local, which accompany this work, will suffice to show that undulation is the prevailing law in all the uplifted or displaced deposits.

PARALLELISM OF THE CRUST-UNDULATIONS.

It is another general fact connected with the disturbed zones of the crust, that where the displacement from horizontality has been great, the strata are arranged in longitudinal tracts, or great belts of parallel waves. These, where their symmetry of structure is not marred by dislocations of the strata, or hid by overlapping superficial deposits, exhibit a remarkable and beautiful resemblance to those great and continuous billows which are called by seamen rollers, and by mechanicians *waves of translation*. Far more continuous in their crests, more strictly parallel, and more symmetrical in form than the wind-produced waves upon the waters of the globe, such great swells or rolling billows, engendered by wholly different forces, are, I conceive, the true archetypes of the undulations visible in the more corrugated portions of the earth's crust. Perhaps in no uplifted district of the surface are these crust-waves so symmetrically developed, or so readily recognised, as in the Appalachian Mountains of the United States. It was there that Professor William B. Rogers and myself, analysing their forms, and tracing and connecting their axes, detected those phenomena of shape and gradation which led us to the general laws of crust-flexures which we have ventured to publish.

This parallelism of both the greater and lesser waves of the strata is conspicuous in every part of the Appalachian chain of Pennsylvania, but nowhere perhaps so obviously as in the region S.W. of the Susquehanna. There it must be discernible even to the passing traveller in the succession of the visible archings of the rocks, and in the extraordinary symmetry of the topographical features of the country resulting from it. Even without the aid of a Geological Map, we cannot fail to notice it in the beautiful parallelism of the long, slender, and gently-curving valleys, and the narrow, continuous, and extremely level mountain-crests. It is not less perceptible both within and exterior to the anthracite basins farther to the N.E., where indeed the law applies to flexures of all dimensions, down to those of very insignificant breadth. The amplest evidence of its universality is contained in the Geological Maps and sections illustrative of this descriptive text.

But we believe that generally all mountain zones, and all corrugated districts, which have been elevated, like the Appalachians, at one epoch, and by crust-movements observing only one prevailing direction, will be found to possess this wave-like structure, under similar conditions of gradation, and in a like conspicuous manner. It is only those tracts which have been revisited several times by the elevating and undulating forces, and especially those where the successive disturbances have not coincided in direction, but have crossed each other, causing interference and intersection of the waves, as in what is called a chopped sea—such districts, for example, as the Swiss Alps and the mountains of Cumberland and Wales—that we fail readily to discern the wave-structure of the strata, or, perceiving it in part, are unable, without extreme toil and patience, to connect the originally-related outcrops of the rocks, and reconstruct in our minds, and represent to the eye, the undulations that actually exist in a broken and disguised condition.

Wherever we have been led, either from observations in the field, or from a careful perusal of the descriptions of geologists, to a clear recognition of the dip-structure of any corrugated zone, whether mountain-chain or otherwise, not confused by different systems of elevatory movements of the crust, we have become impressed with its marked resemblance in all the essential features of the undulations, both as respects the typical forms of the individual waves, and the grouping and gradation of the several sets of waves, to the flexures characteristic of the Appalachian chain of America. I was particularly convinced of this resemblance upon examining, in the summer of 1848, the structure of the Jura chain of Switzerland;* and scarcely less struck with the agreement I noticed between the phenomena on the borders of the Alps, especially in the Bernese Oberland, and the features which distinguish the most corrugated tracts at the S.E. base of the chain of the Appalachians.

RELATIONS OF FLEXURES TO EACH OTHER.

If we regard now the flexures which constitute any great undulated or corrugated belt of strata, we shall find that these display the following laws or general facts of relationship:—

Parallelism.—1. When seen in their simplicity, or undisguised by cross breaks and undulations, those of a particular district show a remarkable degree of mutual parallelism. Not only are they parallel to each other, but to the general trend of the portion of the mountain system to which they belong, and especially to its chief igneous axes, where it possesses such.

This primary fact of parallelism of the anticlinal and synclinal undulations of a district to the general trend of its chief igneous axes, whether the waves be curved or straight, is finely illustrated in the structure of Pennsylvania. The mountain chain of the State is divisible lengthwise into four segments—a N.E. curving convexly towards the Atlantic slope; a central, very nearly straight: a S.W., sweeping convexly from the Atlantic slope, or towards the N.W.; and a S., almost absolutely straight, passing through Maryland into Virginia. Opposite the N.E. segment stands the similarly-curving chain of the highlands of New York and New Jersey; opposite the straight middle group of waves, the equally straight and strictly parallel, deep, synclinal flexure of the Montgomery and Chester Valley; opposite the curving portion of the district of the Juniata, the curving flexures of the metamorphic district of York County, and the S. mountains of Cumberland and Adams; and opposite the straight S. zone, the straight metamorphic range of the Blue Ridge of Maryland.

Parallelism of Groups.—2. The flexures or waves, where the undulated zones are wide and complex, occur in groups or lesser belts, those constituting such subordinate series observing the law of parallelism still more strictly than group does towards group. This remarkable parallelism of the adjacent flexures in an undulated region belongs not only to those waves and groups of waves which are rectilinear in their crests, but to such as curve even very considerably in their lineation. Nowhere, perhaps, is the constancy of this law so well displayed as in the Appalachians. This great mountain-zone of the United States and Canada, about 1500 miles in length, and more than 150 in its maximum breadth, consists longitudinally of eleven different sections, *six* of which are straight, *three* curvilinear, and convex towards the N.W., and *two* also curvilinear, but convex towards the S.E. Three of the straight sections have an approximately E. and W. trend, and the other three an approximately N. and S. course. Notwithstanding the great windings in the direction of the chain thus indicated, it is remarkable that each division or segment of it, whether straight or curved, is made up of crust-waves and groups of waves, which are essentially in mutual parallelism; and wherever a seeming exception to this rule presents itself, as on the Upper Juniata in Pennsylvania, and in Northern Vermont, it will be found to arise from the interference or interlocking of the ends of the waves of different but adjacent segments.

Each of the natural divisions of the undulated zone of the State offers numerous interesting instances of the above-mentioned parallelism of the different groups of waves with each other. One of the most obvious and curious is that furnished by the several sets of flexures terminating W. near the river Schuylkill. First we have in the semi-igneous belt of the South Mountains a succession of closely-packed anticlinal and synclinal waves, terminating like the toes of the human foot, each more Northern one a little behind or E. of its S. neighbour. Parallel with this group of flexures, and just opposite to it towards the N.W., is a strikingly similar series, ranging from the Lehigh S. of the Kittatinny Mountain, and then through that ridge into the Orwigsburg Valley, ending in a series of spurs receding, like the others, in the manner of the human toes. Thirdly, there occurs to the N. of these still another group of waves, parallel to the two former, ranging from E. of the Lehigh through Mahoning and Sharp mountains into the Pottsville coal-basin; and, finally, a fourth belt coming out from Nesquehoning Mountain, traversing Locust Valley, and entering Broad Mountain, the E. synclinal spurs of which it disposes in precisely the same order; the anticlinal flexures separating these spurs being mutually parallel, and forming a group parallel to the three other groups.

This grouping of the individual waves in sets, and the reciprocal parallelism of the several sets compared together, is remarkably distinct in that part of the Geological Map which pictures the country W. of the Susquehanna. We there find between the Kittatinny or Cumberland Valley and Bald Eagle Valley, at the base of Alleghany Mountain, a succession of six groups of principal undulations, corresponding to the six anticlinal coves dividing the W. ends of the coal-basins E. of the river, and these six sets of waves, all gently crescent-shaped, are singularly parallel. Each group, excepting the N.W. one, which is simple, is composed of two or more main anticlinals, and in some instances of several subordinate flexures, like secondary waves undulating the slopes of primary ones, and these lesser ones are themselves disposed in groups, and yet all of these again are strikingly parallel.

Flexures of different Orders.—3. Crossing any great belt of anticlinal and synclinal flexures, such as that of the

* See Abstract of Communication to American Association for Advancement of Science, Cambridge, Mass., March 1849, p. 113.

Appalachians, or that of Belgium and the Rhenish Provinces, it will be noticed, when the undulations are carefully traced and compared, that they consist of more than one class as respects dimensions; indeed, they will be found to be of two or three grades, when grouped according to their length, height, and amplitude. In most parts of the Appalachian chain there are at least two prevailing magnitudes in the waves. The chief class, or primary undulations, are of great size, their length amounting to from 50 to 120 miles, and their breadth to several miles, except where they are closely compressed. The subordinate or secondary waves are seldom more than a fourth of a mile wide, nor do they usually exceed 10 miles in length, and in many groups they are much shorter. Frequently a third class is to be met with, of still smaller and less persistent flexures,—rolls of the strata, as they are called in the coal-mining districts of Pennsylvania,—which seem to be only local corrugations of the more superficial rocks, and not true undulations of the crust pervading the entire thickness of the formations. The relations of the primary to the secondary waves will be enlarged upon hereafter; it will suffice, under the present head of parallelism of flexures, to state that, for the Appalachians at least, those of the second order are not necessarily parallel to those of the first, though within a given district they observe among themselves the same mutual parallelism which the larger or primary waves exhibit.

In no part of the chain is this independence of direction of the lesser or secondary undulations towards the primary or chief flexures more conspicuous than in the three principal Anthracite basins of Pennsylvania. There the secondary waves of the strata, parallel individually, and parallel group with group, are yet not parallel with the chief synclinal axes of the troughs they occupy. Indeed, some of the longer ones range obliquely across the coal-basins, starting in the mountain-barrier of one side, and expiring far out in the Coal-measures towards the other, meeting and passing others coming towards them from the opposite direction. They would seem to be, in fact, symmetrical parallel warpings of only the more superficial pliable strata, compressed by the synclinal bendings of the crust which formed the primary basins. In the Wyoming Valley, or N. anthracite coal-field, this relationship of these smaller waves or saddles is especially manifest, for in consequence of the crescent-like form of this trough they come off into the middle of the basin from its S.E. barrier, at larger and larger angles, as we advance Northward.

FORMS OF THE WAVES.

Symmetrical Flexures.—The individual waves or flexures of a belt of undulated strata occur under three essential varieties of form. The first, or most simple, is that of a convex or concave wave, or, in technical geological language, an anticlinal or synclinal flexure, in which the two slopes of the wave are equal in their degree of incurvation or steepness.—(Fig. 701). This symmetrical form is restricted chiefly to the gentler or flatter undulations, and especially to those of considerable amplitude. We do occasionally meet with steep waves of the strata, having a nearly equal inclination on both their sides; but these are generally broken curves, exhibiting a snap or sudden angle at the anticlinal or synclinal axis, in place of the gradual arching, which is the normal form of all regular crust-undulations.

Fig. 701.—Symmetrical Flexure.

Undulations of the symmetrical type present themselves in Western and Northern Pennsylvania on a very grand scale. Two great groups of these may be recognised beyond the Alleghany Mountain: one enters the State from the N.E., and subdivides the N. bituminous coal-field into six successive basins; five very broad, depressed anticlinal waves penetrating S.W. into the high table-land covered by the Coal-measures. The erosive action of water has denuded the upper firmer strata from off the anticlinal or convex portions of these waves, and cut the district into as many parallel valleys, leaving intervening synclinal spurs. The inclination of the strata upon the opposite slopes of these broad waves is upon the average nearly the same in both directions—in some cases being steepest towards the S.E., in others towards the N.W., but, with one or two exceptions, always at a low angle. The other, or S.W. group of waves, nearly as wide and somewhat more prominent than the above mentioned, is composed of four parallel, equidistant, very straight undulations, traversing parts of Cambria, Indiana, Somerset, and Fayette counties. The anticlinal flexures are those of Negro Mountain, Laurel Hill, Chestnut Ridge, and the upheaved belt W. of Greensburg. In each of these there is an approximation to equality in the inclinations of the two flanks of the waves; though in each instance partaking somewhat of the character of the steeper flexures of the mountain-chain to the S.E., the N.W. slope is somewhat greater than the S.E. All these N.E. and S.W. undulations possess a width of several miles, and it may be noticed that their breadth enlarges, while their curvature or steepness lessens, progressively as we cross them in a N.W. direction. These facts, and an explanation of their cause, will be dwelt upon in another place.

Normal Flexures.—Another and more prevailing form displays an excess of incurvation, or steepness of flexure, on one side compared with the other. Waves of this type have been called *Normal Flexures* by my brother and myself in our descriptions of the Appalachian chain, where they are very common. They are to be seen abundantly in the Jura, and in the exterior hills of the Alps. They abound, too, in the undulated Palæozoic region of Southern Belgium, and are a marked feature in the coal-basins of that country.*

* See Dumont's "Mémoire sur les Terrains Ardennais et Rhenen," &c.

These flexures prevail wherever the forces that disturbed the crust were neither excessively intense nor very feeble. They usually hold an intermediate position geographically between the groups of flat symmetrical waves and those which are closely folded, answering to the middle place they occupy as respects energy of undulation. Almost invariably, those of a simply undulated tract exhibit their steeper slopes directed all to one quarter. The exceptions to this law will be instanced in another place, and their existence accounted for.

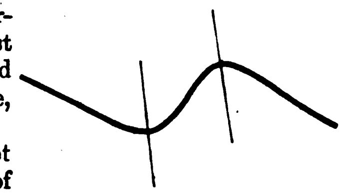


FIG. 702.—Normal Flexure.

Numerous beautiful examples of flexures of the normal type are to be met with singly and in groups throughout every section of the Appalachian chain of Pennsylvania, from the River Lehigh to Maryland. It is, indeed, the characteristic form of the flexures everywhere between the Kittatinny or main Appalachian Valley and the Alleghany Mountain. It distinguishes not only those larger waves which separate the coal-containing strata E. of the Susquehanna into special basins, but the minor undulations which throw the coal-measures of these basins into groups of lesser saddles and troughs. In the Pottsville anthracite basin, the anticlinal ridge called Mine Hill, trenched to its base at the passage of Mill Creek, and the W. branch of the Schuylkill, is a fine example of the normal wave. At both of these passes or gaps the regular arching of the rocks is so well exposed that every portion of the curve may be traced, and its changing inclination measured. The prevailing slope or dip in the S. flank of this wave is 40°, and in the N. flank 65°. The Gate Ridge near the S. side of the Pottsville basin is an instance of a more compressed normal flexure, its prevailing S. dips ranging from 45° to 55°, and its N. dips from 75° to 80°—the latter, however, becoming perpendicular, and even somewhat inverted, in the vicinity of Pottsville. All the flexures in the coal strata crossed by Silver Creek are of the normal type, except the most Southern, which has its N. flank inverted. On Casca William Creek, the coal-measures show five conspicuous waves, every one with a gentle S. dip, and a steeply-dipping N. side, in one or two cases inverted, or dipping S. In the Shamokin basin we have a good example of a normal flexure in Little Mine Ridge, in the S. slope of which the strata dip 20° S., in the N. 69° N. In the more uplifted region W. of the Susquehanna, this style of incurvation in the waves of the crust displays itself yet more conspicuously. The superior elevation of the waves there, conjoined with a denudation which has in many instances trenched out their summits, has developed their structure in the clearest manner, enabling the observer to contrast the slopes of their two flanks without any difficulty. In some cases he beholds the inner harder strata of the arch entire; in others he is enabled to reconstruct the broken arch, by prolonging the curves of its two abutments; and in nearly every instance he perceives a difference of from 15° to 30° in the inclination of the two sides; the N.W. dip, with a few exceptions, being the steepest. A traveller ascending the Juniata has an excellent opportunity for witnessing examples of this prevailing class of crust-undulation in Tuscarora Mountain, and in the pass of Jack's Mountain called Jack's Narrows, in both of which ridges the hard Levant sandstones span the anticlinal waves in almost unbroken crests. At the first-named ridge, the gentler or S.E. slope of the strata scarcely exceeds 20° at the river, and the N.W. is 35° or 40°; but when this wave is traced longitudinally from this point, which is near its termination S.W., to its central culminating portion, both dips increase, the S.E. becoming 40°, and the N.W. about 65°. The flexure which constitutes Jack's Mountain at the Juniata is a double wave, a bolder one sustaining a gentler one on its S.E. flank, but both of these possess the normal type: the principal wave, denuded at its crest, but entire as it recedes from the river, displays a N.W. dip of 75° or 80°, and a S.E. one of not more than 35°; the other, or flanking wave, a N.W. slope of 45°, and a S.E. one of 30°. Numerous instances of the smaller subordinate class of flexures present themselves along the Juniata, especially in the district between Tuscarora and Jack's mountains, but, with scarcely an exception, these conform to the same law of a steep and gentle slope.

The Pass of Wills' Creek Mountain W. of Cumberland, on the Potomac, is a highly picturesque example of a normal arch or wave, cut nearly to its base; and we meet with several beautiful instances of similar archings of the strata, on a grand scale, where the one side is more incurved than the other, in the central ridges of the mountain-chain in Virginia still farther S.

The Jura chain of Switzerland has been already referred to as containing many normal flexures. No one who has not travelled leisurely through the mountain gorges of that most attractive region, can conceive the grandeur and beauty of some of the wide-sweeping, lofty, semicircular precipices which there enchant the beholder in the Cluses or deep oval valleys, trenched by heavy waters out of vast wave-shaped mountains, of the class I am here describing. An American, familiar with the grand passes of the anticlinal ridges of the Appalachian chain, may get a conception of the far superior and wilder beauty of those of the Jura Mountains, if he will imagine the huge waves of his own strata to be three or four times as broad and lofty, and the strata themselves to consist, not of resisting sandstones, but of an alternation of deposits of soft shales and of thick-bedded limestones, the most picturesque of all rocks when carved into crags and cliffs.

Folded Flexures.—This *third* and remaining class consists of flexures in which there is an inversion, or doubling under, of the steeper side of each convex curve or wave (Fig. 703). When this structure is at a maximum, the folding back, downwards, of each convex or anticlinal arch amounts almost to a parallelism of the two branches or sides of the curve; and where there are several such foldings, alternately convex and concave, the strata may be said to be crimped or plicated into one dip, though the entire change of inclination through which the inverted portions have been bent, amounts to the supplement of the angle of the dip or the difference between the apparent dip and 180°.

It is a necessary feature of all such folded flexures, that the approximately parallel sides of the folds dip obliquely and not perpendicularly to the horizon. They are therefore but exaggerated instances of the class of normal flexures, or those where one branch of the curve is steeper than the opposite. As in the case of the normal flexures, the more incurved sides of these folded waves generally look the same way.

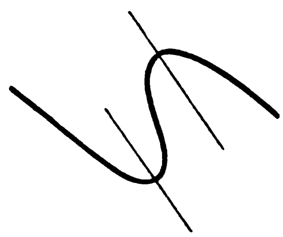


FIG. 703.—Folded Flexure.

An inspection of the general sections illustrating the Geological Map, and of many of the local ones, displaying the stratification in the S.E. portion of the State, will show that the flexures, with inversion of their steep sides, are chiefly confined to the Great Appalachian or Kittatinny Valley, and the Atlantic slope S. of it; though instances of this structure are to be met with N.W. of the Kittatinny Mountain, especially in the coal-measures of the Pottsville basin. The synclinal limestone valley of Montgomery and Chester counties is, in its central and E. portions, of this type; for while the strata of its N. side dip S. seldom steeper than 45°, those of its S. side near and E. of the Schuylkill are somewhat overthrown beyond the perpendicular. But it is in the district S. of this valley that we find the most numerous cases of oblique or folded flexures. Nearly every small insulated outcrop of crystalline limestone in the S. part of Delaware and Chester counties is an instance of a trough or little basin where the S. side has been folded over upon the N., until it has been squeezed down into a S. dip scarcely exceeding that upon which it leans.

The Kittatinny Valley is full of flexures of this extreme type, imparting a prevailing S.E. dip to the whole outcrop. Their number, and the excessive difficulty of detecting and continuously tracing them, frustrates every attempt at mapping them individually: nor was it deemed desirable, with the limited resources of the Geological Survey, to persevere far in a task promising little scientific or practical advantage.

Axis Planes.—It is convenient, for the purpose of expressing the kind of flexure, its degree, and its direction, to have regard to the geometric planes which bisect or equally divide the anticlinal and synclinal bends. These imaginary planes we have called the axis-planes of the undulations, being those which include all the horizontal lines or axes round which the individual concentric strata have bent in the act of undulating or folding. In the first-described class of flexures, or those of symmetrical curvature, each anticlinal and synclinal axis-plane is necessarily perpendicular to the horizon. In the second class, or the normal flexures, these axis-planes are necessarily not perpendicular, but steeply inclined to the horizon, and their deviation from the perpendicular is in proportion to the difference of inclination or of incurvation of the two slopes of the wave, modified, according to a certain law of variation, with the dip. In the third class, or that of flexures with *inversion*, the axis-planes are likewise not perpendicular; and it will be found that, in the great majority of instances, they dip with a less degree of steepness than the planes bisecting waves of the normal or other unsymmetrical type. Indeed, it may be stated generally, that, just in proportion as the flexure departs from the symmetrical-wave form, through greater and greater inequality of dip, up to parallelism of the inverted with the uninverted branch of the curve, the axis-plane departs from the perpendicular direction, to assume a less and less inclination to the horizon. In many districts of extreme plication of the strata—for instance, in the Atlantic slope of the Middle and Southern States of North America, also in the Bernese Oberland, in the Ardennes, and in North Wales—the axis-planes dip at an extremely low angle, consequent on the excessive amount of horizontal movement which the strata have undergone in the act of folding.

The positions and dips of the axis-planes are shown in the preceding woodcuts.

So nearly parallel are the inverted to the uninverted sides of the folds—the axis-planes all, of course, dipping one way—in many districts of close plication, that the detection of the anticlinal and synclinal bends is not a little difficult, especially where the sections, natural or artificial, are not perfectly clear of superficial debris. In such cases the whole plicated mass looks as if it contained but one dip, or consisted of only one thick sequence of deposits, instead of a much thinner formation many times reduplicated. To add to the liability of error, such bodies of folded strata are especially subject to that condition of jointage which is called *slaty cleavage.* In this structure, as I shall presently show, the divisional planes not only tend to obscure the original planes of sedimentation by their greater conspicuousness, but they often, by observing a very prevailing parallelism to the general dip of the folded beds, or, more strictly, to their axis planes, effectually disguise the anticlinal and synclinal curves. It is from these circumstances, and not from any erroneously-supposed power of truncation or denudation, to actually remove the anticlinal bends of the strata, that it is frequently so difficult to detect the true order of original superposition and the real thickness of closely-plicated formations. Of course, no erosion upon an anticlinal axis, however closely folded it may be, can obliterate the bends in those beds which have their curves below the level reached by the denuding agent.

Crust Waves, Straight and Curvilinear.—Regarding the great flexures of the crust as individual waves, which in truth they seem to be, we find them exhibiting, not only the above differences in the sloping of their two sides, but marked differences of form when viewed longitudinally. Thus, many are of extraordinary straightness; some of the larger simple anticlinals of the Appalachians being more than 100 miles in length, without any material or even perceptible horizontal crooking or deviation in their crest-lines. Others again are curved, some of these sweeping convexly towards the quarter of chief crust-dislocation and metamorphism, others curving convexly from it, but we never find these two classes associated in the same group, and in the Appalachians never even in the same segment of the undulated zone. In some districts of this and other chains, some of the principal curvilinear anticlinals and troughs are quite as extended in length as the great axes which are straight. They appear to be independent waves generated from curvilinear fractures of the crust, and not to be merely the bending terminations of adjacent rectilinear flexures. One of the most interesting features belonging to some of them is, their extent of curvature, and the graceful continuous smooth sweep which their curving axes present, often without jog or hitch, from one extremity to the other. This crescent-like form is developed in a high degree in those curving sections of the Appalachian chain, where the waves are convex North-westward, or from the quarter of maximum dislocation—the Atlantic slope. In the Juniata division of the chain in Pennsylvania, some of the curving anticlinals, 80 and 100 miles in length, change their trend between their two extremities as much as 40°; and in the Delaware division of the same chain, which bends with a concave sweep to the N.W., the deflection in more than one great synclinal trough and anticlinal axis is not less than 60°. This fact of the curvilinear form of anticlinals and synclinals of great length in this chain was long ago offered by us, as a phenomenon incompatible with the generalisation of the eminent French geologist, M. Elie de Beaumont, who conceives that the lines of elevation of the crust have been great circles of the sphere, and that those of a given geological epoch have invariably observed one constant direction. The whole of the Appalachian chain having been demonstrably corrugated into its present undulations at one epoch, that of the end of the coal period, the simple fact that its different groups of waves deviate as widely in direction from each other as 60°, while those of each group are reciprocally parallel—the whole chain indeed, if subdivided on this principle of direction, including not less than eleven conspicuous segments—is itself enough to show that no particular constancy of relation can be established between the dates of elevations and the mere directions of the lines or axes of the strata. But this other fact of so marked a change of direction in one and the same axis, as displayed by these crest-shaped waves, is, if possible, in still more striking contradiction with that hypothesis. Another fact connected with the groups of curving waves in the Appalachian chain is particularly deserving of mention in this place, from the bearing it appears to have upon the question of the direction of the pulsatory or wave-like motion of the crust, at the time of the permanent production of the flexures. This is, that the individual waves in all the segments of the chain which are convex North-westward exhibit, as already said, a continuous symmetrical crescent-like curvature; those, on the contrary, which are included in the other curvilinear districts, convex to the South-east, or towards the region of dislocation and metamorphism, present a much less regular incurvation along their anticlinals and synclinals, and a far greater amount of interference and of dislocation. These appear indeed to be the sections of the chain where the greatest amount of tangential wrenching, rupturing, and warping of the crust has taken place, and where the greatest amount of transverse hitching and fracturing has happened to all the strata. The causes of this difference will, I think, be seen, when I shall have developed our theory of the mechanical forces which undulated the Appalachian strata, and set in motion the stupendous billows of the crust, which resulted in the elevation of these mountains. An inspection of the best maps and sections of the more disturbed European zones, leads me to believe that a similar contrast prevails between the curvilinear waves which are convex to the districts of disruption, whence I suppose them to have proceeded, and those which are concave to the same quarters; but before this law in all its generality can be established, geologists must institute far more critical researches into the physical structure of those undulated and plicated districts than they have hitherto conducted.

Flexures or Waves of the Strata, regarded Longitudinally.—Having discussed the parallelism of adjacent undulations of the strata, their several specific forms, symmetrical, normal, and folded, the attitudes of their axis-planes; the straightness of some groups, the curvilinear shape of others; and shown their laws of gradation when severally compared, wave with wave, or group with group, it remains to trace the changing phases of a flexure as we view it lengthwise, or under the several aspects it assumes between its two extremities. Like all true waves or billows, every unbroken anticlinal flexure of the strata—and the description will apply equally to the synclinal, which are but their counterparts—has its maximum elevation in the middle of its length, its crest-line declining in a gentle curve both ways towards its extremities. Commensurate with this longitudinal subsidence, there is a flattening down of its two slopes, and a progressive approach in them to an equality of dip, until, near the terminations, there is seldom an appreciable difference in this respect: thus, the same wave, especially if it be one of the more majestic class, will present every gradation between its centre and two ends, from the normal, or even inverted type of structure, to the flat symmetrical. Crossed in its central portions, it may show the steeper flank thrown partially backward under the gentler; and receding towards either end, the inversion becomes a perpendicular dip, then a steep normal one, and as we still advance, this normal dip grows flatter and flatter, until towards the terminations it equals the opposite gentle one, and the two subside altogether; and this law of gradation holds true of all regular waves, whatever be their amount of flexure in the middle part. It is a consequence of this structure, or rather this structure arises from the fact, that in the middle parts of all regular anticlinals lower rocks than in the terminal are lifted to the same absolute level; they are indeed only very elongated oval bulgings of the strata, more squeezed on one slope than on the opposite, and their strata will be found to dip in all directions away from their primary axes of elevation. Hence, where great waves of the normal structure have been deeply eroded by excavating waters, they often exhibit in their central portion a long oval valley, formed by the cutting through of upper firmer rocks into softer lower ones. The floors of these valleys are merely horizontal sections of the uplifted waves, and generally reveal in their ground-plans the solid forms or styles of modelling of the uplifted billows.

Of the Distribution of Flexures into Groups.—Wherever, in the Appalachian chain, we become minutely familiar with the undulations of the strata, we find it impossible to resist the conclusion that the axes arrange themselves in natural groups. In those districts which are crowded with normal axes, such as the Susquehanna and Juniata divisions of the Appalachian chain, many such groups attract our notice; each assemblage is distinguished by some special character, and we are inclined to regard the comparison and analysis of their several features as of the very highest importance in those investigations of geological dynamics into which the whole subject of flexures evidently leads.

In the very interesting belt of parallel waves occupying Union and parts of Centre and Huntingdon counties between the Lewistown Valley and the valley of the Bald Eagle and West Branch, though there are three chief groups of anticlinal waves, these may be regarded as constituting one grand zone of singularly regular undulations. Viewed together, these waves are ten in number, the axis of each wave passing Eastward from a valley of Auroral limestone, or Matinal slate, through a beautifully-regular mountain-spur of the Levant sandstone, and expiring in the softer upper rocks on one or the other side of the Susquehanna. The ten mountain-ridges which express these ten undulations in the Levant strata are arranged in a beautifully symmetrical order, all of them, excepting the long spur of Jack's Mountain, throwing themselves successively farther Eastward the farther Northward they are. That they all constitute strictly a single group, lifted by the same crust-movement or series of movements, is palpable from the fact that their breadth or amplitude as waves, increases progressively as we cross them North-westward.

Another well-characterised belt of flexures fills the Lewistown Valley in Pennsylvania, applying this name to the whole of the long natural valley which extends from the Susquehanna to the Juniata, S.E. of Jack's Mountain. In a breadth of about 6 miles, there are here usually from five to six long, parallel, and gently-curving anticlinal axes, all of them of the normal form, resembling each other very nearly in the steepness of their dips, or average degrees of flexure. The lowest rocks which they lift to the surface are the Surgent shales, and the highest which their intermediate troughs have retained are the shales of the Cadent series.

A third very natural group of flexures is to be noticed in the E. part of the middle anthracite coal-field of Pennsylvania. The axes in question separate that region into an assemblage of small parallel coal-basins, of which the Beaver Meadow basin is one. Like the previous groups, these axes are characterised by their remarkable parallelism, their similarity in length, their gradually-increasing distances, and their gentle gradation in degree of flexure. They all of them bring to the surface the conglomerate which next underlies the coal; and the troughs which they form contain about the same moderate depth of Coal-measures, growing shallower, however, to the N.W. This collection of axes, unlike the two groups before described, constitutes a straight system.

If it were desirable, we might extend the enumeration of the groups of axes to every part of the Appalachian chain; but abundant evidence has been furnished to show that our anticlinal axes are not irregularly distributed, but maintain relations with each other, which require that they should be classified and studied collectively.

Their generic resemblances examined, they will be found to exhibit general laws and analogies that cannot fail to lead to some highly curious results concerning the forces which have thus undulated the earth's crust. That this curious and most instructive department of geological dynamics has escaped, until lately, the attention of the best investigators, we can only attribute to the fact, that in Europe no belt of axes, equal in extent to the Appalachian system, has come within the notice of geologists. Before a philosophical theory of flexures can be framed, large opportunities must be had for classifying their phenomena and tracing their laws of gradation.

GRADATIONS IN FLEXURES.

Gradation from the Folded to the Symmetrical Waves.—Several phenomena of gradation will be found to display themselves when we cross any broad belt of plicated and undulated strata. Starting from the side of maximum disturbance and contortion, invariably the quarter of maximum igneous action,—displayed either in Plutonic eruptions through the crust, in crust dislocations, or in metamorphism of the sedimentary rocks,—the flexures first met with are of the obliquely-plicated form. Advancing towards the middle of the zone, the folds become obviously less close; and proceeding still farther, they gradually open out, displaying more conspicuously their anticlinal and synclinal curves, until the inverted side of each wave becomes only perpendicular. This perpendicular altitude of the steep side soon becomes a dip towards the opposite quarter from that previously observed by both sides; and as we proceed, the steepness of the slope of the wave now rectified in position grows progressively less and less, until, on the far side of the zone, both slopes approximate to equality.

Gradations of Structure in Individual Flexures exemplified.—To render this subject of the gradations of phase in the same flexure more intelligible, I shall here cite a few instances from the Appalachian chain in Pennsylvania and Virginia. The relation between the degree of development or rise of the axis of an anticlinal undulation, and the steepness of its dips, is admirably exhibited in the great flexures which constitute the chain between the Susquehanna and the Potomac. Selecting as one of the chief of these, that grand N.W. one which encloses Nippenose, Nittany, and Sinking valleys, we can trace it through all its gradations, from the type of a flat symmetrical undulation at its extremities, to that of a greatly-lifted and compressed wave, with a perpendicular steepness on the N.W. side, at its middle part. Its total length is about 120 miles, its axis sweeping in a long and gentle curve from the table-land of Mahoopeny Mountain, at the sources of Little Muncy Creek, to the foot of the Alleghany Mountain west of the Blue Knob in Bedford County, traversing in its length the excavated oval limestone valleys, called Musquito, Nippenose, Nittany, Half-Moon, and Sinking valleys. At each end, and for a few miles, this flexure is flat, and of symmetrical or equal slopes; but approaching nearer the middle portion, it grows bolder, lifting the Levant sandstones into long pointed mountain-spurs, which ascending, divide into monoclinal crests. At these points, where it takes the names of Muncy and Brush mountains, the wave assumes distinctly the normal form, growing rapidly higher, and increasing in the steepness of its N.W. dip as it elevates lower and lower formations, until finally the great Auroral limestone rises to the day in Nittany and Sinking valleys. Between the ends of these and the centre of its range S.W. of Bellefont, the N.W. dip steadily steepens, until centrally it grows perpendicular, and even, in some places between Bellefont and Tyrone Gap, becomes a little inverted. In the vicinity of the Little Juniata, and apparently for some miles N.E., the flexure has given way at its axis, passing into a dislocation visible near the village of Birmingham.

We have another interesting example of a precisely similar gradation from the flat, symmetrical, steep normal structure, in the regularly crescent-shaped anticlinal wave, formed by the strata of Kishicoquillas Valley in Jack's Mountain. The axis of this flexure is traceable from the West Branch of the Susquehanna above Northumberland, to beyond Sideling Hill Creek, a length of 100 miles, and it goes through the same changes, except that it nowhere reaches an inversion of its N.W. flank. Tuscarora Mountain, Shade Mountain, Blue Mountain, Black Log Mountain, and Wills' Mountain in Bedford and Maryland, are all instances of a similar gradation of structure. Another fine example is that of Montour's Ridge, near the North Branch of the Susquehanna; though in this instance the wave only reaches a moderately gentle normal flexure at its midway section.

South of Pennsylvania the Appalachian chain contains many noble instances of normal and even folded flexures, displaying like degrees of alteration in their profiles from their extremities towards their centres. The Knobly Mountain of Virginia, the most Westerly large anticlinal wave S.E. of the coal-region, retains a normal profile in its strata through a length of more than 50 miles. Commencing near Cumberland on the Potomac, this wave-shaped mountain rises and widens, until, in Pendleton County, its N.W. dips become vertical, or a little inverted; and they retain this attitude for 40 miles farther S. to the anticlinal valley of Crabb Bottom. There passing the culminating part of its axis, the wave slowly sinks, and opens out, displaying its previous phases in a reversed order as it advances, until the divided crests close again by declension of the dip of the strata, and it becomes once more a gentle normal flexure, terminating finally at the S.W. in an inconspicuous low ridge or spur of equal opposite dips.

The Bull-Pasture Mountain of Pendleton and Bath counties, Virginia, displays the same gradual steepening of the flexure as its lower strata are successively lifted to the surface, and preserves in its central portion the normal profile without inversion, through a length of more than 50 miles. Jackson Mountain, in Virginia, is part of a great wave of the strata, which, commencing in Pendleton County, runs nearly straight to the deeply-scooped anticlinal valley of the Warm and Hot Springs, and terminates near Covington. Its length is about 70 miles. Manifesting at each end a gentle equal arching, the curvature or steepening of its strata in profile regularly increases, especially along its N.W. side. As far as the strong Levant sandstones span the wave, the mountain is single in its crest, but at the head of the Warm Spring Valley, and thence to the lower end of the Falling Spring Valley, this crest is parted into two ridges by deep excavation on the summit of the wave, the erosion having reached down to the Auroral limestone; and in this most lifted and laterally-compressed central portion, the N.W. side of the wave is perpendicular, and even inverted. At the end of the Falling Spring Valley the harder rocks of the mountain close over the slate and limestone of the valley, and the flexure begins to sink, contract, and flatten off in both its slopes, until at Jackson's River this prodigious wave of the rocks dies out in a low obtuse ridge of very depressed and nearly equal dips.

The very interesting relation here presented between the amount of incurvation or the steepness of the dips in flexures, and the amount of positive uprise of the strata, applies equally to the lesser or secondary anticlinal waves, and pervades every portion of the Appalachian chain. It constitutes an important law of structure connected intimately with the theory of a wave-motion of the crust, through which we seek to explain the curious phenomena of the undulated profile or wave form of the strata, so universal in all the disturbed districts of the globe.

Progressive Expansion of the Waves in one Direction.—Concurrently with this gradation, there is a progressive opening out of the spaces between the crests of the successive waves—such indeed as to amount in the Appalachians, and sundry other broad regions of crust-undulation, to an enlargement by many times of the amplitude of the more compressed class of flexures.

This remarkable and instructive fact is common to nearly all of the Primary class of undulations of the Appalachian chain, and is even common to many of the groups of secondary dimensions. It is manifested on a fine scale in the group of broad low waves which form the six finger-like mountain-basins in which the great bituminous coal-field terminates North-eastward, between the North Branch of the Susquehanna and the waters of the West Branch and the Alleghany River. It is one of several phenomena of gradation in the relations of the Appalachian flexures, which originally suggested to the author and his brother the theory of crust-undulations, or of a billowy upheaval of the strata, and is a fact which no other hypothesis of the origin of anticlinal and synclinal flexures can account for. Although distinctly noticeable in the N.W. side of the belt, the gradation prevails equally in the middle and S.E. tracts; but in the latter the numerous minor flexures, with the interference of groups of different dimensions, prevents our at first perceiving the law in all its simplicity and exactness. Towards the S.E. side of the chain, the flexures become so numerous, and are so often folded or inverted, as in most cases to render the comparison of their distances impracticable; yet even in this quarter, the general truth appears in the diminished space between the foldings as we cross the Great Valley southeastward. Viewing the whole breadth of the chain, the prevalence of the rule is obvious, no matter by what section we cross.

EXCEPTIONS TO THE PREVAILING LAW OF STEEPER N.W. THAN S.E. DIPS IN THE APPALACHIAN CHAIN.

There exist among the undulations of the strata in Pennsylvania a few—they are very few—exceptions to the almost universal law of a superior degree of abruptness of incurvation upon the N.W. slopes of the anticlinal waves. These abnormal instances of relative dip belong almost invariably to the secondary class of flexures, which I have never regarded as true waves pervading the earth's crust, but as comparatively superficial foldings occasioned by the joint agency of pulsation and lateral crumpling. There are a few examples of unusual steepness of the S.E. dips in the Primary class of flexures; but nearly every one of these exceptions applies to only a local portion of the wave, and will be found connected either with a fault in the strata, or with an oblique interference of the end of an anticlinal of another group. I think there does not exist within the whole wide undulated zone of the State, or of the Appalachian chain generally, a wave or group of waves of the first order, which is abnormal as respects the direction of the flatter and steeper slopes, except where we can directly refer it to the influence of some prodigious crust-dislocation.

As instances of exception to the general law, I may cite the second main axis of the Northern bituminous axis of the coal-fields, or that of the Towanda Valley. This is decidedly steeper in its S.E. dip than in its N.W. At the Susquehanna, the two inclinations, both gentle, are nearly equal; but the S.E. is greatly the steepest near the sources of Lycoming Creek, or in the direction towards which the flexure is expiring—a fact sufficient in itself to demonstrate that the irregularity is local, and proceeds from a twisting of the wave against another flexure. Chestnut Ridge, though normal in its profile on the Conemaugh, and, indeed, at both extremities of the long straight wave which it forms in one portion of its length, is locally irregular in the law of its dips, in consequence of an adjoining fracture in the strata at its E. base.

Of the lesser class of flexures of a reversed profile, we may instance many in the anthracite coal-fields, particularly in the Shamokin basin, and two interesting groups affecting the Scalent variegated and grey marls on the Juniata, of which drawings are appended for illustration.

One of these last-mentioned instances is to be seen in the cuts of the Pennsylvania Railroad, a short distance below Mifflintown, where there are three small flexures with their steep and gentle sides reversed, and one with

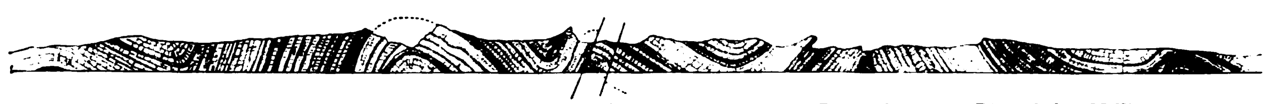


FIG. 704.—Undulations in Scalent Variegated Shales and Sandstones on Pennsylvania Railroad, Juniata River, below Mifflintown, Juniata County, looking S.W.—1 *inch* = 100 *feet*.

symmetrical dips. The irregularity here is evidently connected with the dislocations indicated in the section. The other example referred to is to be met with in a series of cuts on the Pennsylvania Railroad, a short distance below Lewistown, on the Juniata. Here there are three flexures, all with their steepest slopes dipping to the S.E.

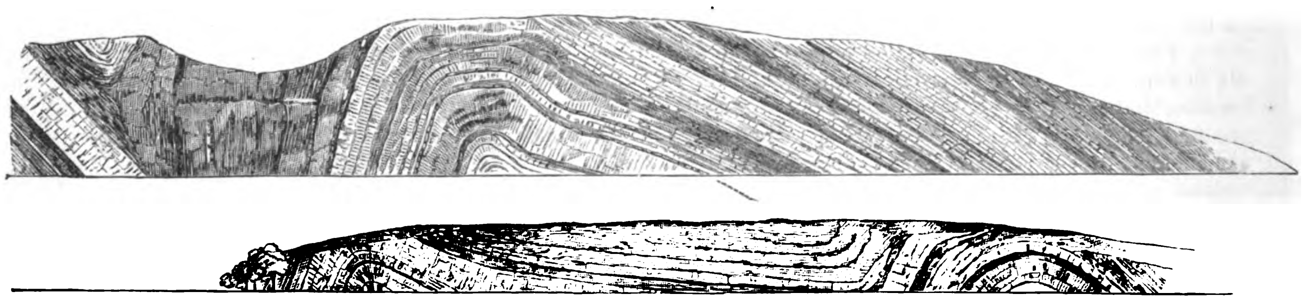


FIG. 705.—Undulations in Scalent Variegated Shales on Juniata River, below Lewistown, looking S.W.—1 *inch* = 50 *feet*.

A few other similar instances of irregular corrugation of the more pliable upper strata might be cited as occurring in the Lewistown synclinal valley, but the above examples will serve as types of the rest of these local rolls. It is worthy of note that the great anticlinal flexures bounding this long valley are all of them not only normal in their profiles or style of curve, but normal in the direction of their steepest slopes; even the four or five parallel undulations, of secondary magnitude, which lift the Pre-meridian limestone in long regular crests in the valley, between the Juniata and Jack's Mountain, observe the prevailing rule. I shall, in a subsequent chapter, when discussing the nature of the movements which undulated the Appalachian strata, advert more fully to the causes which seem to have produced these and other anomalies of dip.

Progressive Flattening-down of the Flexures.—A third feature of gradation shows itself in the progressive sinking or flattening down of the successive individual flexures, until these finally pass into horizontality. These three types of form in the waves, as respects their expansion, their increase of relative distance or amplitude, and their declining height, are conspicuously discernible wherever we cross the great Appalachian chain of the United States, by any section in a direction from S.E. to N.W. An inspection of the engraved sections illustrating our paper on the physical structure of the Appalachians,* or an examination of the more numerous similar diagrams explanatory of the geological surveys of New Jersey, Pennsylvania, and Virginia, will amply avouch for the correctness of this generalisation. It is further borne out in the published reports of the Government Survey of Canada, where the plicated structure of the Green Mountain range of Lower Canada, along all its S.E. border, and the universality of the S.E. dip of the folded strata—in other words, of the dip of the axis-planes,—is very distinctly set forth by Sir William Logan.

Not only does the entire chain in its breadth exhibit a general gradation in the several features here described, but each of its great component groups of flexures presents the same progressive opening, recession, and flattening down of its waves in the same uniform N.W. direction.

Similar phenomena of gradation will, we feel assured, disclose themselves in any section made from the Taurus range N.W. through the Rhenish Provinces and Belgium, where, on the one side of the zone, the more ancient and much metamorphosed strata at the base of the Palæozoic system, according to the observations of Murchison and Sedgwick, present much reversal of the dip; one and the same dip—namely to the S.S.E.—being continued with very few exceptions across a belt of 50 miles, while on the opposite or N. side, the flexures of the Belgian coal-fields, so well shown in the beautiful sections of M. Dumont, are of the normal type, and much more open and dilated.

Nowhere perhaps in Europe are these gradations in the undulations of strata more beautifully exposed than on the flanks of the Alps. Deep in, towards its higher central igneous chains, the plication of its stratified rocks is excessive, and the inclination of the axis-planes remarkably low; but advancing outwards, the waves gradually lift their crests, throw forward their inverted sides, and assume that type of flexure which we have called the normal one; while again, at the outward base of the mountains, just before these undulations are concealed by the overlapping Tertiaries of the plains of Switzerland and of Northern Italy respectively, the curves become, in many instances, broad, depressed, and almost symmetrical in form.

From the descriptions here given of the structure of the Appalachian chain and other disturbed districts, it is obviously a general law that the axis-planes of the flexures are not only inclined all in one prevailing direction, though at different angles, but that they dip invariably towards the quarter or zone of maximum disturbance and rupture of the crust.

Fig. 706.—Generalised Section of the Appalachian Chain from N.W. to S.E., through the Juniata District of Pennsylvania.

FRACTURES OR FAULTS IN TRACTS OF UNDULATED STRATA.

Two classes of dislocations abound in all zones of plicated and undulated strata, where the crust-waves exhibit much steepness, and especially where they have the inverted or folded form. By far the most numerous, though the shortest and least conspicuous class, are the breaks or faults which run approximately transverse to the strike of the anticlinal and synclinal axes. These may be extensively recognised in the Appalachians, where they are a primary cause of the deep ravines or breaches through the ridges, which furnish passage to nearly all the rivers, and even lesser streams, which drain this chain. Such ravines are especially frequent near the extremities of the large anticlinal waves, particularly where they have been cut through along their crests by denuding waters, and have given rise to valleys of elevation and erosion, enclosed by monoclinal outward-dipping sandstone ridges. It would seem as if the elliptical folding round of the strata towards the ends of the great denuded waves had caused the horizontal wrenching which resulted in these fractures. Mr William Hopkins of Cambridge, in an able paper on the subject of dislocations affecting dome-shaped elevations of the earth's crust, has indicated the true source, I conceive, of the double system of fractures to be met with in all elliptical anticlinal belts. An elongated anticlinal wave is, in truth, only a greatly-lengthened elliptical dome, in which the radial cracks caused by a maximum tension in the strata transmitted from the more central portion of the crust-wave, are distributed, some of them longitudinally, others transversely, as respects the anticlinal axis, the transverse ones multiplying themselves where the elliptical strain has been greatest, towards the two extremities of the waves.

Those parts of the Appalachian chain which most abound in the larger and more deeply-denuded class of anticlinal and synclinal waves in the strata, embrace many beautiful examples of the deep notches or gaps in the mountain-ridges, above alluded to as indicative of transverse breaks or dislocations in the rocks. They occur both in the sandstone barriers which surround the anthracite coal-basins, and in those which encompass the limestone valleys of the chain S.W. of the Susquehanna. It will suffice in this

* Transactions of the Association of American Geologists.

place to mention, as among the more interesting of the first-named series, the Mountain-gaps through which the upper branches of the Schuylkill and the Swatara rivers pass out of the Southern or Pottsville coal-basin, those by which the tributaries of the Mahanoy and the Shamokin leave the middle or Mahanoy and Shamokin coal-field, and those by which the N. branch of the Susquehauna enters and quits the Wyoming basin. Under the second head, it will be enough to call attention to the Kishicoquillas and Gosling Run gaps of Kishicoquillas Valley, and the sundry other deep mountain-notches which outlet the waters of the raised anticlinal limestone valleys and coves of this portion of the chain into the exterior valleys which hold the larger streams.

FIG. 707.—Delaware Water-Gap.

By far the larger number of these transverse ravines in the great ridges betray no perceptible horizontal displacement or heave of the rocks, though it is probable that a trivial amount of such actual dislocation does exist at nearly every one of them. In some of them, however, the break is very discernible, and in a few instances it becomes a conspicuous feature in the scenery. Thus the pass of the Delaware through the Kittatinny Mountain, called the Water-gap, shows a striking inequality in the inclination of the strata of the opposite sides of the gorge,—those of the New Jersey shore dipping at an angle of not less than 40°, while those of the Pennsylvania side decline as gently as 25°. As a consequence of this derangement between the opposite sides of the cross fracture, the summit of the mountain, or rather the same outcropping hard ribs of rock, appear thrown several hundred feet farther North on the New Jersey side than on the Pennsylvania.—(See View of Delaware Water-gap, fig. 707). There is a similar dislocation in the same mountain at the Susquehanna.

One of the most obvious of these transverse dislocations crosses Sharp Mountain, and the Coal-measures at Lorberry Creek, N.W. of Pine Grove, E. of the gap by which that stream passes through Sharp Mountain: the strata in this S. barrier of the coal-field range about S. 72° W., and dip in an *overtilted attitude*, at an inclination of rather less than 70° S.; while on the W. side of the gap, the course of the rocks is S. 57° W., their posture being nearly vertical,—the whole mountain, and the Coal-measures N. of it, being at the same time moved or heaved towards the S. as much as 30 yards.

It is probable that a fracture of the same kind passes through the gap of the W. branch of the Schuylkill, 2 miles W. of Pottsville; for the Coal-measures which E. from this neighbourhood are traceable with a moderate degree of regularity for several miles, appear no longer in their ordinary range when they are sought for on that stream.

Not unfrequently the cross dislocations are obliquely transverse, and not perpendicular to the strike of the strata; and in such cases, where the horizontal heave is considerable, we behold the two broken ends of the same hard belt of rock thrust past each other, as in the fracture of a man's thigh-bone. An example of this class of faults occurs on a grand and striking scale in Canoe Mountain, near the Juniata, at the point where the main road crosses the mountain. The ridge, composed of the Levant sandstones, here in full development, has been fractured in an oblique N.E. and S.W. direction; the Northern part has been shoved forward towards the N.W., and the S. forced past it N.E., so that they lap past each other. The ridge being double-crested, by virtue of the superior hardness of the lower and upper Levant sandstones compared with the middle, a directly transverse section crosses the mountain twice, crossing four summits instead of two.

The reader will find a cut displaying this dislocation in the chapter describing Canoe and Lock mountains.

There is a somewhat similar oblique lapping of a mountain-ridge of the Levant sandstones, from a similar cause, in the N.W. barrier of the Kishicoquillas Valley, opposite Belleville.

The anthracite coal-fields are full of such oblique fractures, causing the broken ends of the coal-beds to overlap each other.

The other far more conspicuous class of dislocations connected with these crust-undulations are the great longitudinal ones. These are of frequent occurrence in the more contorted portions of the Appalachian zone, especially in those where the chain is convex to the S.E., and in the straight sections of South-western Virginia and Eastern Tennessee. But I am persuaded, from the descriptions of geologists and from my own observations, that the fractures of this class are equally numerous in the Jura Mountains, in the Alps, in the district of the Ardennes, in Belgium, and in the mountain-chains of Scotland. A leading feature of these great fractures is their parallelism to the main anticlinal axes, or lines of folding of the chains to which they belong. They are, in fact, only flexures of the more compressed type, which have snapped and given way in the act of curving, or during the pulsation of the crust. They coincide, in the great majority of instances, neither with the anticlinal nor the synclinal axis-planes of the waves or folds, but with the steep or inverted sides of the flexures, and almost never occur on their gentler slopes. This curious and instructive fact may be well seen in the Appalachians of Pennsylvania and Virginia, by tracing longitudinally any one of their great faults from its origin on the steep flank of an anticlinal wave along the base of its broken crest to where the anticlinal form is again resumed. The following brief description, from our "Memoir on the Physical Structure of the Appalachians," taken from the *Transactions of the American Association*, will show the general phases through which these fractures pass:—

"From a rapidly steepening N.W. dip, the N.W. branch of the arch (or flank of the wave) passes through the vertical position to an inverted or S.E. dip, and at this stage of the folding the fault generally commences.

"It begins with the disappearance of one of the groups of softer strata lying immediately to the N.W. of the more massive beds, which form the irregular summit of the anticlinal belt or ridge. The dislocation increases as we follow it longitudinally, group after group of these overlying rocks disappearing from the surface, until, in many of the more prolonged faults, the lower limestone formation (Cambrian or Lower Silurian) is brought for a great distance, with a moderate S.E. dip, directly upon the Carboniferous formations. In these stupendous fractures, of which several instances occur in South-western Virginia, the thickness of the strata engulfed cannot be less, in some cases, than 7000 or 8000 feet."

One of these enormous faults in South-western Virginia has a length of more than 80 miles, and is almost perfectly straight. It follows the S.E. slope of Brushy Mountain, from the head of Catawba Creek to the vicinity of the court-house of Smyth County, engulfing all the strata of the S.E. half of a synclinal basin, of which Brushy Mountain remains as the other half. Where the dislocation attains its maximum intensity, or shows the greatest displacement of the strata, the lower formation—the Auroral Appalachian limestone, the equivalent of the Festiniog group of England—of one side of the fissure rests in an inverted attitude, with a gentle S.E. dip, directly on the South-east-dipping Vespertine grits and shales—represented in Great Britain by the lowest Carboniferous strata—forming the other wall of the fault.

General Parallelism of the Faults to the Axis-Planes.—It is a very general feature of the great longitudinal faults, whether these coincide with the anticlinal and synclinal axis-planes, or occur, as they more frequently do, on the steep sides of the flexures, to dip in the same direction with the axis-planes. In the Appalachian chain their inclination, therefore, is almost invariably towards the S.E. A consideration of the nature of the forces which have folded and ruptured the strata, shows that such a direction of their dip is an almost inevitable consequence of the undulatory movement. It is only in districts of low symmetrical crust-undulations, or those where the strata are absolutely flat, that the great fractures descend perpendicularly.

In corrugated zones, like those of the Appalachians, the Alps, and the Ardennes, the magnitude of these main longitudinal fractures, both as respects length and vertical displacement of the dislocated strata, is in proportion to the sharp bending or close folding of the waves to which they belong. Thus they invariably possess their grandest dimensions in the S.E. or most plicated belt of the Appalachians, or on that side of the zone where the crust-movements have been most energetic.

This obliquity or dip towards the quarter whence the movement has proceeded, is evidently the cause of that overlapping of the newer, less-lifted side of the wave in which the fault lies, upon the steeper, more perpendicular, or inverted flank; for the forward or horizontal thrust which accompanied the propagated wave-movement resulting in the fracture, has, when this once occurred, found an inclined plane, up which the uninverted slope of the wave slid over the edges of the strata composing the inverted side. In many instances, as the Appalachian sections will prove, one flank of the wave has been shoved forward and upward, unconformably, upon the crushed and buried flank to an enormous distance. Subsequent erosion having cut down the higher strata of the up-driven, gently-sloping side of the wave, its lower beds are exposed to view, in immediate contact with the unremoved upper strata of the other side. Where the lower formations, cut into by the water on both sides of the fault, have been equally easy of excavation, especially where they are all of the same composition, as in the case of the great lower Appalachian limestones, the denuding waters have so effectually planed down the great inequalities of surface at first caused by the dislocation, as sometimes to have left in the landscape almost no external traces whatever of the gigantic rupture which lies beneath the soil. It is, then, only by a recognition of the ages of the respective strata, thus abruptly placed in contact, and usually, though not always, by some sudden difference of dip, that we are enabled to detect the presence and the magnitude of the dislocation.

Dislocation at an Anticlinal Axis-Plane—uninverted Side of Wave shoved over the Inverted (see Fig. 708).—It seems also necessary, on this occasion, to explain the effects of those great longitudinal obliquely-dipping faults, when they occur directly in the anticlinal and synclinal axis-planes, which are their occasional positions. The same forward upward-sliding, just described as having occurred where the fracture is between the anticlinal and synclinal curves, must have taken place where it has coincided with these; and as the movement must necessarily have been in the same direction—lifting, that is to say, the lower strata cut by the fault upon the edges of higher and higher beds, in the forward propulsion of the flat side of the broken wave—we have no difficulty in understanding how fractures in these positions, as well as in the other already spoken of, must have given rise to that very common phenomenon of the dipping of newer formations under older ones in plicated and dislocated countries like the Alps and the Appalachians. This puzzling feature of stratification, long an enigma to geologists, can, I conceive, be explained upon no other analysis than that which is here given—namely, the oblique folding of undulated strata, the obliquity of the planes of the faults, either coincident with, or parallel to, obliquely-dipping axis-planes; and the forward upward thrust of the uninverted upon the inverted broken strata, through a tremendous tangential force incident to a wave-motion.

Dislocation at a Synclinal Axis-Plane.—Where the dislocation has taken place, as it very frequently has, in the plane of a synclinal fold, it has generally been accompanied by a similar forward and upward thrust of the strata above the fault, but these strata belong in such instances to the inverted side of the adjacent anticlinal wave. This kind of fracture and displacement presents, therefore, an inverted set of strata, resting over an uninverted or right set, a relation the converse of that which characterises a dislocation at an anticlinal axis; but the relation of the strata brought thus unconformably into contact as respects their stratigraphical position is the same as in the cases of fracture through the axis-planes of anticlinals; for the movement being an upthrow of the overlying mass in the plane of the fault, its effect, conjoined with denudation, has been to display lower rocks leaning invertedly upon upper.

The accompanying diagrams are designed to illustrate the several conditions of contact of strata displayed

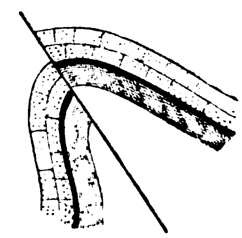


FIG. 708. — Upward displacement of uninverted side of fractured anticlinal.

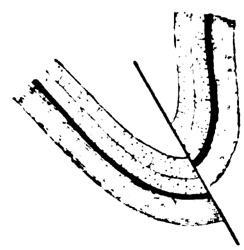


FIG. 709.—Upward displacement of inverted side of fractured synclinal.

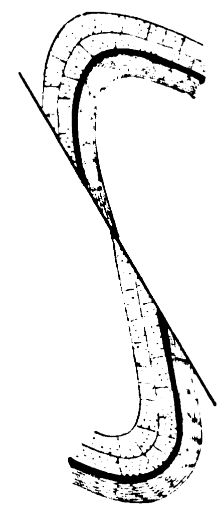


FIG. 710. — Upward displacement of whole anticlinal flexure; fault in the inverted side.

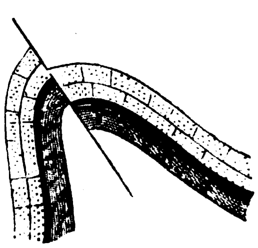


FIG. 711. — Downward displacement of uninverted side of fractured anticlinal.

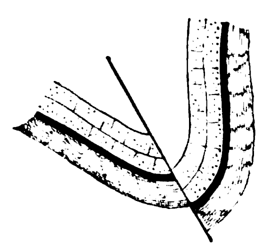


FIG. 712. — Downward displacement of inverted side of fractured synclinal.

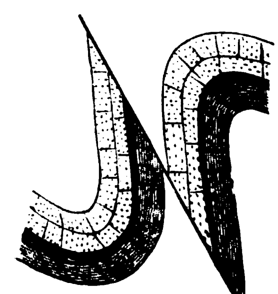


FIG. 713.—Downward displacement of whole anticlinal flexure; fault in the inverted side.

by faults coincident severally with anticlinal and synclinal axis-planes, and by faults parallel with these, but situated in the overturned and crushed sides of steep folded flexures.

Instances of great Longitudinal Dislocations.—Numerous instances of longitudinal faults, nearly all of them dipping obliquely, and for the most part South-eastward, are to be met with in the Pottsville coal-field and other disturbed plicated belts in Pennsylvania. The principal features of the lesser ones—which are chiefly interesting where they affect the Coal-measures—have been already described in that portion of this work which is devoted to the Anthracite region. It will suffice here to exemplify our general statement of their nature, by pointing to one or two of the larger dislocations of this type to be met with in other parts of the State.

An interesting longitudinal dislocation ranges along the W. margin of McConnellstown Cove. From its N. end Southwards, it buries successively Cadent, Meridian, Pre-meridian, Scalent, Levant, and Matinal rocks under the Auroral limestones of the Cove, and Southward it allows them to rise out again in a reversed order. Near the middle of its length, inverted South-east-dipping Auroral limestone leans at a steep angle on the more gently South-east-dipping higher Cadent and even Vergent rocks. This great fissure evidently dips steeply towards the E.S.E., and has its place about half-way between the anticlinal axis of McConnellstown Cove and the synclinal of the mountain-trough of Scrub Ridge; it therefore belongs to the N.W. flank of a great wave, and not to either axis. There is an interesting smaller fault in Path Valley, W. of Fanettsburg, the features of which have been shown in the chapter giving the geology of that district. It is to Virginia and Eastern Tennessee, however, that we must look for the grandest and most instructive examples of the class of great longitudinal faults.

Those not unfrequent instances of a Y-shaped branching of a dislocated bed of coal, known to miners in the Pottsville and other disturbed coal-fields, are for the most part cases of fracture at the synclinal turn of the coal-bed, with an upthrow or shoving upward and forward of the steeper near side of the trough, unconformably upon the far side (see Fig. 709). We have a good instance of this in the narrow broken basin of the so-called Peach Mountain Coal-seam, on Silver Creek, and some of the streams which cross it farther E. The Y is formed by the steeply North-dipping S. side of the trough overriding the gentler-dipping N. side, and it leans as the letter does, if we assume ourselves looking Westward. Here the plane of the fault has been almost coincident with the top slate of the South-dipping bed.

An opposite case sometimes occurs of a Y-shaped branching of a faulted coal-bed, where the stem of the Y ascends, and the fork is downward, like the letter Y inverted ; thus, ⅄. This is simply an example of a dislocation at or near a sharp anticlinal flexure, the broken-off leg of the wave having been *moved after the fracture upward and forward unconformably over the inclined edge of the other portion* (see Fig. 708). Like the previously-mentioned Y-shaped fault, this ⅄-shaped dislocation has the plane of the sliding nearly coincident with the coal forming the longer branch ; but it is the longer leg, and not the shorter, which has in this case shoved itself over the other, and the fault is under, and not over it.

EXEMPLIFICATION OF THE LAWS OF FLEXURE BY THE PHENOMENA OF SOME OF THE UNDULATED ZONES OF EUROPE.

Analogous Phenomena of Axes in Great Britain and Ireland.—A perception of the important and novel bearings of the curious laws of structure here described upon many points in geological dynamics has led us (Professor W. B. Rogers and the Author) to examine with deep interest the valuable and accurate labours of Fitton, Martin, De la Beche, Dumont, Murchison, Sedgwick, Weaver, Hopkins, and other eminent European geologists, in the expectation of finding in the phenomena they describe evidences of analogous laws.

While studying with this view such memoirs, sections, and maps as were within our reach, we have enjoyed no small gratification in discovering what we consider numerous striking proofs of the prevalence of similar structural features in some of the most interesting geological regions in Great Britain and on the Continent.

Among these we would first mention the peculiarly interesting districts of Wales, to which the admirable researches of Sedgwick and Murchison have imparted so high a geological importance.

In the beautiful and elaborate works of the latter geologist, the publication of which forms one of the great eras in geological science, we think we discern very distinct proofs that the Cambrian and Silurian axes of Wales possess similar structural features with those of our Appalachian chain. While the older strata of the Berwyn Mountains, as described by Sir Roderick Murchison in his *Silurian System*, would seem, by their altered character and frequently inverted dips, to mark a close proximity to one of the great lines of disturbance of the district,—that lying towards the N.W., from which a combined uplifting and tangential force has been propagated ; the contour of the undulations lying more towards the S.E., when unaffected by faults or local disrupting action, exhibits a general conformity to our law of a steepening flexure on the side towards which the movement has proceeded. As illustrations of this law, we would beg to refer the reader to a few of the sections appended to Murchison's work on the *Silurian System* :—

1st, PLATE XXXI. fig. 5.—Section across the Ludlow and Brecon Anticlinal, exposing the Valley of Elevation of Wigmore Lake.

2d, PLATE XXXIV. fig. 3.—This exhibits to the N.W. the lower Silurian *on end* for some distance from its contact with the Cambrian, after which it passes by a bold sigmoid flexure, in which the S.E. dips are *very steep*, beneath the upper Silurian.

3d, PLATE XXXIV. fig. 9.—Displays an *inverted* and *folded flexure*, succeeded by steep S.E. dips in the flagstones of the Cambrian, following which are two *normal arches* in the lower Silurian.

To these sections may be added the vignette, page 359, presenting an axis in the Cambrian rocks of Caermarthenshire.

In the E. portion of this district, bordering the Malvern Hills, according to the same law, the flexures would appear to be related to the great line of elevating action, extending in a N. and S. direction through that region. The *steeper* sides of the arches are now towards the W., and the lower rocks are often overturned, so as to dip towards the E., thus exhibiting a direction of flexure nearly opposite to that of the strata near the Berwyn chain. As examples of these phenomena, we would refer to Plate XXXVI. fig. 8, presenting a transverse section of the Malvern and Sedbury hills, and Figs. 9, 9 B, and 10 of the same Plate, exhibiting the structure of the Woolhope axis.

The same general structural features will, we confidently believe, be found to prevail in the perplexing stratification of those parts of Devonshire and Cornwall, which elicited some years ago so much earnest theoretical discussion among British geologists. An inspection of the sections accompanying Sir H. De la Beche's elaborate report—those, for example, from Combemartin to Bolthill, and from Linton to Bideford—and a careful examination of the descriptions of this region given by him in that work, and by Sedgwick and Murchison in their very able memoir "On the Physical Structure and Older Deposits of Devonshire," induces us to venture the prediction, that throughout the region to which they refer, the phenomena of folded axes will be found of very extensive occurrence, and that this folding and inversion, together with the general law of steepening flexure in a particular direction, will explain the frequent repetitions of certain groups of strata, and assist in removing much of the obscurity which still hangs round the intricate geology of some parts of that district.

Similar indications are, we think, presented in the structure of the S. and S.E. parts of Ireland, as described by Weaver, Griffith, Hamilton, Austin, and others. Among these may be instanced *the great predominance of S. dips*, those to the N. being only occasional and of short continuance; a result, in our view, naturally arising from a succession of folded and steeply normal flexures due to a pulsatory movement propagated from the S. The evidences of such foldings and inversions are, we think, quite observable in the account given by Mr Weaver of the parallel bands and patches in echelon of the older limestones, while the steepened dip and extensive folding and inversion among the higher rocks, resulting from the same forces, are strongly implied in the section given by the same author through the Dromagh coal-field.* Similar phenomena would seem to be referred to also by Mr Austin, when, in speaking of the neighbourhood of Waterford, he ascribes the numerous contortions of schistose rocks, considered by him as being of the age of the Silurian, *to excessive lateral pressure*.† From the observations of Dr Fitton on the structure of the Wealden and associated formations, as detailed in his admirable memoir on the strata below the Chalk, and likewise from the more recent investigations in the same region by Mr Hopkins, of which a summary is to be seen in the *Proceedings of the Geological Society of London* for 1841, it would appear that in the districts of the Wealden and Bas Boulonnais, the numerous axes observe a *curved* form, and are nevertheless *parallel* to one another. Mr Hopkins, after describing several of these flexures, states that "all these lines observe a remarkable parallelism with each other, and with the curved central axis of the district." It would further appear, from the observations of these distinguished geologists, unless we have given an erroneous interpretation to their sections and descriptions, that a great number, if not all of these axes, present a much steeper dip on one side than on the other, and that this stronger inclination generally occurs on the same side—viz., *the Northern one*. Speaking of the line from Farnham to Seven Oaks, Mr Hopkins uses these words, "It is a line of flexure,‡ with a great dip to the N., but without the corresponding dip to the S. necessary to form an anticlinal arrangement, except in one or two localities. Towards the W. it runs immediately at the foot of the Hogsback, with a dip which, near its W. extremity, amounts to 70° or 80°. Tracing it towards the E.," he adds that "at some points the line assumes a distinct anticlinal character."

Dr Fitton, in describing the interior of Kent (pp. 134 and 135), gives several drawings of sections of this or an adjoining axis, in all of which the predominance of the dip on the N. side is distinctly marked. Alluding to one of these sections, he says,—"Both sides of the saddle are visible within a few paces; the beds on the N. rising at an angle of about 60°," while on the S. they decline at an angle of 45°. As illustrating the same law, we would more particularly refer to the following coloured sections appended to Dr Fitton's Memoir:—

1. The section across the Weald, from the South Downs, Western Sussex, to the Surrey hills. In this the dip on the N. side of the great axis is represented as slightly greater than on the S. side.

2. The two combined sections along the S.E. and S.W. coasts of the Isle of Wight. The axis traversing this island, and continued to Purbeck, is represented on the map accompanying the Memoir of Dr F. as parallel with that of the Weald. The sections referred to cross this axis, and exhibit a much greater steepness of dip on the N. than on the S. side.

3. The three sections across the Vale of Wardour transverse to the axis of that region. In all of these the preponderance of dip on the N. side is very great.

This series of curved or undulating axes, which are in the main parallel to each other, would thus appear to manifest laws of structure strictly analogous to those of our Appalachian region; and they serve still further to confirm us in our belief of the prevalence of similar features among the flexures in all regions of extensive disturbance, as well as to increase our reliance on the justness of the theoretical views by which we have attempted to explain them.

In conclusion, we would express our belief, founded on the phenomena referred to in this chapter, and on numerous similar geological facts, of recent as well as ancient date, which cannot be mentioned in this place, that all great *paroxysmal actions*, from the earliest epochs to the present time, have been accompanied by a *wave-like motion of the earth's crust*.

Belgium and the Rhenish Provinces.—Embracing in one view the undulated districts of Southern Belgium, the Rhenish Provinces, the Westphalian coal-field, the Ardennes, the Hundsruck, Taunus, and Hartz ranges, as described and mapped by M. Dumont and other geologists, we can discern most distinctly all the phenomena of flexure and of dislocation of the strata, here indicated as characteristic of the structure of the Appalachians. We

* See "Memoir on the Geological Relations of the South of Ireland," by Thomas Weaver, Esq., *Trans. Geol. Soc. Lond.*, 2d Series, Vol. V.

† See *Proceedings of the Geol. Soc. Lond.*, No. 74.

‡ By the term flexure, as explained by the phrase *one-sided saddles*, used in the same connection, we infer the author to mean what we denominate *oblique flexures*, while he restricts the term anticlinal to those bendings which give approximately equal dips on the opposite sides.

there perceive a wide zone of crust-undulations having its strata most invaded by igneous rocks, and most ruptured and metamorphosed along its S.E. side, and displaying its most ancient sedimentary formations in a state of close plication, with innumerable inversions of the dip, imparting to wide tracts one uniform parallel inclination towards the S.E. Crossing the zone N.W., we enter newer and newer strata, until we come to the undulated coal-field of Westphalia or Belgium, our traverse taking us from the non-fossiliferous formations, at the very base of the Palæozoic system. In whatever meridian we make our section, we find the N.W. sides of the waves, with few exceptions, steeper than the S.E. ones, not only where they are inverted, but where they have a normal dip. We find, moreover, as we advance, that the waves grow more and more open, and that the distances between them increase; that they subside in height, and that the two slopes approximate nearer to equality. These gradations are admirably disclosed in any traverse across the strike N.W., from the water-shed of the Ardennes to the Belgian coal-fields of the Meuse. I can detect, in the features of Dumont's exquisite map of Belgium and the neighbouring countries, the very same relations of the longitudinal faults to the flexures that have engendered them which prevail in the fractures of the Appalachians above described. They evidently, for the most part, occur on the N.W. sides of the anticlinal axes, and cause older strata to ride upon newer ones plunging under them, with approximately parallel dip. Even the phenomena of cleavage, presently to be described, will be seen to exhibit the very same laws in the metamorphic S. half of this wide zone of plication, which they present along the S.E. side of the Appalachian chain, and the Atlantic slope bordering it. This region of the Rhenish Provinces and Belgium further agrees with the Appalachians in being a zone of undulations and plications, where the folding movement has been all in one direction.

The Jura Chain of Switzerland.—The Jura chain of Switzerland, as I pointed out in 1848, in communications to the Geological Society of London, and in 1849 to the American Scientific Association, is another very interesting belt of crust-waves, displaying in its structure a close resemblance to the Appalachians.

It embraces, like the American mountains, many groups of waves differing in the directions of their axes in different districts of the chain, the individual groups being composed of waves which are remarkably parallel. Few of these undulations exhibit actual inversion of their steeper sides, the dip in some instances passing the perpendicular, and generally not exceeding on an average 70°, the gentler or opposite slopes only having a mean slant of about 40°. In four traverses which I made across this chain, I observed one almost invariable law as to the direction of the steep and gentle sides of the undulations, or, in other words, of the axis-planes. Contrary to first anticipation, and to the belief of many Swiss geologists, I found the steeper curvature of the waves directed toward the Alps, and not from them, implying that the crust-movement which lifted these grand and picturesque arches proceeded from the N.W., and not from the chain of the Alps. This also is a belt whose undulations are chiefly in one direction.

The Alps.—The great chain of the Alps is much more complex in its structure than either of the undulated zones yet described. It contains but few waves of the open or normal type, but innumerable close foldings or plications. Throughout a great portion of its length, this lofty and rugged zone of mountains consists of two approximately parallel chief crests. The great feature in the geological structure of the whole zone is the presence of belts of closely-plicated Mesozoic and Tertiary strata on both flanks of each of these great constituent ranges. But the most striking, and, at first view, perfectly enigmatical feature, is the inward plunge of the newer strata beneath the older, in the sides and at the base of both chains. When, however, the plicated strata are structurally arranged and traced, we find that this phenomenon assumes the character of a symmetrical folding of the rocks in two opposite directions from each high central axis. The individual foldings, with scarce an exception, lean outwards from the central tracts of the mountains, or from the quarters of igneous disturbance, rupture, and maximum metamorphism of the crust: in other words, the axis-planes of the plicated strata of the flanks of the Alps dip inwards towards the centre of the chain; those nearest to it at a low angle, and those more remote at angles steeper and steeper as the waves recede, expanding to the outer base of the range. High on the flanks of the Alps, or, what is the same thing, deep in towards the roots of the mountain, where only the synclinal bends of the flexed strata have been protected from denudation by inward folding, these closely-compressed troughs lie pinched in between the older strata in oblique inward inclination. The transverse sections expose these bendings, which are called V's by some of the Swiss geologists. Here then we behold an exact counterpart in the stratification or structure of a single flank of the Alps, of that folding with inversion which characterises the Appalachian chain, or that of the Ardennes, a single side of the Alps being the equivalent of the whole of either of those zones; it consists, that is to say, of a belt *undulated in one direction.* Crossing the Alps, or rather one of its component great chains, we find another *similar* belt of the same strata, plicated in the same way, with their axis-planes dipping also under the crest or orographic axis of the mountain, but of course to the opposite quarter of the compass as compared with the plicated zone of the other flank. This is, I conceive, a correct picture of that feature which, hitherto imperfectly analysed, has been called by some of the geologists of Switzerland, expressively enough:

The Fan-like Structure of the Alps.—Viewed as a single chain, this mountain system consists, then, of two belts undulating in opposite directions; but, as already stated, it is for the most part of its length a double chain; and I think each range, especially where these are widest apart, has a plicated belt of strata upon each of its slopes, so that, for some distance at least, the fan-like structure is twice repeated; in other words, there are four belts of closely-folded waves, each having its axis-planes dipping towards the base of its own high mountain system.

A conspicuous and pervading cleavage-structure coincident in the direction of its dip, as I shall presently show, with the oblique axis-planes of the folded rocks, contributes greatly, I conceive, to the illusive phenomenon of an inward dip of all the strata, or to that general feature which has been called fan-shaped.*

This inward dip is rendered still more obvious by the circumstance that the foliation or crystalline lamination of the more altered strata itself obeys very generally a similar law of parallelism to the axis-planes of the flexures.

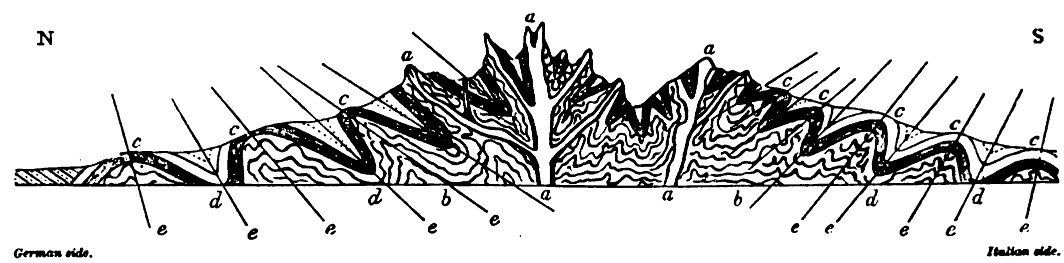


FIG. 714.—Generalised Section of the Alps, displaying the Dipping of the Folds of the Strata on both Sides in towards the Igneous Axis.

Where this crystalline grain of the rocks does not coincide with the stratification, it exhibits a great tendency to a coincidence of dip with any system of cleavage-planes belonging to the same or other parts of the mass. In either case it will dip inwards towards the igneous axis of the chain, if the strata possessing it are themselves closely folded in conformity with the prevailing law. But the phenomena of cleavage and foliation will be noticed afterwards. We now proceed to discuss the

GENERAL PHENOMENA OF SLATY CLEAVAGE IN THE APPALACHIANS, AND OTHER ZONES OF PLICATED STRATA.

Cleavage approximately parallel with the Strike, but independent of the Dip of the Strata.—It is now a good many years since Professor Sedgwick and other geologists announced the important general fact that the structure called *cleavage* pervades the altered strata affected by it, in directions independent of their bedding or laminæ of deposition. That eminent geologist further announced that these planes are approximately parallel to each other over large spaces of country, however contorted the dip of the rocks. He likewise enunciated a second general law of much importance, " That when the cleavage is well developed in a thick mass of slate rock, the strike of the cleavage is nearly coincident with the strike of the beds." Subsequently Professor Phillips gave to this rule of the cleavage a still more comprehensive and exact expression, when he stated to the British Association in 1843, that the cleavage-planes of the slate rocks of North Wales are always parallel to the main direction of the great anticlinal axes. Other geologists have abundantly confirmed these generalisations. Since 1837, these phenomena of the close parallelism of the cleavage-planes of a given district with each other, and with the main axis of elevation of the district, have been constantly observed and recorded by my brother, Professor W. B. Rogers, and myself, in our Geological Surveys of Virginia, Pennsylvania, and New Jersey.†

In 1849 I submitted to the American Association for the Advancement of Science, at the annual meeting held at Cambridge, Massachusetts, in a communication on the analogy of the ribbon structure of glaciers to the slaty cleavage of rocks, a statement of what I had for some years previous regarded as the true law of the direction of the cleavage-planes of a district of undulated and plicated strata.

In its simplest expression the rule is, that *the cleavage dip is parallel to the average dip of the anticlinal and synclinal axis-planes*, or those bisecting the flexures. The generality of this rule was shown on the occasion mentioned, by sections exhibiting the flexures and cleavage in the Appalachians, in the Alps, and in the Rhenish Provinces; and I have since become convinced of its universality from the inspection of the phenomena of other districts, and from a study of the descriptions and sections of geologists. Want of space prohibits me from here citing the abundant evidence for this law to be found in the best recently-printed memoirs upon slaty cleavage; but I hope to be able ere long to give my own observations in support of the highest British geological authorities, who, unaware of the relationship itself, have furnished the most satisfactory data for the recognition of it. I cannot, however, refrain, in this place, from sustaining the generalisation I am here venturing to put forth, by instancing the support it receives from the excellent descriptions recently given by Professors Harkness and Blyth of the Cleavage of the Devonians of the South-west of Ireland. In their paper in the *Edinburgh New Philosophical Journal* for October 1855, they not only establish an agreement between the strike of the cleavage-planes with that of the several rolls (or anticlinals) which affect the island of Valentia, but they show that, while the cleavage dip is S., the anticlinal "curves have been pushed over in a more or less N. direction," inverting

* From the analysis above given of the structure of the sides of the Alps, it will be seen that I entirely concur with Professor James Forbes, and with all the more eminent of the Swiss geologists, in recognising the fan-like dip of the newer strata, Tertiary and Mesozoic, conformably in appearance at least under the older strata, metamorphic and gneissic, of the higher more central tracts, and that I dissent entirely from the theoretical section offered by Mr Daniel Sharpe.

† See Annual Reports on those Surveys, 1837-40, and other Essays.

the carboniferous limestones and coal-measures. Their general statement is, that the cleavage-structure of rocks does not result from the simple rolling of the strata, but from this cause combined with a considerable amount of pressure; and this latter force acting from the S., has pressed over the strata in a series of oblique curves to the N., and given to the inclined cleavage its greater or lesser degree of S. dip. They support the doctrine of Mr Sharpe respecting the cleavage of rocks,—"That there has been a compression in the mass in a direction everywhere perpendicular to the planes of cleavage, and an expansion of this mass along the planes of cleavage in the direction of a line at right angles to the line of incidence of the planes of bedding and cleavage;" or, in other words, to the direction of the dip of the cleavage. From this view of the mechanical nature and direction of the force engendering cleavage, I beg leave respectfully but explicitly to dissent.

Fan-like Arrangement of the Cleavage at the Anticlinal and Synclinal Axis-Planes.—A second general fact or law of direction of the cleavage-planes in folded strata must be here enunciated. At first view it is in seeming contradiction with the universality of the primary rule above stated, of the invariable approximate parallelism of the cleavage-planes to the axis-planes of the flexures; but closely examined, it will be seen, I think, to be in beautiful accordance with that law, and with my hypothesis of the origin of the cleavage-structure. The rule is this, that where the cleavage is fully developed, and the anticlinal and synclinal flexures are also conspicuous and very sharp, the cleavage-planes immediately adjoining those bendings are not parallel to the axis-planes, but partially *radiate from them in a fan-like arrangement* upwards in the anticlinals, and downwards in the synclinals.

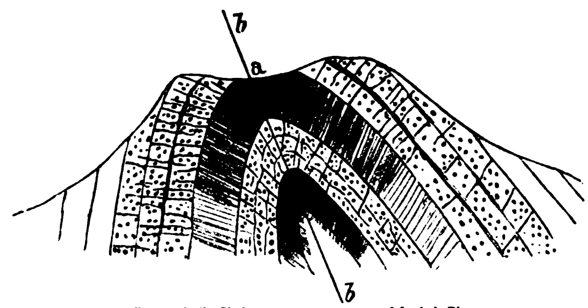


FIG. 715.—Fan-like arrangement of Cleavage at an Anticlinal Axis.

This aberration from the normal direction is furthermore different in degree upon the two sides of the geometric axis-plane, being usually greatest upon the inverted or steep side of the wave.

Another aberration of the cleavage-planes from their normal direction of parallelism to the axis-planes, is their tendency to conform partially to the dip of the strata, when the two are nearly coincident. This operates to flatten the inclination of the cleavage upon the gentler slope of each wave, and steepen it upon the more inclined one; and as in every belt of uniform flexures closely plicated with inversions, the uninverted or normal dips greatly exceed the inverted ones, it produces in such cases a prevailing lower inclination in the planes of cleavage than in the planes bisecting the flexures.

Relation of Cleavage to the Mechanical Constitution of the Strata.—There is yet another law respecting cleavage; it is the dependence of this structure upon the mechanical texture, and possibly upon the chemical composition, of the fissured rocks.

Geologists have for several years recognised the fact, that in formations composed of alternations of the coarser mechanical rocks, such as silicious grits and conglomerates, with fine-grained argillaceous beds, as slates, shales, or marls, the coarse beds are unaffected by cleavage, while the fine-grained ones are often pervaded by it. Indeed, one may observe in a given locality almost a strict proportion between the degree of intimate fissuring of the rocks by cleavage-planes, and the degree of comminution of their particles.

Connected probably with this interruption in the distribution of the cleavage-condition through such heterogeneous groups of strata, I have observed another general fact of modification of the cleavage-planes, which should not be passed unnoticed here. They tend, in the fine-grained argillaceous beds, to curve a little from the normal direction into an approach to parallelism with the surfaces of bedding of the adjoining coarser mechanical deposits, presenting, in a transverse section, a kind of gentle sigmoid or double flexure. This is well shown in the cleavage-traversed rocks at the base of the anthracite coal-formation of Pennsylvania, especially in the tran-

FIG. 716.—Beds of Red Shale with Cleavage alternating with beds of Sandstone without Cleavage; Cleavage curving towards parallelism with the bedding at its boundaries. Section near Ashland, Pennsylvania.

sition or passage beds which connect the Umbral red shales of that region with the base of the coal-sustaining conglomerate, and also where these shales alternate with the upper coarser members of the Vespertine sandstone. The small section here appended, showing the cleavage, in one of these groups of alternation of red shale and sandstone, from a railway-cut near Ashland, in the middle anthracite coal-field, exemplifies well the phenomenon referred to.

The tendency here shown in the cleavage-planes to conform to the planes of bedding, where abrupt changes of composition interrupt the continuity of the fissures, is but another variety of the phenomenon already adverted to, of a deflexion of the cleavage in bands of plicated strata towards a parallelism with the gently-dipping slopes of the anticlinal waves. This remarkable fact of an intimate dependence of the cleavage upon the composition and mechanical texture of the structure is, I conceive, of itself sufficient to refute the hypothesis somewhat in favour at present, of the purely mechanical origin and nature of the cleavage-producing force; for we cannot conceive how a mechanical force, either of compression or of tension, transmitted, as necessarily it must be, very equally through parallel layers of coarse and fine materials, should have exerted no fissuring action the moment it reached the surfaces of the coarser beds, and yet have been able to cleave into thin parallel slaty laminæ the whole body of the fine-grained argillaceous strata. One would more naturally suppose that the less firmly aggregated softer mud-rocks or shales would have been even less easily fissured by sharp cleavage-joints than the more massive and better cemented grits. It is of importance to notice here, that subsequent disruption of the strata may change the normal position or dip of the cleavage after its formation, and give rise to some of the apparent deviations from the general law of direction above enunciated.

The Cleavage Susceptibility alternately greater and less in Parallel Planes.—Cleavage is a susceptibility in rocks of a certain composition, and in a particular stage of metamorphism, to split in definite straight parallel planes. The cohesive force is obviously at a minimum of intensity in the direction perpendicular to these planes. In the other two rectilinear axes of the cube, one side of which is coincident with the cleavage-plane, the force of cohesion next in degree of intensity is the horizontal one, or that in the direction of the strike of the cleavage, while the most intense cohesion of all is that in the direction of the cleavage-dip. It is in this latter direction that the molecular forces of attraction engendering incipient crystallisation seem to have been most powerfully awakened, while the polarities have been feeblest in the lines perpendicular to the cleavage-planes; but apart from these three directions and grades of corpuscular force, we have indications, in any homogeneous mass of cleavage-traversed slate, or other rock, of the presence of two grades of the minimum cohesion, constituting the cleavability, disposed side by side in alternate parallel order; in other words, where the cleavage is fully developed, the rock will be found to contain certain nearly equidistant closely-contiguous planes of maximum cleavability, or, what is the same thing, of minimum lateral cohesion—the material of each thin plate of the slate cohering more strongly together than these adjacent plates cohere to each other. The existence of such planes is indicated by the manner in which any mass of very cleavable slate, long exposed to atmospheric agencies, invariably breaks up, as we may see in any naked outcrop. If the cohesion of the mass in a direction perpendicular to the cleavage-planes were equally strong in all parallel planes that we can imagine pervading it, it is impossible to understand how any uniformly-acting disintegrating forces,—either expansion and contraction by heat, soakage and drying, or freezing and thawing,—could subdivide it by planes or fissures so regularly distributed as we find them. These could only have arisen, I conceive, from the presence of parallel planes of weaker and stronger cohesion. In this interesting structure we discern a striking analogy to that alternation of thin plates of solid blue crystal ice, and white porous ice of less cohesion, which is so distinct a feature in the fully-developed ice of glaciers, and which has been expressively named by Professor James D. Forbes the Ribbon Structure.*

FOLIATION.

The relations of the foliation or crystalline lamination of metamorphic strata to the cleavage-planes and the planes of stratification, come next to be considered. Two facts may be stated of foliation, which possess, perhaps, the constancy of general laws. One of them is, that this structure, as it is seen in gneiss and mica-schist, observes, when the strata are not traversed by cleavage, an approximate parallelism to the original bedding. Apparent exceptions to this rule occur in several localities near Philadelphia, and elsewhere in the United States, and have often been noticed in Europe by Mr D. Sharpe and other good observers; but all of them can be reconciled to the general fact, and reduced, it is conceived, to one comprehensive law—namely, that the planes of foliation, or the laminæ, formed by the crystalline constituents of the foliated rocks, are *parallel to the planes or waves of heat* which have been transmitted through the strata. Wherever large tracts of the gneissic rocks retain a nearly horizontal undisturbed position, the foliation is almost invariably coincident with the stratification; and in this

* In a communication submitted to the American Association for the Advancement of Science, in 1849, I attempted to show this analogy of the ribbon structure of glaciers to the slaty cleavage of rocks, in the following remarks:—"The ice of glaciers consists of thin alternate parallel bands or plates of blue crystal ice and white porous ice, each not more than $\frac{1}{3}$ or $\frac{1}{2}$ of an inch in thickness. These pervade the whole mass of every glacier, and are clearly exposed on the sides of the transverse fissures. Near the sides of the glacier they are almost absolutely parallel with its mountain-walls, but they sweep away towards its medial line, and form, like all the other planes which divide the glacier, a series of innumerable loop-like curves. This looped or festooned form is obviously caused in part by the downward tendency of the movement or flow of the semi-plastic ice, and in part by the influence of the terminal moraine to induce that parallelism to itself which the rocky sides of the glacier produce in the ice near them. The most general fact noticeable in relation to these structural planes is the approximate parallelism to the rocky walls and terminal moraine confining the icy mass; or, in other words, to the surfaces of higher temperature which enclose the glaciers. However the direction of the ribbon-lines may alter by irregularities in the onward flow of the glacier, their position near the region of the nevé is strictly parallel with the surface of the warmer mountain-sides."

case, the wave of heat producing the crystalline structure can only have flowed upwards through the crust, invading stratum after stratum, in parallel horizontal planes. Again, when injections of granite occur in uplifted gneissic strata, the crystalline lamination is generally seen to be parallel to the plane of outflowing temperature. The other general rule is, that *the foliation is parallel or approximately so to the cleavage*, wherever these two structures occur in the same mass of rocks. This fact, recorded by Darwin, of the gneissic rocks and clay-slates of South America, has been noticed likewise by Mr D. Sharpe, Mr David Forbes, Mr Sorby, and other geologists in Great Britain, and by the Author in many localities in Southern Pennsylvania, and in other districts of the Atlantic slope. An interesting instance of such parallelism of the foliation to the cleavage, tending to show convincingly that both phenomena are the consequences of one species of force, or are only different degrees of development of the same molecular or crystallising agency, is presented in the great synclinal trough of the lower Appalachian limestone, North of Philadelphia. On the N. side of this trough, the Primal and Auroral rocks dip S. over a wide outcrop at a very regular angle of about 45°. On the S. side they have been lifted into, and even a little beyond, the perpendicular position, so that the synclinal axis-plane of the belt dips at an angle of 65° or 70° to the S. Neither formation shows cleavage-structure on the N. side of the valley, the limestone being there of an earthy texture, and in thick massive beds, but on the S. or upturned side this limestone is altered into a mottled blue-and-white crystalline marble, and is pervaded with cleavage-planes, dipping at angles of 70° and 80° S. Many parts of the rock are like a foliated calcareous gneiss, thin laminæ of mica and talc dividing the slate-like plates of the marble. It is especially worthy of notice that the foliation of the mica and talc, composing some of the thin partings between the original beds of the limestone, is itself very generally parallel to the cleavage in the adjoining calcareous rock. Indeed, wherever the cleavage is excessive, the mass becomes, by introduction of fully-developed talc and mica between its laminæ, a true foliated stratum. An especial interest annexes to cases of this kind, from their showing that, in the contrasted conditions of the absence and presence of metamorphism in the two opposite outcrops of the same synclinal fold, both effects, cleavage and foliation, have originated at the same time, and from one and the same cause, and are, in truth, but different stages of the same crystalline condition, superinduced in the mass by high temperature at the period of its elevation. The above general fact of the prevailing parallelism of the foliation to the cleavage, is but a corollary of the more general relationship already expressed of the parallelism of the resulting planes of crystallisation to the waves of heat which have produced the metamorphism.

EXAMINATION OF THE PREVAILING THEORIES OF ELEVATION.

Perhaps the most current notion respecting the force which has displaced and elevated the originally horizontal strata of the globe, is that which represents the granitic and volcanic rocks as forcibly injected in a melted state into fissures, and violently thrust in solid wedge-shaped masses upwards through the incumbent crust. That this is the prevailing idea is apparent from the manner in which nearly all geological sections, even the most modern ones, designed to represent the relations of the Plutonic to the sedimentary rocks, are to this day constructed. Where igneous rocks constitute the whole or a large portion of the central axis of a mountain chain, or even that of a simple anticlinal ridge, they are usually represented in cross sections, in the form of a broad wedge, and the stratified rocks are drawn as leaning upon the sloping flanks of the wedge or prism. This is not, I think, the true relation in nature of the igneous to the sedimentary masses, as I propose to show from the following considerations.

Hypothesis of Wedge-like Intrusion of Melted Matter.—The notion of an upward wedging, or intrusion of molten mineral matter into or through the superincumbent strata in the manner of a wedge, implies a function in the soft material which belongs to the mechanical action of a solid, and is incompatible with the dynamic properties of fluids. Until a fissure from below first penetrates or traverses the invaded overlying strata, it is not possible to conceive that the liquid matter could introduce itself in the mode of a wedge. Some force must first crack the crust, and then the molten matter, flowing into the fissure, may act as a narrow wedge or key, to keep the walls of the chink distended; but such plates of solidified refrigerated volcanic matter, known as veins and dykes, must necessarily be narrow, and have the shape rather of walls with parallel surfaces than great wedges broad at the base.* They will also abound chiefly in the districts of subsidence, or in the concave waves, not in those of elevation, or in the convex, where the wedge-like form tapering upwards is usually represented. Where a rupturing of the strata has taken place in a tract of elevation, or at an anticlinal, the fissure or fissures will be found to gape upwards, and the melted volcanic matter which has flowed to the surface will be seen widening outwards, and tapering as it descends—the very opposite of the form usually assigned to such outbursts in the igneous axes of uplifted chains. So common is this upward enlargement of the Plutonic masses in certain regions, that it constitutes, I conceive, one element of the fan-shape or inward dip of the boundary walls of the rocks, so frequently encountered in the Alps and other much-disturbed mountain-systems. A true conception of the formation of a mineral vein or dyke will represent it as the *consequence*, not the cause, of the fissure which it

* It is in consequence of this natural expansion of surface-cracks outwards in anticlinals, that the miner so frequently finds his mineral lodes contracting or dying out as he descends. Several striking instances of this thinning of veins downwards could be cited from the mines of the United States situated in anticlinal flexures.

fills, the real process being, not a protrusion of the fluid matter through the crust, breaking it in its passage as a solid wedge might, but an actual injection or pumping of it into the newly-opened vacuous cavity, from the pressure or tension below.

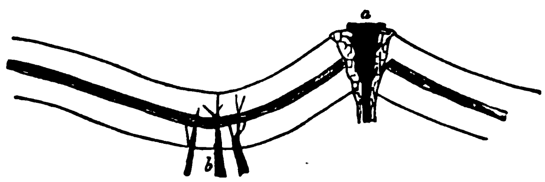


FIG. 717.—Dykes expanding upwards in Anticlinals and downwards in Synclinals.

Intrusion of the Igneous Rocks in Solid Wedges.—The other notion, frequently connected with the above idea, of a forcible propulsion of igneous matter through the crust, is that of the violent thrusting upward of volcanic or granitic matter already solidified, in broad wedge-like masses through the strata. This conception I hold to be at variance both with sound mechanical laws and with the physical facts. For the solid igneous mass to have acted in the manner of a wedge, it is absolutely necessary that it should have moved freely upward through the opening in the strata, which it is supposed to have wedged apart and to have uplifted, and even corrugated, by lateral compression. But it is impossible to imagine such a slipping of the assumed granitic wedge past the edges of the strata confining it, since we can imagine no force acting downward upon these latter, to prevent their moving upward along with the wedge of granite, nor any localisation of the force below, to prevent it operating on both alike. We have furthermore no evidence of that discontinuity between the igneous rock and the ruptured strata, which the notion of a sliding wedge obviously pre-supposes, but, on the contrary, every proof, from general theory and from observed facts, that the two descriptions of rock are intimately bound together in closest crystalline contact, keyed together by veins, branching from the mass of the one into the fissures of the other, and even fused together by an actual incorporation of substance. Any upward movement, therefore, of Plutonic masses, bearing sedimentary rocks upon their flanks, cannot have been in the manner of a mechanical wedge; and those results—corrugation, for example—of the adjacent strata, habitually attributed by many geologists to an imagined wedge-like lateral thrust, must be accounted for upon some other sounder mechanical theory.

A modified form of this conception of an igneous wedge lifting and displacing the strata, assumes no sliding or wedge-like protrusion of the solid granitic matter past the edges of the rupture in the bedded rocks, but, recognising the inseparable cohesion of the two, regards the stratified masses flanking the anticlinal mountain as merely borne upward by the uprising of the central igneous nucleus. I deem this notion to be a much truer picture of the procedure of nature; for it so far accords with what we notice in anticlinal districts having igneous crests or centres, that it represents the stratified rocks leaning against the walls of the great granitic central dykes, at steeper and steeper angles, the higher we ascend towards the summits. It is inexact, however, in picturing the granitic nucleus of the anticlinal mountain as a wedge or broad prism tapering upward, for reasons already shown. Undoubtedly such a mountain if we can imagine it denuded or truncated to lower and and lower levels, would disclose a progressively increasing quantity of intrusive igneous rock, but this would be in the multiplication of the lateral granitic injections, and it is only in this erroneous sense that the igneous nucleus can be regarded as a prism. Its cross section is branching rather than wedge-like.

The Upward Movement of an Igneous Dyke would tend to Stretch and not to Corrugate the Flexible Strata.—The view here admitted of the elevation of the igneous nucleus of a mountain, along with the strata which mantle it, while it is perfectly compatible with the hypothesis, to be hereafter advanced, of the origin of anticlinals generally, is wholly inconsistent with the somewhat current notion of the mode of origin of undulations and plications in the stratified rocks, by pressure from the tangential horizontal thrust of such uprising igneous axes: so far from its producing a lateral corrugating pressure upon the strata adjoining, and resting against it, a central granitic or other igneous dyke lifted vertically by one or many successive movements, paroxysmal or gradual, would rather *stretch* or distend the strata as it carried them upward than compress them.

Theory of Upward Tension against Lines or Points of the Crust.—Another common theory of crust-movement and elevation of anticlinal belts supposes, vaguely, an upward tension or stretching of the crust of the earth along one or several lines, or at one or several focal points, without attempting to account for the linear or focal force, or to assign a cause for the restricted limits within which it is assumed to act. This conception, though confessedly indistinct, is frequently appealed to in explanation of the lifting of mountains, the corrugation of strata, and even the formation of regular groups of parallel anticlinal waves. I propose to consider its weak points.

Any theory henceforth admissible into physical geology must explain the now clearly-established general fact of the regular wave-structure of the earth's disturbed zones. But this wave-structure cannot be interpreted on the mere supposition of simply an upward pressure exerted either along one or many lines. The peculiar configuration of the crust-waves, shown in this paper to be characteristic of them in all undulated regions, requires an hypothesis which will furnish both an undulating and a horizontal tangential motion; moreover, the ordinary doctrine, if it assumes the pressure from beneath to be exerted along a single line at a time, fails altogether to show us how this pressure could have shifted to new and parallel lines, or how it could take up new positions, and exhibit that relation of relative distances constantly widening, which is seen in all undulated belts. No simple upward pressure along a line in the crust could form a defined or limited anticlinal flexure. Whether the pressure were exerted by a liquid or a solid subterranean mass, it would produce rather a wide general moderate elevation, than a narrow, sharp, anticlinal wave.

If, again, this vague theory be modified to admit the action of a series of simultaneous linear pressures, coincident with the observed anticlinal flexures of an undulated district, it is not possible to understand why, being contiguous, they should not all conspire to lift the outer mass or crust into one general bulge or broad distended dome, rather than into a series of alternately synclinal and anticlinal waves. In addition to these difficulties, this notion of self-awakened linear pressures contains no clear hypothesis of the *origin* of the linear forces.

Hypothesis of Corrugation from Sinking of Tracts of the Earth's Surface.—Another theory of the cause of flexures in the crust conceives them to have been produced from a sinking of the ground by removal of matter by volcanoes, or by the contraction of argillaceous rocks by heat and pressure. Sir C. Lyell, who appears to advocate this view, supposes that pliable beds may, in consequence of unequal degrees of subsidence, become folded to any amount, and have all the appearance of having been compressed by a lateral thrust; and the creeps in coal-mines are adduced as affording an excellent illustration of this fact.* With every respect for this eminent geologist's ingenious views, I must confess that this conception seems to me quite as much beset with difficulties as the somewhat kindred theory of elevation and simple upward protrusion. Apart from the objections that it supplies no cause for the peculiar shape of the crust-waves, nor any explanation of their parallelism and their remarkable laws of gradation, it appears to me quite inadequate to account for lateral corrugation at all, or for more than a very insignificant amount of it. A downward pressure or tension over a single area, produced by release of support arising from vacuities beneath the surface, ought not to engender, on any known mechanical principle, a series of flexures, either within or around the area, but should result in a mere subsidence or flattening of the portion from whence the support has been withdrawn. If the centring of a very flat dome, too weak to sustain itself, be removed, the dome either suddenly collapses with a fracture, or it indents itself, and sinks where it is weakest and most yielding, till it meets the supporting floor. Before the wide nearly level dome of a segment of the earth's crust can corrugate either itself or the adjoining strata, some alternate upward and downward force must undulate them, or they must contain alternate weak and strong belts, and even then these must be somewhat undulated; none of which conditions the hypothesis of subsidence is prepared to supply.

Hypothesis of a simple Horizontal Compression.—A somewhat favourite and familiar mode of accounting for the undulation and plication of strata, is that which assumes them to have been corrugated by a purely horizontal or tangential pressure, without elevation and without pulsation; and this imagined mode of folding has been ingeniously illustrated by Sir James Hall, Sir H. De la Beche, and other geologists, by their placing flexible layers of clay, or cloth, or other substances, horizontally under a weight in a trough, and forcing one or both ends towards the centre, so as to contract the length of the strata, and thereby produce a series of miniature plications. It has been alleged that this folding of the clay or cloth is an exact imitation of the flexures of strata seen in nature; but I must deny the assumed analogy. The plications thus produced are merely irregular contortions; they exhibit no definite form of curvature, no constancy in the direction of their gentler and steeper slopes, and no law of regular gradation. Their anticlinal and synclinal axis-planes, if they can be said to have any, lean some one way and some another; and the flexures, when the crowding is great, have a tendency to the horse-shoe form, and not to that of waves.

This hypothesis of corrugation, while it is erroneous in thus failing to present a true representation of the waves of the crust, is also defective in its mechanical principles, for it assigns no cause for the origination of the wave-structure. A purely lateral or horizontal force should, as already intimated, simply bulge out to a feeble extent the whole compressed arch, but ought not of itself to wave it; some independent agency, producing alternate upward and downward flexure, is indispensable to give even the most powerful tangential pressure the ability to plicate the flexible mass. This hypothesis is furthermore imperfect in not suggesting any cause in nature for the assumed horizontal pressure. It has been already shown, when discussing the hypothesis of simple elevation, and of simple subsidence of areas of the earth's crust, that neither of those movements, unaccompanied by an actual pulsation of the strata, would be competent to corrugate the crust at all; the mere elevation of an igneous axis having the tendency to stretch rather than compress the adjoining strata; and the simple sinking of an area, by retreat of support beneath, having only the effect to warp the surface irregularly, but in nowise to undulate it.

VIEWS OF GEOLOGISTS CONCERNING CLEAVAGE AND FOLIATION.

Professor Sedgwick, as early as 1822, discovered and subsequently publicly taught the true nature of slaty cleavage, distinguishing it from joints, and showing it to be a tendency to separation in perfectly parallel planes, which are irrespective of the bedding. He ascertained that the slaty cleavage is usually confined to the finer-grained rocks—alternating coarser beds possessing it very imperfectly—and laid it down as a rule, that the *strike* of the cleavage is nearly coincident with the strike of the beds. He referred it to crystalline or polar forces acting simultaneously and somewhat uniformly in given directions. Subsequently, in 1835,† after many additional observations on the modifications of slaty cleavage, he showed that the rule admitted of many

* See LYELL's *Elementary Geology*, 5th edit., p. 50.

† Geol. Trans., 2d Series, iii. 461.

limitations, which the geologist is compelled to notice in working out the structure of complicated districts. In a recent publication, his *Synopsis of the Classification of the British Palæozoic Rocks*, he proves conclusively that the cleavage structure is "the compound effect of all the crystalline forces acting on the mass, and that it cannot be due to a mechanical action." In this work he also mentions the important fact of the existence frequently of a second cleavage-plane, generally inclined at a great angle to the primary.

Sir J. Herschel has suggested that the rocks possessing cleavage may have been so heated as to allow a commencement of crystallisation, or heated to a point at which the particles may have begun to move among themselves, or on their own axes; surmising that some general law has determined the positions on which the particles have rested on cooling, and that this position has had some relation to the direction in which the heat escapes.*

Professor Phillips† has shown that, in some slaty rocks, fossil shells and trilobites have been much distorted by cleavage; and he imputes this to a creeping movement of the particles of the rocks along the cleavage-planes. This displacement, uniform over the same tract of country, he states to be as much as a quarter or even half an inch. Hard shells are not thus affected, but only the thin ones. Professor Phillips, in 1843, stated that the cleavage-planes of the slate rocks of North Wales are cleavages parallel to the main direction of the great anticlinal axes.

Mr Daniel Sharpe conceives that the present distorted form of the shells in certain slates has been produced by a compression in a direction perpendicular to the planes of cleavage, and an expansion in the direction of the cleavage dip.‡

He conceives that the planes of cleavage range vertically along certain lines or belts, and dip towards those lines on each side of them; those nearest the central vertical belts at high angles, the angles gradually diminishing as the distance from the vertically-dipping cleavage increases. This is his explanation of the fan-like arrangement of dip noticed in some countries. "This regularly-descending series of planes being found on each side of parallel lines of vertical cleavage, the two series either meet in the centre in a sort of anticlinal axis, or coalesce into an arch. The planes between two lines of vertical cleavage appear to form a complete whole, and the area bounded by the vertical cleavage may be considered as belonging to one system of cleavage, and may be called an area of elevation of the cleavage." He thinks the cleavage-planes are really parts of great curves, which, if completed, would represent a series of semi-cylinders turned over a common axis.

Mr Sharpe thinks "that there is reason to believe that all slaty rocks have undergone a compression of their mass in a direction perpendicular to the planes of cleavage," connecting with this view his supposition that the cleavage arrears are great anticlinal waves. He supposes that the compression of the slaty mass, and its expansion in the direction of the cleavage dip, have been due to the stretching of the strata in the direction of the curve representing the cleavage dips.

Mr Charles Darwin,§ reviewing his observations on cleavage in South America, says,—"The cleavage laminæ range over wide areas with remarkable uniformity, being parallel in strike to the main axes of elevation, and generally to the outlines of the coast." He recognises the fact that the cleavage-planes frequently dip at a high angle inwards, and he cites an instance of cleavage dip, in the mount at Monte Video, where "hornblendic slate has an E. and W. vertical cleavage, with the laminæ on the N. and S. sides near the summit dipping inwards, as if the upper part had expanded or bulged outwards." Mr Darwin first proposed the term foliation for the laminæ in gneiss and other crystalline rocks, or the alternating layers or plates of different mineralogical composition. He pointed out the parallelism of the planes of foliation of the mica schists and gneiss with the planes of cleavage of the clay-slate in Tierra del Fuego and Chili, as seen by him in 1835. He conceives that foliation may be the extreme result of the process of which cleavage is the first effect, or that the crystalline form may have been most energetic in the direction of cleavage. He further suggests, "that the planes of cleavage and foliation are intimately connected with the planes of different tension to which the area was long subjected, after the main fissures or axes of upheavement had been formed, but before the final cessation of all molecular movement," "and that this difference in the tension might affect the crystalline and concretionary processes."

Mr Sorby, adopting the mechanical theory of cleavage, maintains that it varies directly as the mechanical changes, and inversely as the chemical (molecular) changes, which the strata have undergone. He thinks he has shown that the cleavage of certain limestones, microscopically examined by him, varies directly as the amount of mechanical compression to which they have been subjected, and that this compression was such as would necessarily change the structure of uncleaved into cleaved rock. He alleges "that cleaved limestones possess no crystalline polarity," and that in place of crystallisation producing slaty cleavage, it has a contrary tendency, and, when perfect and complete, obliterates it altogether. Mr Sorby conceives that the absolute condensation of the slate-rocks amounts, upon an average, to about one-half of their original volume.|| This condensation he ascribes to the forcing together of the particles, and the filling up of their interstices by pressure perpendicular to the cleavage, and partly by elongation in the direction of the cleavage dip.

* LYELL's *Manual*, p. 610. † Report, British Association, Cork, 1843. ‡ *Quarterly Jour. Geol.*, viii. 87.
§ See *Geological Observations on South America*. || LYELL, p. 612.

Mr David Forbes,* writing upon foliation in rocks, leans to the conclusion that foliation is a distinct phenomenon from cleavage, and that the causes producing them were also distinct. He refers the foliation to chemical action, the cleavage to mechanical pressure. He admits that the planes of foliation and those of cleavage are often parallel to one another.† But the parallelism of the foliation to the cleavage he ascribes to a previously induced cleavage-structure facilitating crystalline lamination in its own planes.

He supposes foliation to have resulted from a chemical action combined with a simultaneous arranging molecular force, developed at heats below the semi-fusion of the mass; also that the arrangement of foliation is often due to the proximity of igneous rocks, and tends to follow the direction of any lines in the rocks where the cleavage stratification, *or striæ of fusion*, follow preferably those lines offering least resistance.

Examination of the Prevailing Theories of Cleavage and Foliation.—From the theory of the origin of cleavage by mechanical compression exerted perpendicularly to the cleavage-planes, as adopted by Mr Sharpe, Mr Sorby, Mr David Forbes, and other geologists, I am constrained to dissent, and upon the following grounds:—

1. It has been already shown, in the general description of the phenomena of cleavage, that this tendency of fissuration is stronger and weaker in alternate closely contiguous planes, and is not diffused equally, even in the one direction, through the mass. Now it is impossible to conceive how a purely mechanical compression could have occasioned a regular alternation of greater and less condensation of particles, all equally free to move and adjust themselves into positions of statical equilibrium, and all equally subjected to the same amount of force. The well-known law of a *quaquaversal* tension of fluids is manifestly applicable to partially soft and flexible rocky matter, if we are to impute to this an actual rotation of its parts, such as the mechanical theory assumes; and I cannot see why one uniform condition of aggregation should not be the result.

In partially metamorphosed strata, imbedding nodules of flint or chert, we not unfrequently find the ovoidal lumps all arranged with their larger diameters set in the direction of the cleavage, and not in that of the stratification. An instance of this structure has been already alluded to in the description of Fox Hill, near the Delaware Water-Gap (see Vol. I. p. 285.)

It is impossible to conceive how these large, flattish, ovoidal flints could have had this direction impressed upon them by any mere mechanical force. All geologists admit the concretionary origin of such nodules. Now, on the hypothesis of the derivation of cleavage from pressure, if they could only have concreted *before* the cleavage structure was imparted to the stratum enclosing them, their wider diameters must have been originally parallel with the bedding. If so, the nodules could only have acquired their new position of parallelism to the cleavage which is transverse to this bedding, by either a bodily rotation, or a plastic compression of their substance, despite their intense rigidity of cohesion. Imbedded in a material softer than themselves, it is obvious that neither of these changes could take place. It is difficult, moreover, to imagine how any mere compression or rotation of the individual nodules could have ranked them into new planes transverse to the layers in which they were originally disposed. We know that silicious nodules, like the lumps of clay ironstone of the coal shales, and indeed all similar concretions, are distributed in layers or courses, these layers marking the horizons where the material was originally in excess; but once formed, they could not shift into new attitudes without a corresponding displacement of the strata imbedding them. But supposing, for the sake of argument, the nodules to have been from the first not arranged in strata, but promiscuously scattered, no transverse pressure could even then squeeze them into parallel and distant courses or strata.

2. In the second place, it assigns no reason for the presence of cleavage-planes in fine-grained argillaceous and calcareous rocks, and their absence in silicious ones, both fine-grained and coarse, even when the two classes alternate with each other in intimate parallel contact, where they must have been exposed to precisely the same pressure, both in direction and in amount. In other words, there is no relation discoverable between the known susceptibility of different materials to cleavage, and their susceptibility to compression. But, on the other hand, some of the most compressible are the least subject to this peculiar structure. The different susceptibilities of different kinds of mineral matter to molecular polarity is, I conceive, the true explanation of this marked contrast in rocks.

3. Another quite conclusive objection, I conceive, to the pressure theory of cleavage is, that it fails to show how the cleavage-traversed strata can have received the pressure in one constant direction, and under an equalised intensity, through all the contortions and bendings which we know they must have possessed before cleavage was imparted to them. It is obvious that no mechanical pressure, come from what quarter it might, could transmit itself uniformly through convex and concave curves, through bodies of rock placed edgewise and flatwise towards it; but, on the contrary, dynamic considerations must convince us that the resultants of such a pressure would be as various in their directions within the mass, as the ever-changing planes of the corrugated stratification. Not only would the posture of the strata at any point next the quarter of the primary pressure influence the form and direction of the resultant planes of pressure at that point, but the differences in pliability of the different layers compressed would greatly modify them. In other words, while the dip of the cleavage-planes within even wide limits is usually remarkably constant, whatever the contortions of the strata, any pressure

* See his Paper—*Quarterly Journal Geological Society*, 1855.

† See his Paper for a good figure of deflection of cleavage and foliation in the margin of a vein of quartz.

transmitted through these contortions must be as various, in different portions of the flexures, as the innumerable resultants produced by the ever-varying resistances and the pressure combined.

4. A like difficulty opposes itself to the pressure theory, in the constancy of the direction of the elongation or stretching of the mass in the line of its cleavage dip. This extension, well expressed by Professor Phillips as a "creeping movement of the particles," seen not only in the fibrous grain of cleavage-slates, but in the distortion of imbedded fossils, and of the whole substance of the rock indeed—ascribed to mere compression by the authors above cited, but attributable, I think, to an actual molecular movement of the mass, in obedience to crystallising polar forces—is so equally graduated in amount, and so wonderfully constant in direction (never deviating much from the line of dip of the cleavage-plane), that it could never have acquired this constancy from a merely lateral mechanical force, liable to infinite modification, in both of these respects, by the continually varying resistances consequent on the contortions of the beds.

5. A further objection lies against the pressure theory, in the contradiction it offers between the direction which it assumes the compression to have come from, and the direction in which we can demonstrate the strata to have been actually pressed and moved. In every district of plicated and undulated strata, it can be shown, from the shape of the waves, from the declension in their curvature and height, from their mutual recession, from abatement in all the metamorphic signs of igneous action, and, finally, from the direction of the great planes of fracture in the crust, that the movement and pressure were upward and forward from the quarter of chief crust-disturbance. Now it is nearly at right angles to this established direction of the forces, that the hypothesis I am reviewing assumes a pressure to have been applied to produce the cleavage. The planes of fissuration dipping inward towards the igneous side of the belt, any cleavage-producing pressure to be perpendicular to these planes, as the theory alleges it to have been, must have come either from a point or line elevated at least 45° above the earth's surface, or else from a point or region far below the earth's crust on the opposite side, or in the quarter where the cleavage is absent, or is invariably the least distinct, and where the flexures of the strata, and all other evidences of crust-movement, are vanishing. This is, I conceive, a dynamic dilemma in which the compression theory finds itself,—either to make the force emanate from a quarter external to the crust entirely, or from just that quarter where we have the fullest evidence of the absence of any force at all. Thus, if the theory is applied to explain the South-dipping cleavage of the Northern flank of the Alps, it implies either that the pressure came, not from within the crust below the crest of the chain, but from some point in the air high over the summits of the mountains, or else from some deep-seated subterranean region far to the North of the Alps, under the undisturbed planes of Northern Switzerland or Germany. In the case of the Appalachians, it requires that the pressure should have come, not from under the convulsed and ruptured region of the Atlantic slope, but from some high aerial point above this, or else from a spot diametric to it, deep under the plains of the Western States, where neither cleavage, metamorphism of any kind, nor undulations of the strata exist, to indicate the former presence of any compressing force at all.—(See *Sections of the Appalachians and Alps*, figs. 706 and 714.)

6. Besides this general difficulty, I have a special one to offer connected with the laws of cleavage dip. This applies not only to the theoretical generalisation of Mr Daniel Sharpe respecting the relations of the cleavage-planes to each other in different parts of a zone of slaty cleavage, but to the observations upon which his generalisation has been built. His sections of the cleavage in North Wales and elsewhere represent it as perpendicular or steepest in the belts of maximum igneous action, and flattest in the regions most remote from these, where he places the anticlinal axes of his cleavage-curves. Now, just the reverse of this steepening of the cleavage planes towards the regions of chief metamorphism will be found to be the real law of gradation in the Appalachians, the Alps, and the district of the Ardennes and Southern Belgium. Obedient to a law already explained, the cleavage dip, following the dip of the axis-planes of the flexures, is not most but *least* inclined in the districts most convulsed, and grows progressively steeper as we advance across the undulations to the districts of minimum disturbance. In the Alps the plications lie flattest next the high central crests of the chain, and there the cleavage dip is often at a very low angle; but receding towards the plain of Switzerland, where the theoretical view requires that it should be flatter, it is really steeper, and even approaches to perpendicularity: and precisely analogous is the gradation when we cross the Appalachians from S.E. to N.W. Generalising the dips of the cleavage-planes on both sides of a double belt of flexures like that of the Alps, and excluding the central crests, where the jointage of the igneous rocks and the cleavage structure impressed by them is more vertical, the real curve of dip for the whole zone will be found to be a *synclinal* one, and not the two halves of two anticlinals, the generating axes of which are far outside the chain—one in the plain of Switzerland, the other in the plain of Northern Italy.

I am much gratified to find that my objections to the mechanical theory of cleavage find support in the able writings of Professor Sedgwick, who, in a note in his "Synopsis," states several cogent reasons for rejecting the hypothesis. While some of my own objections are but an expansion of those presented by this eminent geologist, others are independent of his, growing out of my own observations. This accordance gives me additional confidence in the soundness of the generalisations upon which they rest.

THEORETICAL VIEWS.

Theory of the Flexure and Elevation of Undulated Strata.—The wave-like structure of the Appalachians and other undulated zones has been attributed by the Author and his brother, Prof. W. B. Rogers, in their communications to the American Association in 1842, and to the British Association in the same year, to an actual undulation of the supposed flexible crust of the earth, exerted in parallel lines, and propagated in the manner of a horizontal pulsation from the liquid interior of the globe. We suppose the strata of such a region to have been subjected to excessive upward tension, arising from the expansion of molten matter and gaseous vapours, the tension relieved by linear fissures, through which much elastic vapour escaped, the sudden release of pressure adjacent to the lines of fracture producing violent pulsations on the surface of the liquid below. This oscillating movement in the fluid mass beneath would communicate a series of temporary flexures to the overlying crust, and these flexures would be rendered permanent (or keyed into the forms they present) by the *intrusion* of molten matter. If, during this oscillation, we conceive the whole heaving tract to have been shoved (or floated) bodily forward in the direction of the advancing waves, the union of this tangential with the vertical wave-like movement will explain the peculiar steepening of the front side of each flexure, while a repetition of similar operations will account for the folding under, or inversion, visible in the more compressed districts. We think that no purely upward or vertical force, exerted either simultaneously or successively along parallel lines, could produce a series of symmetrical flexures, and that a tangential pressure, unaccompanied by a vertical force, would result only in an imperceptible bulging of the whole region, or an irregular plication dependent on local inequalities in the amount of the resistance. The alternate upward and downward movement necessary to enable a tangential force to bend the strata into a series of regular parallel subsiding flexures has been, we conceive, of the nature of a pulsation, such as would arise from a succession of actual waves rolling in a given direction beneath the earth's crust. It is difficult to account for the phenomena by any hypothesis of a gradual prolonged pressure exerted either vertically or horizontally. And, further, the formation of the grand yet simple flexures so frequently met with cannot be explained by a *repetition* of feeble tangential movements, since these could not successively accord either in their direction or in their amount; nor can it by a repetition of merely vertical pressures, for it is impossible to suppose that these could, without some undulating action, shift their positions through a series of symmetrically-disposed parallel lines. We find it equally impossible to understand how, if feeble and often repeated, these vertical pressures should always return to the same lines to produce the conspicuous flexures we behold. The oscillations of the crust to which the undulations of the strata are attributed have been, we conceive, of the nature of the earthquakes of the present day. Earthquakes consist, as we think we have demonstrated, of a true pulsation of the flexible crust of the globe, propelled in parallel low waves of great length and amplitude with prodigious velocity, from lines of fracture, either conspicuous volcanic axes, or half-concealed deep-seated fissures, in the outer envelope of the planet.

Theory of Cleavage Structure.—Concerning the cause of slaty cleavage, I have adopted the explanation originally proposed by Professor Sedgwick, that it is due to crystalline or polar forces, acting simultaneously and somewhat uniformly in given directions on large masses having a homogeneous composition. And following up the further suggestion in extension of this idea, ingeniously proposed by Sir John Herschel, that this molecular force was of the nature of an incipient crystallisation, and has been developed in the particles, by their being heated to a point at which they could begin to move among themselves, or upon their own axes, I have endeavoured to show, that whether the cleavage-traversed strata have been much disturbed or not, the cleavage planes invariably approximate to parallelism with those great planes in the crust which appear to have been the planes of maximum temperature. It has been already stated that the cleavage dip is parallel to the average dip of the anticlinal and synclinal axis-planes, or those bisecting the flexures. Now, it is easy to prove that these axis-planes, and the inverted parts of the flexures, are just those portions where the greatest wrenching, fissuring, and opening of the strata must have occurred, and where the highly-heated pent-up volcanic steam and gases, and liquid mineral matter, must have found their chief channels upwards to the surface.

Without attempting at present to apply this doctrine in detail, I will content myself with reviving a suggestion I formerly put forth, that every plicated belt of strata may be looked upon as having, from the causes here adverted to, become traversed, at the time of their folding and metamorphism, by a series of alternate hotter and cooler parallel planes or zones of temperature, arranged in oblique dip, coincident approximately with the axis-planes of the flexures. These planes or surfaces of high temperature we may suppose to have acted to polarise the particles in corresponding planes, by transmitting through the half-softened mass a succession of parallel waves of heat, stimulating the molecular crystallising forces which are ever resident in mineral matter, and which only await there the quickening influence of such a temperature to develope in the mass special lines and surfaces of maximum and minimum cohesion.

This conception, that the surfaces or planes of crystalline lamination, including cleavage, which is but a lower grade of the same species of molecular metamorphism, are approximately parallel to the surfaces of the waves of temperature which have moved through the strata, is not a mere hypothetical speculation, but an induction at which I have arrived from a comparison of many observations of my own with phenomena well recorded by the ablest geologists. Nearly all observers who have noted the influence of igneous dykes and veins upon the strata adjoining them, both in mines and external exposures, have seen a more or less distinct lamination or cleavage adjoining the walls of the once heated mineral matter, and have been struck by its very general parallelism to the surface or the axis of the vein. Cases occur in strata of all ages, and are frequently brought to light in coal-fields, when nearly vertical dykes cutting low-dipping or horizontal shales, susceptible of the cleavage metamorphism, have occasioned in the latter a true cleavage perpendicular to the stratification, or parallel, more strictly speaking, with the once hot surface of the intrusive rock.

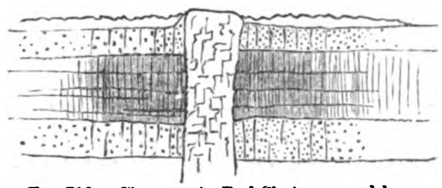
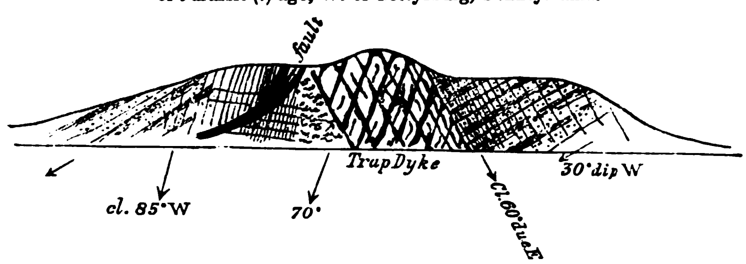


FIG. 718.—Cleavage in Red Shale, caused by a Trap-dyke parallel to its walls, near New Hope, Pennsylvania.*

Other instances are often presented of masses of superincumbent trap-rock, baking and altering argillaceous and other strata, in which a like law of parallelism of the cleavage to the heat-imparting surface of the molten matter is shown in the horizontality of the cleavage-planes, whatever be the dip of the strata. Numerous examples can be cited, where one igneous dyke cutting another, or traversing a mass of earlier Plutonic rock, produces in the latter a crystalline grain, amounting to a sort of cleavage, adjoining the bounding surfaces of the newer injection, and in planes invariably parallel, or nearly so, to the walls of the fissure. A similar fact of the occurrence of a cleavage parallel to the walls of highly-heated fissures, may be seen in the faults and great dislocations which traverse some parts of the anthracite coal-basins of Pennsylvania. Here the greatly indurated argillaceous shales, and even sometimes the coal itself, display a cleavage-structure invariably parallel to the general plane of the fracture. Such fissures would be the natural channels through which heated volcanic steam would ascend from the interior, and the action of this upon the strata most susceptible of cleavage would be precisely analogous to that of a molten dyke, in transmitting a wave of heat perpendicular to its surface, partially softening and half polarising the matter as it passed.

FIG. 719.—Cleavage superinduced by a Trap-dyke in Red Argillaceous Sandstone of Jurassic (?) age, W. of Gettysburg, Pennsylvania.



GENERAL RESUMÉ

1. *Wave-like form of all belts of uplifted strata.*
   a. It is a general fact that strata dip in curved and not in straight planes.
   b. Wherever wide areas of the crust have been elevated or depressed from the level at which their strata were deposited, these strata will be found, except where their dip is disordered by crust-dislocations, to constitute, in their varying angles of dip, one or more wide regular curves.

2. *Parallelism of crust-undulations.*
   a. It is another general fact, that these undulations of the strata are in the form of long parallel waves, resembling much those great continuous billows called in dynamics "waves of translation," and by seamen "rollers."

3. *Relations of flexures.*
   a. Parallelism of the waves to the general trend of the part of the mountain system to which they belong, and especially to its chief igneous axis.
   b. Parallelism of flexures extends not only to adjacent individual waves, but to contiguous groups, and is as true of curvilinear as of straight ones.

* There is a similar instance cited by Professor Phillips, I think, in his *Geology of Yorkshire.*

c. The waves of the strata are generally of two or three grades of magnitude, as respects their length, height, and amplitude, and while those of the same grade are parallel, the different grades are not necessarily so.

4. *Laws of form and gradation of waves.*

There are three characteristic forms of crust-waves : symmetrical flexures, equally steep on the two slopes ; normal flexures, curving more rapidly on one side than on the other ; and folded flexures, or those with a doubling under of their more incurved slopes, and among which the steepest slopes are generally directed to the same quarter.

The geometric planes bisecting the anticlinal and synclinal bends of the strata, here called axis-planes, are nearly perpendicular in the symmetrical waves, but inclined in the other two classes, dipping at the lowest angle in the folded flexures. In many belts the plication is such as to amount to parallelism of all the inverted to the uninverted sides of the waves.

Some waves are straight, some curvilinear and crescent-shaped, and many of them extremely regular, changing their trend 40° or even 50°. The curvilinear ones convex *from* the disturbed sides of the zones, are generally more regular than those which are convex *towards* them.

5. *Gradations in flexures.*

a. In all undulated zones, the succession, starting from the most disturbed side, is invariably from the folded waves to the unequally sloping or normal ones, and from these to the equally sloping or symmetrical.

b. The waves grow progressively wider apart, or increase their amplitude, as they pass from the folded to the equally sloping form.

c. The waves progressively flatten down as they recede from the folded side of the belt.

d. The axis-planes of the flexures of any great undulated zone all incline towards the same quarter, that of maximum disturbance, the angle of inclination being less the nearer the wave or plication is to that side.

6. *Fractures or faults.*

In undulated districts, the dislocations are of two kinds : (1.) Numerous short ones, transverse to the strike of the axes, and shifting the strata to but a trivial extent ; (2.) longitudinal ones, fewer in number, of great length, and producing often great displacement.

The longitudinal faults very generally dip towards the same quarter as the axis-planes ; indeed, they are either ruptures in the axis-planes of the flexures or in the steep or inverted sides of the waves.

This slanting of the plane of dislocation parallel with the leaning of the wave, causes the newer or upper formations, on the inverted side, to dip under the older or lower on the uninverted side of the flexure or the fault, for almost always the uninverted side has been shoved forward and upward across the inverted.

Some undulated belts are single, or have all the axis-planes of the flexures dipping to one quarter, as the Appalachians and the zone of Southern Belgium. Others are double, or consist of two such zones, both dipping inwards towards one central line of chief igneous disturbance, and these latter present in this inward general leaning a fan-like structure, as in the Alps.

7. *Phenomena of slaty cleavage.*

a. The cleavage dip is independent of the dip of the strata; and still more remarkably, the cleavage-planes of a district are generally parallel to the axis-planes of its flexures.

b. Immediately within the anticlinal and synclinal axes, the cleavage-planes depart from their parallelism to the axis-planes and dip inwards towards them in a kind of fan-like arrangement.

c. The cleavage is only present where the rocks consist of certain materials, abounding most where they are most argillaceous and of finest texture, disappearing and reappearing with changes in the composition of the strata, even where these closely alternate.

d. In such groups of alternating cleavable and non-cleavable beds the cleavage-planes curve from the normal dip they possess, to approach to a parallelism with the planes of separation of the strata as they near their surfaces.

e. The cleavage susceptibility is alternately greater and less in closely-adjacent parallel planes. The ribbon structure of glaciers is probably analogous to the cleavage structure of argillaceous rocks.

8. *Foliation.*

In districts of crystalline, metamorphic, or gneissic strata, not much disturbed or corrugated, the foliation generally coincides with the stratification. In regions much corrugated, the foliation, on the contrary, is often at a steep angle to the stratification, and shows a tendency to dip, as cleavage does, parallel to the axis-planes of the flexures. Generally the direction of the foliation appears to conform to that which the waves of heat metamorphosing the rocks would take in slowly flowing through them.

9. *Theories of elevation.*

a. A common hypothesis of the cause of the elevation of strata is that of a wedge-like intrusion of melted matter. But this implies a function in semifluid or fluid matter incompatible with the dynamic properties of liquids. Some force must have first cracked the strata before the molten rock could insert itself. Veins and dykes tapering upward do not belong to lines of anticlinal elevation, where geologists so frequently indicate them, but to synclinals or concave curves.

b. The kindred idea of the intrusion of igneous rocks in solid wedges separating and lifting the crust is also at variance with sound mechanical laws. To exert this lifting and thrusting force, the assumed wedges must have moved freely through the fissures they fill; but we see no proofs of discontinuity between the igneous and stratified rocks, but only evidences of the closest cohesion.

c. A modified view of the wedging up of the flexible strata, conceives them to have been simply carried up by the lifting of the igneous nucleus. Such movements have no doubt occurred, and have served to steepen the strata leaning against the igneous rocks, but they cannot have corrugated the strata, which would be rather stretched than compressed by the elevation.

d. The hypothesis of a simple upward pressure at points or lines in the crust, which does not include an explanation of the wave structure of disturbed districts, cannot be a true theory; it must show how the pressures have shifted to new and parallel lines, and lines constantly receding; and also show why, if the linear pressures were simultaneous, they should not have produced a wide general arching, rather than a series of contiguous sharp waves.

e. The hypothesis of the origin of flexures from a sinking of the ground by removal of volcanic matter beneath it, supplies no explanation of the origin of zones of regular undulations. The sinking of any weak segment of the earth's crust might produce a trivial general warping, but not a belt of waves.

f. The hypothesis of a simple lateral or horizontal compression, illustrated by the folding of layers of any flexible material squeezed edgewise, and kept down by a weight, is open to the objection that this mode of folding offers no true analogy to the great symmetrical parallel flexures met with in nature. Flexures thus artificially produced, show neither the forms nor the gradations characteristic of the crust-waves. A purely tangential force would cause the district within its influence to bulge slightly upward, but not to corrugate into regular undulations, and it fails to find an origin for a pressure in the direction assumed.

10. *Theories of cleavage and foliation.*

a. The prevailing notions of geologists respecting the origin of cleavage and foliation are, on the one hand, that they have been produced by different intensities of molecular crystallising polarities, excited by heat operating in a definite direction; on the other hand, that they have been caused by mechanical compression of the strata applied perpendicularly to the cleavage and foliation planes.

b. One main objection to the pressure hypothesis is, that it does not account for the existence of planes of alternately stronger and weaker cohesion.

c. Another difficulty is, that it fails to explain the dependence of cleavage upon the texture of the rock, especially its chemical nature, and particularly where cleavable and non-cleavable strata alternate in close contact.

d. A third important objection exists in the dynamic difficulty, that the cleavage is nearly parallel and constant in its dip, despite the inequalities which a lateral pressure should undergo in its transmission through all the contortions and various postures prevailing in the strata.

e. A fourth difficulty, analogous to the last, is presented by the constancy in the amount and direction of the elongation or creep of the cleavage rocks in the direction of their cleavage dip; a constancy not compatible with the ever-varying tension which the flexures and bendings of the strata would occasion.

f. An additional objection presents itself, in the direction of the pressure implied by the theory, which, assuming the force to have been perpendicular to the cleavage-planes, implies it to have come either from a source above the earth's surface, on the side towards which the cleavage-planes are dipping, or from a source far beneath the crust, in that quarter where invariably the cleavage and all other symptoms of metamorphism are least abundant, or entirely wanting.

g. Still another important objection arises, in the contradiction exhibited between the law of gradation in the steepening of the cleavage dip demanded by the theory, or one form of it, and the actual law of the gradation of this dip witnessed in all districts of regular crust-plications. The theory represents the cleavage dip as growing progressively steeper the nearer it is to the lines of greatest igneous action; the facts in nature show that the cleavage, the foliation, and the axis-planes of the flexures, with which these are approximately parallel, grow progressively steeper the farther they recede from those lines of maximum energy.

Concluding theoretical views.

The wave-like structure of undulated belts of the earth's crust is attributed to an actual pulsation in the fluid matter beneath the crust, propagated in the manner of great waves of translation from enormous ruptures occasioned by the tension of elastic matter. The forms of the waves, the close plication of the strata, and the permanent bracing of the flexures, are ascribed to the combination of an undulating and a tangential movement, accompanied by an injection of igneous veins and dykes into the rents occasioned by the bendings.

This oscillation of the crust, producing an actual floating forward of the rocky part, has been, it is conceived, of the nature of that pulsation which attends all great earthquakes at the present day.

11. *Theory of Cleavage.*

The cleavage-planes having been shown to be parallel to the axis-planes of the flexures, and locally to the planes of the great faults, and these being obviously the belts of maximum temperature in a plicated district, it is suggested that both cleavage and foliation are due to the parallel transmission of planes or waves of heat, awakening the molecular forces, and determining their direction.

CLASSIFICATION OF THE SEVERAL TYPES OF OROGRAPHIC STRUCTURE VISIBLE IN THE APPALACHIANS AND OTHER UNDULATED MOUNTAIN-CHAINS.

FEATURES OF GENERAL EROSION.

I.—EROSION OF HORIZONTAL STRATA.

Various circumstances have influenced the erosion of even horizontal or approximately horizontal strata, and consequently the features of their denudation are somewhat diversified. The smaller or more local ones will be considered under a separate head, and I shall here allude only to the wider and more conspicuous ones. These belong chiefly to the edges or level outcrops of the strata; for where the deposits of a region are very nearly horizontal, no striking changes of slope or scenery on a large scale can arise on the level plain or surface of the formations, but only where their edges are exposed. This exposure may result either from a descent in the surface of the country intersecting strata absolutely level, or from a slight inclination or dip in the strata themselves, the ground remaining at one general height above the sea; or it may arise from both combined—a sloping surface and a gentle dip.

The prominent phenomena of wide erosion under these conditions depend on a diversity in the cohesion of the strata, enabling some of the beds, when cut into and exposed, to resist the destruction to which others readily yield. The essential structure resulting from a general and deeply-penetrating erosion, of an alternating series of firm and incohering beds, is that of a succession of terraces, or of plains terminating by abrupt slopes or escarpments—the width of the terraces and the height and contour of the escarpments being controlled by the relative thicknesses of the strata, by their departure from horizontality, and by the greater or less general slope of the country. Wherever the stratification is very nearly level, and the softer groups of strata much exceed the harder shelf-forming ones in thickness, the plains are broad between the successive escarpments, unless, indeed, a deep valley or denuded plain cuts off the whole series, and gives it the external structure of an elevated terraced plateau. Even in this case, the terraces which bound the plateau are comparatively wide. If, on the contrary, the softer members are thin in proportion to the harder, and the other conditions are the same, the individual terraces are narrow; and if the entire series stands out as a plateau above a lower adjacent country, its general escarpment is necessarily steeper.

I proceed to illustrate the several varieties of Terraces and Terraced Plains.

a. *Where each principal Stratum is Homogeneous as respects its Hardness or Softness.*

Not only is a certain extent of contrast in hardness and softness in the alternating strata essential for the production of prominent features of escarpment and of level terrace, but a very considerable degree of uniformity in composition throughout each member is no less important. Where these two conditions prevail in a high degree, the surface of each terrace or plain is level and uniform, and its edge or escarpment precipitous and bold; but where the individual strata are neither homogeneous in themselves nor much unlike each other in degree of hardness or cohesion of their particles, the surface will be uneven, and will form a sloping plain, and their edges will produce only slanting and more or less faintly-benched hill-sides.

1. *Plateaus with Simple Escarpments.*—These occur where there are but two strata, and the upper one is much the harder. The greater or less degree of precipitousness in the edge of the plateau or terrace will depend, as we have seen, upon both the relations of thickness and of hardness in the two masses. But peculiarities of rock-structure, such as the presence or absence of great joints, likewise exert an important influence in deciding the steepness and form of the escarpment. We must also infer that, all these elements being the same, there will arise a marked diversity in ruggedness or softness of outline, as the stratum may have been cut by violently-moving heavy currents of water, or may have been more gently washed and worn by thin and feeble ones.

The annexed section of the cliffs of the gorge of the Niagara River at and below the cataract will illustrate the escarpments of this class, where jointage in the upper rock conspires with its greatly superior hardness under erosion, to impart the character of a cliff or precipice.—(Fig. 720.)

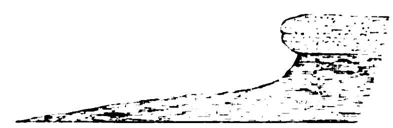


FIG. 720.—Plateau with simple Escarpment, Shelf of Niagara.

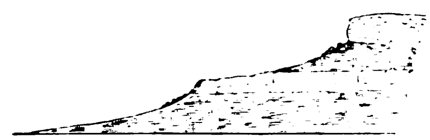


FIG. 721.—Plateau with complex Escarpment, Mountain-ridge, New York.

2. *Plateaus with Complex Escarpments.*—This feature in the edges of plateaus occurs where there are four or more chief beds alternating in composition and hardness, and where the lowest of the softer masses and the uppermost of the hardest are comparatively thick. Under these conditions the one or more subordinate terraces or shelves on the face of the slope cannot be wide, and the whole descent from the upper to the lower plain has the structure of two or three majestic steps or platforms.

Such are the features of the mountain ridge or terrace south of Lake Ontario in Western New York and Upper Canada, a profile of which is here appended.—(Fig. 721.)

3. *Terraced Plains.*—This structure of the surface arises from that continuation of nearly horizontal stratification, and nearly horizontal general denudation, which throws the outcrops of the several hard and soft strata very wide apart. The whole district is in this case a succession of very broad platforms. Such, in a general profile, is the entire plain of Western New York here illustrated (Fig. 722); and on a still grander scale, the great interior plain E. of the Rocky Mountains.

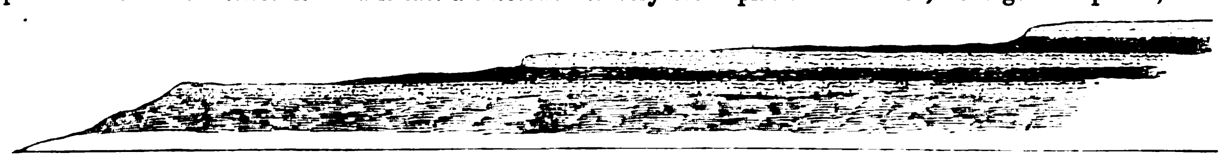


FIG. 722.—Terraced Plains.

b. *Where each separate Stratum is complex in Composition and Degree of Hardness.*

I have already shown that the want of homogeneousness in the chief members of a series of strata, and the consequent approximation of the several members to each other, is expressed in the profile of the surface by less conspicuous features, less precipitousness in the escarpments, less levelness in the terraces, and by more numerous but fainter benches on the edges of all the plateaus.

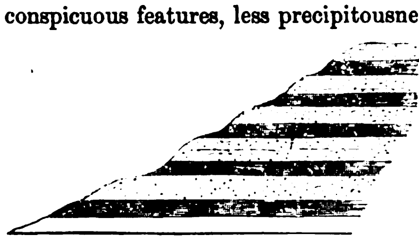


FIG. 723.—Plateau with terraced Escarpment, Pokono Mountain.

1. *Plateaus evenly benched in their Escarpments.* —This condition is presented wherever there exists a somewhat frequent and nearly uniform alternation in thickness and hardness of the eroded strata. If the firmer rocks are perpendicularly cleft by numerous parallel joints, and the softer ones are extremely soft or friable, the benches, though not necessarily wide, will be sharp and steep, and step-like; whereas, if the hard layers are coherent throughout, and the interposed ones somewhat firm, the benches will be rounded and obscure, and the whole escarpment an undulated inclined plain of steeper and gentler convex and concave slopes, like greatly-worn and rounded rocky stairs. Such in many places is the great sloping escarpment of the high table-land of the Pokono and Catskill mountains, and on a much smaller scale some of the plateau-like hills of horizontal Coal-measures in Western Pennsylvania. The Pokono Mountain, in its S.E. slope, is here indicated with its benches.—(Fig. 723.)

FIG. 724.—Plateau with upper Escarpment terraced, Alleghany Mountain, Pennsylvania.

2. *Plateaus benched only on their upper Escarpments.*—In those plateaus which are capped by an alternation of two or three hard and as many soft rocks, and underlaid by a thick stratum of less-enduring material, there will be seen an upper steep slope with benches, and below it a long, smooth, gently-spreading inclined plane. Such is the structure and the very usual profile of the S.E. front of the main table-land of the Alleghany Mountains in Pennsylvania.—(Fig. 724.)

3. *Plateaus terminating in precipitous Escarpments passing downwards into benched or terraced Slopes.*—In these instances the alternation is in the inferior or softer group of beds, and not in the upper harder one, as in the previous case; and the capping stratum must be massive and resisting. Where these conditions prevail, we have a terrace, or it may be a mountain plateau, bounded at its edge by a bold steep precipice, rising from a long inclined escarpment, benched more or less distinctly or obscurely, as the nature of the lower alternating series may determine.

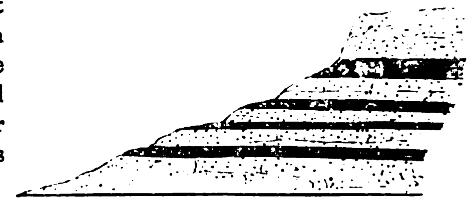


FIG. 725.—Plateau with lower escarped Slope terraced, Catskill Mountain.

This is a description of the structure of the external features of the more escarped front of the Catskill Mountain which faces the Hudson, and is characteristic likewise of certain portions of the edge of the Alleghany Mountain in Pennsylvania. (See Fig. 725.)

II.—FEATURES OF EROSION OF MONOCLINAL BELTS.

The erosion of tracts of strata dipping in one direction has led to a great variety of external features. Where the region denuded embraces crust-undulations of decided flexure, each monoclinal zone, whether wide or narrow, exhibits, of course, a gradation in the steepness of its dips, varying in obedience to the nature of the flexures. The subordinate belts of dissimilarly-dipping rocks having presented their edges to the abrading waters at different angles, and therefore with unlike degrees of resisting strength, show unlike external outlines, even where the currents have been similar in force and direction, and where the relations of the subordinate strata to each other, in respect to their thicknesses, texture, and composition, have been nearly identical. But these two other sets of elements have themselves been very different in different districts; the waters have not wrought with the same weight and velocity, or in the same manner as to their currents and eddies, on all the rocks exposed to them; nor were the conditions of the several rocks, in all that influenced their unequal liabilities to erosion, equivalent in the different zones, or different belts of the same zone.

A study of the surface features of those districts of inclined strata which retain, as many do, the sculpturings left by the waters in all their freshness, and undisguised by any clothing of drift, will readily indicate—with a little reflection upon the modes of action of the eroding agent upon the variously-placed and constituted masses subjected to its wearing energies—the special influences of the several elements which have been here alluded to. It will show us that a general movement of the currents longitudinally with the outcrops of the inclined deposits, excavated the softer beds to a greater depth than the currents directed transversely; and it willindicate that the results produced where the strata were very steep, or merely presented their edges to the sheet of fluid and fragmentary matter which planed them down, were very different from those left upon more gently-dipping groups of hard and soft beds.

To enter elaborately into the consideration of all the modifications in the topography of monoclinal belts of strata, and to trace each to its causes, would take me beyond my present plan, which is chiefly to point out the existence of such modifications, and the general laws which control them. The principal features of erosion of evenly-dipping hard and soft rocks deserve, however, to be illustrated; and I proceed to exhibit them here.

a. *Where the Strata are alternately firmly and feebly cohering, and those of each Class are alike hard and soft.*

It is characteristic of formations thus composed to leave a surface after denudation more or less grooved and ridged along the outcrops, but approximately level in its wide features. The inclination of the rocks, and the difference in the hardness of the two sets, will determine, of course, the depth of the depressions or degree of ridging of the plain.

1. *Ridged or undulated Plains or wide Valleys.*—Here both the hard and soft rocks possess the average tenacity of these classes over a wide space. This feature is seen in many parts of the great Appalachian Valley.—(Fig. 726.)

FIG. 726.—Ridged and grooved Plain.

FIG. 727.—Ridged and grooved Table-land.

2. *Ridged and grooved Mountain-crests.*—Here the alternation of hard and soft rocks forms a general belt harder than the strata above and below them. The monoclinal mountains enclosing the Shamokin coal-basin display this structure in a marked degree.—(Fig. 727.)

b. *Where there are several Groups of Strata differing in their Degrees of Hardness.*

1. *Single-crested Monoclinal Ridges.*—These consist of three or more groups, and the central group is much harder than the flanking ones; and having been less cut away by the waters, stands forth as the higher part or crest of the edge. The Primal white sandstone and the Meridian sandstone frequently form ridges of this profile.—(Fig. 728.)

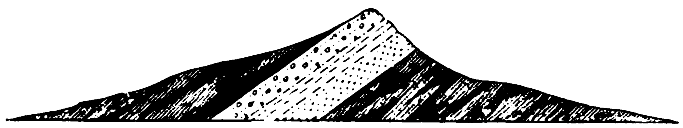


FIG. 728.—Single-crested Monoclinal Ridge.

2. *Double-crested Monoclinal Ridges.*—In these there are five or more groups, two of them hard formations, forming the crests; and between these a softer, making a high or crest valley; and outside, or below and above them, are still softer ones.—(Fig. 729.)

3. *Double Monoclinal Ridges with single Crest, but broad high Shoulder or Terrace.*—These are modified forms of the preceding class, consisting, like them, of five or more sets of strata, but having one of the harder groups considerably less resisting than the other. The most common and marked variety is where the lower hard rock has been the weaker of the two. Such is the very usual profile of the monoclinal ridges of the Levant series surrounding the Auroral limestone valley of Central Pennsylvania—(Fig. 730). The other variety is where the lower of the hard masses has been the firmer or more resisting one—(Fig. 731).

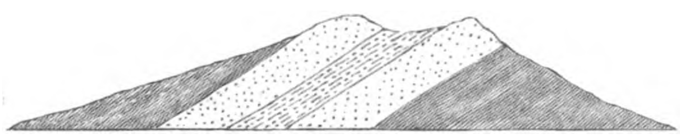


FIG. 729.—Double-crested Monoclinal Ridge.

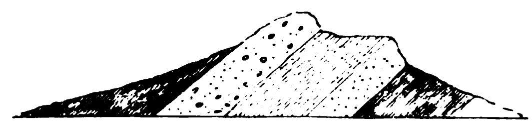


FIG. 730.—Double Monoclinal Ridge, with terrace on the back.

4. *Complex Monoclinal Ridges.*—These are composed of central harder rocks, and softer flanking ones—one, two, or all of the three series being complex, or containing an alternation of harder and softer beds.

There are several varieties dependent on the group or groups in which the marked alternation of hardness in the beds resides. Where it belongs to all three, the crest series and the lateral ones also, the mountain is then much terraced, being benched on its crest and on its sides.

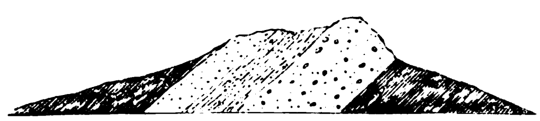


FIG. 731.—Double Monoclinal Ridge, with terrace on the front.

FIG. 732.—Complex Monoclinal Ridge.

A more common condition is where the middle group is homogeneous, and the upper or face side series is an alternating one. This is the structure of many of the monoclinal ridges bounding the anthracite coal-basins. A section is here presented.—(Fig. 732).

Another variety is exhibited where the middle or hardest set and the uppermost or face side strata are both of them complex or alternating groups. Ridges of this composition are benched or grooved alike on their summits and their dipward flanks. This structure is distinctive of the more Western anthracite valleys, and has its fullest development in the crests which enclose the Great Shamokin Basin. Here is a simple section.—(Fig. 733.)

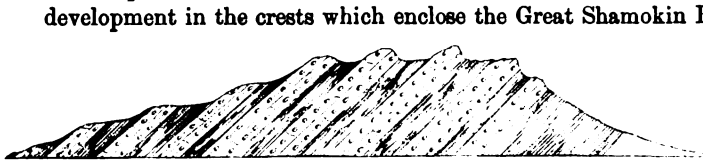


FIG. 733.—Complex Monoclinal Ridge.

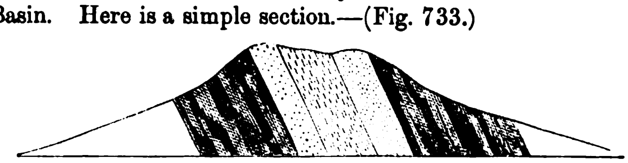


FIG. 734.—Monoclinal Ridge, a Profile of the Kittatinny Mountain, near the Susquehanna (strata inverted).

In all of these forms of monoclinal ridges, the relations of the different features to each other, the crests and slopes, terraces and benches, are more or less modified by every marked variation in the dip of the strata; and the deviations from the average orographic characters here given are the widest where the dip is inverted, or the rocks are overturned. This will be seen by comparing the annexed sketch of a ridge of Levant and Surgent strata inverted in their dip, as they sometimes are in Pennsylvania. The sketch (Fig. 734) shows the usual profile of the same rocks in their more natural or normal posture, which exhibit a double monoclinal ridge, with single crest and broad high shoulder.

All the long narrow monoclinal mountains are termed ridges in the United States, and so, indeed, are all elongated crests of whatever structure or precise shape; but in the Jura chain of Switzerland, the *crêts* are those only which have this monoclinal structure, and the anticlinal ridges are by the Swiss geologists called *voûtes*.

5. *Single-trenched Monoclinal Valleys.*—The conditions essential to valleys of this structure, which are extremely numerous in the Appalachian chain, are the superior softness or erosibility of the central or valley group over those

which adjoin it, and the absence of hard strata in the middle of it. All the anthracite basins are surrounded by valleys of this class.—(Fig. 735.)

6. *Double-trenched Monoclinal Valleys.*—In valleys having this profile there are at the least five groups or sets of strata, the two external ones of the five, superior enough in hardness to the rest to stand forth in ridges, and the central one of all, less firm than these, but harder than the valley-masses adjoining it. Upon the relative degrees of hardness and of thickness of all five masses, depend the minor variations of feature of every such belt.

FIG. 735.—Simple Monoclinal Valley.

This type of valley is very common inside of the anthracite basins between the ridges of the Levant and Vespertine rocks, the central ridge being of the Meridian sandstone.—(Fig. 736.)

7. *Complex Monoclinal Valleys.*—These occur where the softer sets of strata are variously alternated with harder interposed formations. Where the alternation extends throughout the whole of the softer excavated groups, both the general bed of the valley and its slopes are more or less ridged and terraced.

FIG. 736.—Double Monoclinal Valley.

Belts of this order are numerous on a small scale in all the more complex formations, especially in the wider monoclinal tracts of moderately-inclined anthracite Coal-measures. On a large scale they are perhaps most frequent in the Appalachians, along the S.E. base of the plateau of the Alleghany Mountain, the complex valley being between that ridge and the parallel crests of the Levant sandstones. The section (Fig. 737) represents this belt in Centre County, Pennsylvania.

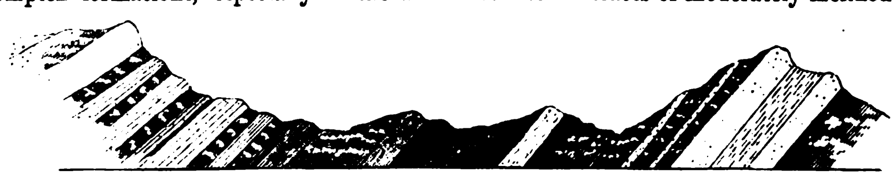


FIG. 737.—Complex Monoclinal Valley.

The relative prominence of the ridges and depth of the valleys of monoclinal structure is very closely connected with the conditions which controlled the energy of the longitudinally-acting portions of the excavating currents, as will clearly appear presently, when we are considering the mountain-notches, their origin and effects on the drainage.

In the United States, these long, narrow, monoclinal trenches between the mountains are called simply *valleys*, as are the wider anticlinal and synclinal and complexly-undulated ones, even where they have the relative width of plains. But in the Jura chain of Switzerland, the narrow elevated monoclinal and anticlinal valleys or troughs between the crests are designated *Combes*.

III.—FEATURES OF EROSION IN ANTICLINAL BELTS.

a. *Where the lowest Strata exposed, or those of the Anticlinal Axis or Summit of the Wave, are the hardest.*

1. *Single-crested Anticlinal Ridges.*—The conditions essential to this structure are a lower hard stratum and an upper softer one, bent into either a regular or an unsymmetrical anticlinal wave, so eroded on its summit as to expose the harder mass in a central crest.

Ridges of this composition and form are numerous in the Appalachians, and other undulated chains, though in their very simplest type, or without terraces on their sides, they are less common.

Some of the anticlinals of the Primal strata in South-eastern Pennsylvania are of this form. In the coal region they are always benched. A section of Montour's Ridge, towards its N.E. end, displays this simple form. Some of the spurs of the South Mountains also show it. The figure (738) represents the Primal white sandstone exposed in the crest, and Primal slates on the flanks.

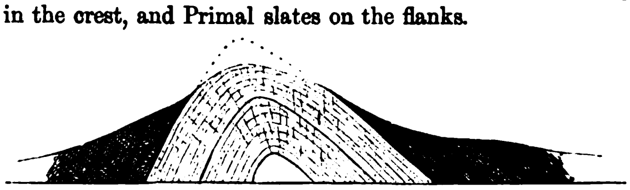


FIG. 738.—Single-crested Anticlinal Ridge.

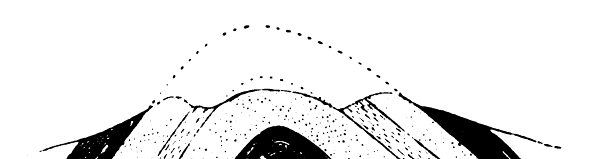


FIG. 739.—Triple-crested Anticlinal Ridge.

Every such interior anticlinal ridge or crest is in the language of the Swiss geologists, as applied to the Jura Chain, a *Voûte*, and the present simple type constitutes Thurman's *First Order* of anticlinal ridges.

2. *Triple-crested Anticlinal Ridges* (or ridges with a central anticlinal crest, and two lateral monoclinal crests or shoulders).—The ridges of this type, of which there occur some striking examples in the Appalachians, have been formed by the erosive action of the ancient waters on four separate sets of strata—two hard ones and two soft ones—the lowest of all, a hard formation, saddling the axis, and standing above or on a level with the two monoclinal crests of

the upper hard mass, while between these and the central crest the lowest soft deposit appears either in two high monoclinal valleys, or in a level wide terrace, the uppermost of the four rocks forming by its superior softness the two external flanks of the whole compound elevated belt.—(Fig. 739.)

A good instance of this structure is presented in Shade Mountain of Juniata and Union counties, Pennsylvania, of which an average section is here presented. Chestnut Ridge and Laurel Hill, of the bituminous coal region, are other instances.

The denuded anticlinals of this type occurring in the Jura chain, are those ranked by Thurman as his *Second Order* of upheavals.

b. *Where the lowest Strata exposed along the Anticlinal Axis are softer than those resting on them.*

1. *Simple Valleys of Elevation* (or double-crested ridges, with anticlinal valleys or plateaus enclosed between them).—The anticlinal belts of this structure are of two classes—those which belong to mountain-ridges, and those which are central parts of wider plains or valleys; but the present section is devoted to those which are features of ridges.

The essentials to this form of anticlinal ridge are, the exposure by erosion of three sets of strata, a lower soft group, a middle hard one, and an upper soft one again. The lower mass saddles the axis, the denudation not penetrating through it, but the harder middle rock is longitudinally cut away at the crest, and left in two parallel crests embracing a high valley between them, by the wearing of the inferior softer one, and the previous removal of the overlying soft group.

Such is a very frequent feature, on a small scale, in the Appalachians. It occurs in the anthracite coal-fields; is seen in belts of Pre-meridian limestone between ridges of Meridian sandstone, and in other valley-rocks; but it is more conspicuously displayed on a larger scale in the long regular anticlinals of the Levant sandstones S.W. of the Susquehanna. The best example on the large scale is the Blue Ridge of the Juniata, here presented in profile.—(Fig. 740).

The terminal portions of many of the other Levant sandstone ridges present a structure identical with this.

These high anticlinal valleys, no less than the elevated monoclinal ones, are termed *Combes* in the Jura.

2. *Complex Valleys of Elevation.*—These are valleys formed by a deep denudation in the back or summit of an anticlinal wave, exposing at least *five* sets of strata, the lowest being soft and cut into, but not cut through. The second, a hard formation, longitudinally intersected over the arch, outcrops in two parallel crests, or it may be in two shoulders of high terraces; the third a softer mass, likewise of course cut through, forms these terraces, or else two high monoclinal valleys, by its outcrops; while the fourth, a second hard material, still further sundered, forms two

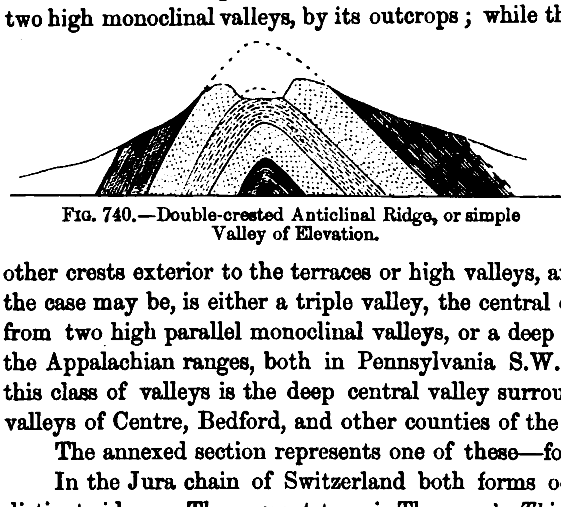


FIG. 740.—Double-crested Anticlinal Ridge, or simple Valley of Elevation.

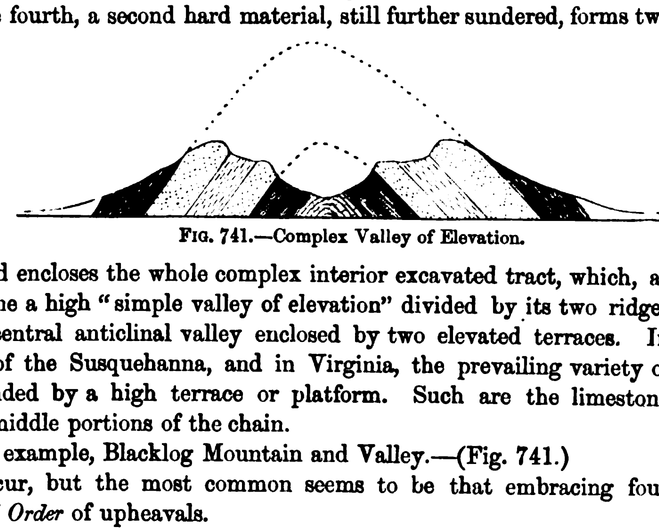


FIG. 741.—Complex Valley of Elevation.

other crests exterior to the terraces or high valleys, and encloses the whole complex interior excavated tract, which, as the case may be, is either a triple valley, the central one a high "simple valley of elevation" divided by its two ridges from two high parallel monoclinal valleys, or a deep central anticlinal valley enclosed by two elevated terraces. In the Appalachian ranges, both in Pennsylvania S.W. of the Susquehanna, and in Virginia, the prevailing variety of this class of valleys is the deep central valley surrounded by a high terrace or platform. Such are the limestone valleys of Centre, Bedford, and other counties of the middle portions of the chain.

The annexed section represents one of these—for example, Blacklog Mountain and Valley.—(Fig. 741.)

In the Jura chain of Switzerland both forms occur, but the most common seems to be that embracing four distinct ridges. The present type is Thurman's *Third Order* of upheavals.

It is obvious that the forms of eroded anticlinal belts will be more and more complex in proportion to the number of alternating hard and soft formations lifted and denuded in the back or arch of the wave; and that if seven, in place of the five such strata above represented, were embraced in the belt, there would be an interior valley, either of five lesser ones, and of four ridges separating them, or else a deep central valley of denudation, bordered on each side by a *double* terrace; or, in other words, a valley of three platforms of level in place of two between the high exterior crests. An intermediate structure, derived from an erosion developing six sets of alternating hard and soft strata, is likewise of frequent occurrence. This is where the lower or first formation is a hard one, and has been denuded but not cut through by the water, and projects therefore as a simple or single-crested monoclinal ridge in the middle of the central valley, which, when it is prominent, it even divides into two monoclinal ones. This more extreme degree of exposure of the central arch is conspicuous in the Jura, especially in the chain of Mont-Terrible, and is the type of Thurman's upheavals of the *Fourth Order*. It there constitutes the limit to which the elevation and denudation of the anticlinals have proceeded. The most developed anticlinals of the Appalachians are likewise not advanced beyond this point of orographic structure, nor do they indeed present it in quite its fullest completeness. Only the widely and deeply-denuded anticlinal belts of Nittany Valley and Morrison's Cove display it in any very distinct degree, and there even it is not the prominent feature. It exists in those belts where the erosion has extended down to the relatively harder Auroral magnesian limestone, and especially where the base of this formation, the Auroral sandstone, has been reached and exposed. In this latter case there is an anticlinal sandstone ridge in the middle of the valley; and generally, in fact, the whole bed of the valley is more or less arched through the superior hardness of the whole Auroral series over that of the Matinal soft limestone and slate, outcropping along each margin of the plain. In a fainter degree, therefore, even the other narrower limestone valleys of the same part of the chain, which expose no medial ridge of the Auroral sandstone, are instances of an incipient advance towards the structure we are now considering, of an anticlinal of six alternating hard and soft strata, cut down by water to the exposing of the lowest in an unbroken arch. As this feature of the greater anticlinals of Pennsylvania is connected with important economic interests, no less than with

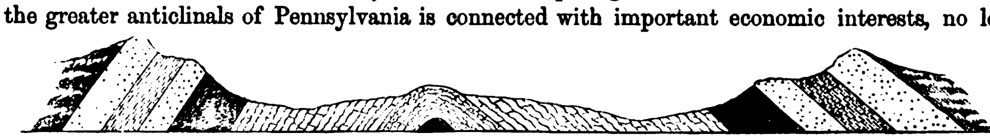


FIG. 742.—Complex Valley of Elevation, with central Anticlinal Ridge.

these laws of orographic structure, I will here present a section of this type of denudation. It will stand for a profile of Nittany Valley, and the enclosing mountains in a meridian E. of Bellefont.—(Fig. 742.)

The exposure of the lower Auroral rocks, especially of the sandstone ridge, is invariably attended by two conditions interesting to the inhabitants—great nest-deposits of hæmatitic iron-ore, and barrenness as to water.

The above four or five varieties of our anticlinal mountains, constitute in reality but one series of the successive stages of elevation and erosion of the larger anticlinal waves. They owe their features primarily to the fact of an alternation in the relative hardness and softness of the strata uplifted and cut into, and each derives its special character merely from the particular amount of the vertical elevation at the arch, and the extent of the denudation, or the stage, at which the washing off or excavation paused. Of course, the depth to which this erosion would penetrate, with a given energy and duration in the removing waters, would be somewhat influenced by conditions independent of the simple height of the exposed anticlinal wave; such, for example, as the relative thicknesses of the hard and soft alternating strata, also their differences of hardness and of softness, and especially the greater or less extent to which the outer strata might be cracked, dislocated, and made to yawn on the back of the anticlinal by the undulating uplifting crust-movement preceding or accompanying the lashing of the waters. These several phases of erosion of the Appalachian anticlinals are to be seen both detached and blended together, in the district of the Juniata River, where the four forms above described are beautifully typed in the Tuscarora, the Blue Ridge, the Shade, and the Blacklog mountains; and blended together, or graduating into each other, in the mountain-group of Union, Centre, and Mifflin counties, where each of the single anticlinal crests of Union, ascending W., divides into two monoclinal ridges, with a high plateau between to form the second phase of a simple high valley of denudation; and out of the middle of this again, at its W. end, there rises by-and-by a central unbroken anticlinal ridge or knob, to make, with the two outer crests, and the now double plateau, the third or triple-crested form; while still farther forward, in Centre County, with the progressive rising of the axis, and deepening of the trench upon it, the fourth marked type is developed in the beautiful elliptical coves or oval-headed valleys, which scooped deep in the Matinal slates and limestones, are bounded first by two inner monoclinal crests or shoulders forking from the central knob, and externally by the two crests before produced by the similar forking of the original single ridge, the high terraced branches of the upper valley or plateau being embraced between these inner and outer crests.

The attentive student of our Appalachian geology will readily perceive that a still further amount of uplift or flexure in the anticlinals of Centre County would have brought the hard Primal sandstones which underlie the soft limestone of the valleys, and even the soft slates beneath those sandstones, equally within the trenching force of the waters, andthat in this case there would have been produced a fifth and a sixth distinct type; one, the first of these, with a high central ridge in the valley, and the other with this ridge forking into two escarpments, and enclosing a deep interior valley, relatively lower by several hundred feet than the beds of the present ones. Such more complex anticlinal valleys of erosion, resulting from denudation upon six or seven in place of five alternately hard and soft strata, do exist, as we have seen, in the Jura Mountains, and even in a faint degree in the valleys of Centre County. In the Jura, from the extreme relative softness of the more easily excavated beds, and the firm, cliff-forming, jointed character of the limestones, which are the harder members, the scenery of some of these deep secluded and wall-surrounded oval valleys is wonderfully impressive and picturesque.

Though the Swiss geologists, especially Thurman and Gressly, have classified the denuded anticlinal valleys of the Jura chain somewhat as I have now been grouping those of the Appalachians, their arrangement, it will be seen, is not complete, there being really five phases of structure covered by Thurman's four orders of upheaval. Gressly has ascribed to these anticlinals, moreover, an erroneous origin. He assumes them to have resulted from a subterranean explosive volcanic action, exerted at certain points in foci along the anticlinals, and imputes too little agency to the carving force of waters working through breaches in the ridges, and scooping them at such enfeebled points into these terraced oval valleys by the revolving eddying currents of the tremendous waves which swept transversely all the summits of this chain. To this excavating action of water, propelled in gigantic billows and rushing sheets across our anticlinal ridges, when these were lifted by successive but sudden earthquake movements, higher and higher through and above the ocean, while at each paroxysm they were becoming more and more permanently arched, we must, I think, attribute, conjointly with the differences in the susceptibility of the strata to erosion, all the phenomena of excavation which I have described.

IV.—FEATURES OF EROSION IN SYNCLINAL BELTS.

a. *Where the highest Strata exposed, or those of the Synclinal Axis or Trough of the Wave, are the hardest—of this Class there are several Varieties.*

1. *Simple Synclinal Ridges.*—These occur where the highest strata, or those in the middle or axis of the flexure, are the *hardest*. Where such upper harder rocks are of one nearly uniform degree of resisting strength, they form smooth slopes, whose steepness is progressively greater as we ascend to the edge or very brow of the plateau which, narrower or wider, invariably terminates all ridges thus composed having synclinal dips. But where the upper firmer rocks are alternating in degree of hardness, the sides are benched or terraced, but the shelves for the most part are less sloping, and more ravined than on the faces of anticlinal ridges. The narrowness or width of the summits of these synclinal ridges, depends mainly on the steeper or gentler degree of dip of the strata at the axis, or the closer or more open form of the flexure. Where the synclinal dips are very steep, or the fold much compressed, the ridge is usually a narrow, flat-topped crest, or is cut by cross denudation into a chain of oval ridges or flattish hills or knobs. Such are the features in which many of our more slender synclinal sandstone ridges terminate. Again, where the dips are flatter, and the synclinal curve gentler and more open, the summit is broader, and is usually a true table-land or high plateau, being sometimes even basin-shaped. (See Figs. 736 and 737.)

Examples.—The longer simpler spurs of the Broad Mountain, Schuylkill County, and those of the Lehigh coal-basins, have this structure; also the terminating spurs of Nittany and other synclinal mountains of the Levant lower sandstones.

2. *Triple Synclinal Ridges, or a Central Synclinal Ridge or Plateau enclosed by two Monoclinal Ridges or Shoulders*).—This second feature of synclinal topography is where the synclinal wave admits within it three several strata or series of rocks above those of the exterior country, or four in all—namely, a hard, a relatively soft, and again a hard group. In this instance we will have the first or lowest hard mass basining or sinking from a high plateau, and forking into two crests or ridges, and admitting a double narrow valley within it, and between these two valleys of softer matter will rise in a ridge or plateau the uppermost hard formation, placed centrally like a citadel enclosed by its moat and exterior rampart.

We have an example of this structure in the Broad-Top Mountain of the Juniata, where the hard Vespertine rocks of the Terrace Mountain and Sideling Hill enclose the forking valley of Trough Creek, with its soft Umbral shales; and this embraces between its branches the table-land of the Broad-Top Mountain, composed of the harder inferior strata of the semi-bituminous Coal-measures. It is likewise beautifully exhibited in the ridges which divide the branches of Kishacoquillas Valley and those of Penn's Valley, and indeed in many others of our synclinal Levant mountains, where the lower Levant sandstone forms a first plateau, and the upper a higher ridge resting upon it.

b. *Where the highest Strata embraced in the Synclinal flexure are relatively soft—of this Class likewise there are several Varieties.*

1. *Simple Synclinal Valleys and basin-shaped Plateaus* (synclinals where the highest strata are *softer* than those supporting them).—Such belts are invariably trough or basin shaped. Of this type are the coal-basins of the anthracite region of Pennsylvania, if viewed from their exterior red-shale valleys. There the relatively hard conglomerates, at the base of the Coal-measures, rising in steep narrow monoclinal ridges on each side, basin under these softer upper coal-strata reposing nearer the synclinal axis, and the harder less erosible rock *is also underlaid* by easily-denuded strata. In these instances the harder rocks either form *plateaus* basining in their centres, but lifted above the exterior plain or valleys of the lower softer group; or else two parallel ridges, with the upper softer strata between them, and the lower softer series in a belt on the outside of each. Both of these conditions occur in the great synclinal basins of the Pennsylvania anthracite, where the soft Umbral red shale surrounds in some cases, as in the Lehigh district, high table-land basins of the Coal-measures; and in other cases encircles in narrow exterior valleys the steep narrow ridges of the harder strata which enclose the often equally depressed interior valley-basins that hold the Coal-measures.

Examples.—The tongue-shaped valleys or basins of Umbral red shale, enclosed by ridges of Vespertine hard sandstones, like the Lehigh Kettle, Hunter's Cove, and Parnell's Mountain, in Franklin County, are good examples.

2. *Complex Synclinal Valleys, or concentric Valleys of Depression.*—This type of ridges and valleys is presented where there are four alternating hard and soft groups of strata above that of the general plain of the country, or five in all, and the uppermost a soft group. In this, as in the previous case, the highest soft strata lie in a topographical

basin, between monoclinal inward-dipping ridges of the next inferior hard rocks, which unite at the head of the basin in a high synclinal knob ; and this inner basin itself rests within another, scooped in the lowest soft group which, in its turn, is similarly enclosed by two converging ridges of the lowest of the hard masses, or the first of the four formations. Such concentric synclinal troughs bear a striking resemblance to a nest of spoons, where a smaller spoon rests within a larger one.

The form here illustrated is that derived from five groups of alternately hard and soft strata, but there are synclinal belts or basins in our Appalachian chain, where the erosion of seven or even of nine such masses at their outcrops has produced a symmetrical and curious topography, consisting of three or four concentric basins, each basin being composed of a soft easily-excavated member resting within an enclosing mountain-rim of hard resisting sandstones, and each, save the innermost or uppermost of the softer strata, branching into two narrow parallel valleys from a regular terminating spoon-shaped cove. While these narrow lateral valleys thus unite in pairs in the terminating synclinal coves, the ridges which separate the valleys converge by the same law, and coalesce by pairs at the ends of the basins in high synclinal plateaus and swelling mountain-knobs—usually the loftiest eminences of the symmetrically undulated portions of the Appalachian chain.

Very similar are the topographical features of the synclinal mountain-tracts of the Jura and other chains, where the same essential conditions of structure and stratification prevail, the anticlinal and synclinal flexures approximately parallel, and the region consisting of strata alternately soft and resisting to the action of the waters which eroded their outcrops. Indeed, it is impossible to imagine how, with identical combinations of the physical circumstances, there should not have been produced an identical topographical structure, and a close resemblance in all the phases of scenery which result from the forms of the ridges, hills, and valleys. Through the agency of the same few simple controlling conditions of undulation in the crust, and of composition in its materials, arises that wonderful and impressive likeness in scenery and aspect which so frequently exists between distantly remote tracts of the earth's surface—not merely narrow local spots, but whole mountain-zones. Hence it is that an American, familiar with the Appalachian ridges and deep trough-like valleys, and the wild gorges and defiles which connect these, is impressed, on traversing the Jura chain, everywhere with a something in its yet more picturesque passes and perspectives which, with the freshness of another land in the mere outward accessories of sky and verdure, and the garb of a peculiar life, has yet the deeper charm of a profound and pervading likeness to the scenery of his home in all its bolder features. These two mountain systems are creations upon one and the same essential plan, modelled both upon one archetype idea, through the secondary agency of one class and combination of forces. The same gigantic billowy undulations have ridged the crust in both regions, and similar stupendous currents of repeatedly-uplifted waters have cut down the crests of the great crust-waves in exactly the same manner, ploughed lengthwise the softer strata into similar groups of narrow valleys, and breached crosswise the newly-made ridges into the same deep notches and winding cliff-confined gaps and rocky passes. No marvel, then, that Nature should wear the same face to her beholder in lands so similarly created ; for her features, in all such instances, in their strongest and their softest and most subtle lines, are but the external expressions of the same class of forces or pressures with which her great pulse has throbbed in her moods of highest energy or of gentlest life. The tone of the landscape is the same, however unlike its outward incidentals, and it is the same by reason of the identity in the movements and actions which the now sleeping upheaved strata indicate or express.

Returning from this digression to descriptive topics connected with features of structure in the undulated and eroded region of the Appalachians, and of other similarly-formed mountain-chains, I may remark, as a generalisation upon the details thus far submitted, that all the conditions of orographic* structure here illustrated, all the physiognomy of the surface produced by the denudation of anticlinals and synclinals composed of alternating hard and soft strata, and by that of their combinations which give rise to the beautiful reflexed or zigzag windings of certain mountain-crests and their included valleys, and to the meandering outcrops which so perplex and disappoint the miners of our Appalachian anthracite coal-seams, and, in fine, all the possible modes in which the strata are presented at the surface, are referable to simple geometrical laws, and are deducible from the few conditions of the intersection of the approximately level, yet everywhere unevenly acting and locally-irregular knife edge of the cutting waters, with the unequally exposed strata in the variously-presented anticlinal and synclinal waves of the crust.

In the forms of those solid crust-undulations, their symmetrical and unsymmetrical arching and troughing, in their various dislocations, in their parallelism, and in their want of it, their rising and expanding singly and in groups, and their sinking, contracting, and expiring, and in their modes of coalescing and of fading out one into another, reside the conditions under which the strata they contain have been exposed to or protected from the great *planing* mechanism of the horizontally-working waters.

But the horizontally-moving waters have by no means acted on the corrugated and dislocated surfaces over which they have so often rushed in broad diffused sheets, or in contracted and grooving currents, with an absolute horizontality. The waved and ridged floor which they washed, at times transiently, at times with a somewhat prolonged presence,

* *Orographic*, appertaining to mountain-chains.

must, even if we can assume it to have been itself in repose, which the very hypothesis of the upheaval of the crust-undulations prohibits, have deflected the waters into many local eddies and internal streams, variously oblique to the general plane of their motion, as up the slopes of the newly-born mountain-waves, through the freshly-opened breaches in their cracking summits, and down their opposite flanks with an accelerating speed, that has ploughed them everywhere with ravines, or gashed them with deep and yawning gulfs. Thus, while the internal crust-motions exposed the strata unequally to the erosive power of the displaced waters, the waters in their turn, worked unequally on the strata upturned to meet their fury, and therefore *all* the resulting conditions of the two combined agencies concurring to beautiful and harmonious results, while so apparently antagonistic, are only to be understood when we can consider and analyse the direct and reflected operations of both the influence of the moving inundation, to cut down and modify in shape the barriers lifted to oppose it, and the influence of the thus newly-created local features to modify and divert the localised currents of the retreating sea, for the production of those last-impressed finer and gentler features with which the waters, working with more than a sculptor's power and delicacy of touch, have shaped the face of the lands they have chiselled, softened, and adorned.

The annexed sections represent the general structure of the *simple synclinal ridges* and spurs, the first (Fig. 743) where the fold is compressed, as in Egg Hill, in Centre County, and the second (Fig. 744) where it is more open, as in the W. part of the Nittany Mountain. The anthracite coal-basins end in spurs of both of these forms dependent on the closeness of the flexure.

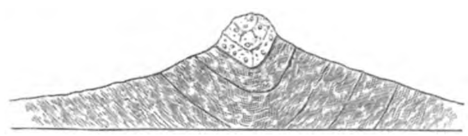


Fig. 743.—Simple Synclinal Ridge, flexure close.

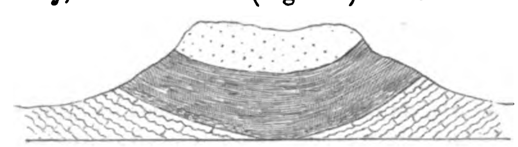


Fig. 744.—Simple Synclinal Ridge, flexure open.

The sections (Figs. 745 and 746) here attached display two very usual forms of the *triple synclinal ridges*; the first being that of a synclinal ridge or knob enclosed between two monoclinal ridges, the very usual structure of the belts enclosing the terminal spurs of the anthracite basins; the second, the prevailing condition in the synclinal Levant ridges in their fullest development as they occur S.W. of the Susquehanna, but visible on a lesser scale in various other formations.

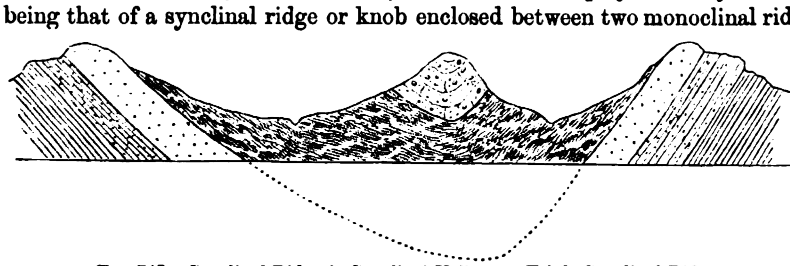


Fig. 745.—Synclinal Ridge in Synclinal Valley, or Triple Synclinal Ridge.

Perhaps the most common form of the *simple synclinal basins* is that which is here annexed (Fig. 747.) It will represent such slender trough-shaped ridges as Parnell's, where the Levant series presents, as it does in its extreme S.E. outcrop, but one crest-forming sandstone; or it gives us the general structure very fairly of the more slender and tapering anthracite coal-basins, such as the Dauphin, Wiconisco, and Shamokin basins in their W. parts, if we overlook the absence of the lesser benches marking the outcrops of the coal-beds. Of course, these synclinals are of various features, the dip and hardness of the strata modifying these greatly.

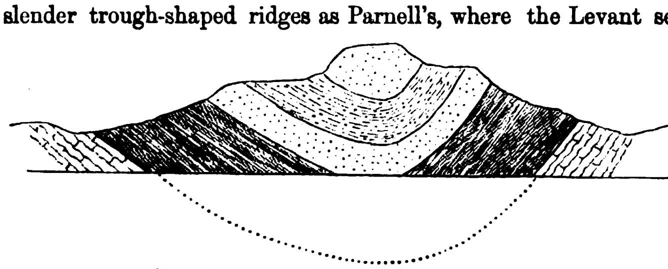


Fig. 746.—Triple Synclinal Ridge or Terrace.

A very usual form of the *complex synclinal valleys* is shown in the accompanying cut (Fig. 749). This topography is characteristic of the belts which contain the anthracite Coal-measures, viewing the basins from the valleys or plains external to their outside ridges. The double mountain-barrier due to the superior hardness of the Vespertine conglomerate and sandstone and Seral conglomerate at the base of the Coal-measures, and relative feeble cohesion of the Umbral red shale between them, is an interesting feature not common in other coal-formations. Of course, the lesser geological and terraced features of structure and composition—namely, undulations of the softer coal-beds—are all omitted.

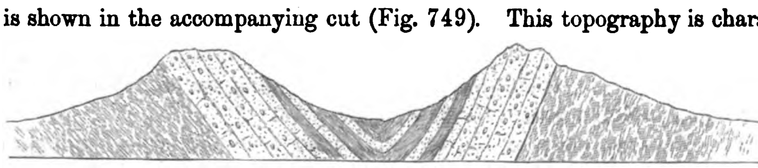


Fig. 747.—Simple Synclinal Valley or Basin.

A modification of this structure (Fig. 748) distinguishes all the synclinal basins of the Levant sandstones of the counties S.W. of the Susquehanna, where these synclinals are wide and deep enough to receive in the middle of the trough a portion of the lower soft slates of the Surgent series. As in the case of the two forms of our triple synclinal ridges, we have, in the comparison of the two varieties of this more complex type of our synclinals, essential differences, dependent on the relations of hardness of the two sets of strata involved in them. Indeed, all the synclinals, simple and complex ridges, and simple and complex basins or valleys, have, where the materials of the ridges are the Levant sandstones, very different orographic features from those which the same types exhibit where the mountain-rocks are the carboniferous conglomerates. And the main reason of this contrast is the very marked dissimilarity in thickness and relative softness of the interposed less cohering argillaceous stratum in each case. In the Levant series, the middle red sandstone, though softer than the over and under lying silicious grey sandstones, is yet of too firm a texture to be deeply eroded; and from this cause, and its being only a few hundred feet in thickness, it forms high monoclinal shoulders, and not deep monoclinal valleys like those in the softer and far thicker carboniferous red shales of the coal-basins.

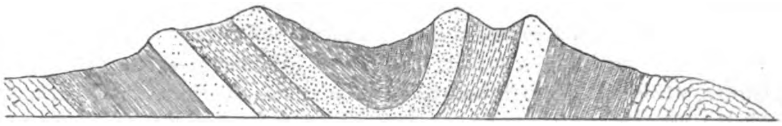


FIG. 748.—Complex Synclinal Mountain.

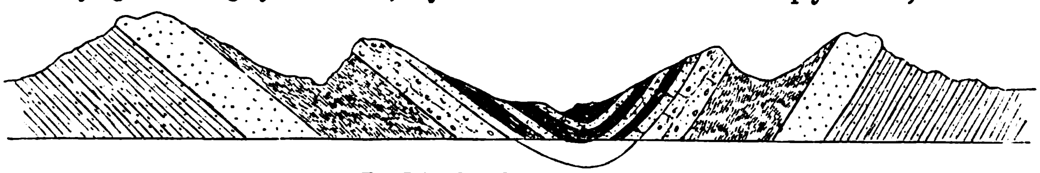


FIG. 749.—Complex Synclinal Valley.

FEATURES OF LOCAL EROSION.

Having now treated of the various general phases of mountain structure arising from the erosion of monoclinal, anticlinal, and synclinal belts of alternately resisting and yielding strata, without regard to any features but those due to the action of diffused horizontally-moving waters, it is needful to consider, in the next place, those lesser and more local modifications of these broader elements of the scenery which have resulted from the reaction upon the waters by particular forms of the surface previously established, such as deflecting barriers, steep mountain-slopes, high terraces pouring off the floods, and deep transverse gorges dividing the broad flowing sheets into special and more sharply-trenching currents, which have worked in unusual directions, and at levels oftentimes different from those of the larger-moving tide, which in its earlier stages shaped the mountain-summits and their higher valleys. These minor aspects of erosion, insignificant though they are for the most part in the crests, and on the flanks of the ridges in the general scale of the landscape, are, however, of prominent interest to the geological observer, and of the highest local importance to the mining engineer and the practical explorer of the outcrops of the denuded strata.

They include nearly all the cases of local deflections of outcrops from their more prevailing or normal directions, as produced by horizontal denudation; and therefore it is proper in this, which is intended as both a scientific and a practical chapter on the external physical structure of the Appalachian chain, to elucidate the various modes in which the lines of the strata at the surface are caused to curve, elbow, and wind, and to ascend and descend the hill-slopes in obedience to simple general geometric laws of the intersection of surfaces.

These features of local erosion may be grouped under the following forms:—

Local Erosion of Horizontal Strata.	Local Erosion of Anticlinal Strata.
„ „ of Monoclinal Strata.	„ „ of Synclinal Strata.

V.—LOCAL EROSION OF HORIZONTAL STRATA.

a. *Where the Strata have the same general degree of Hardness.*

1. *Confluent Ravines intersecting a level Plain.*—This feature, the result of a diffused erosion of a nearly horizontal plain or plateau, is variously modified by special conditions in the floor which the waters washed, and by the manner of movement of the fluid,—influences to be considered in a future page. But the essential character in every case is that of a confluence of narrow and shallow channels of drainage to constitute larger ones, and the union of these again to form others still wider and deeper. As the channels or valleys deepen in the direction of the currents which passed through them, we find that their borders are more and more intersected by short lateral and relatively steep ravines, and that each large valley receives other streams of compound drainage like itself, longer and larger, as this is farther from its own sources. The whole is like a flattened plant, built up of continually subdividing branches; and as in the instance of the plant, each tribe exhibits a different species of symmetry in its plan of ramification, each eroded district has its own law of convergence of its channels, and its distinctive resulting topography dependent on a delicate yet positive equilibrium in every case between the excavating fluid and its resisting bed. This ramified erosion is of course most symmetrical where the surface is almost absolutely level, and the strata are very homogeneous; but as

these conditions rarely prevail over great areas, it is chiefly on the small scale that we meet with it in its highest degrees of regularity. No tract of Pennsylvania has the structure essential to it on an extended scale, for nowhere are both the general surface and the stratification sufficiently horizontal to have allowed the denuding waters to produce it. No mere section of a surface thus eroded can convey a true conception of its complicated features; but in the next chapter, where allusion will be made to the modes of origin of the various types of scenery, a sketch of this variety will be presented.

2. *Rounded conical Hills, and insulated Saucer-shaped Hollows.*—This structure of the surface occurs in its fullest perfection where the general surface of the country is level, and the superficial deposit in which these features reside is imperfectly stratified, or composed of very incoherent materials, as is the case with the great *drift*-deposit which covers all the Northern temperate and arctic latitudes of both the Asiatic-European, and North American continents. I do not know that this type of surface is indeed anywhere to be met with exterior to the limits of the drift-formation, of the mode of origin of which it is eminently expressive. It seems to have resulted from an excessive turbulence in the waters which transported the drift, and to be connected more immediately with whirling and eddying currents. These have scooped the stratum of loose fragmentary material which the general sheet of moving water strewed along its floor into the dish-like depressions which are so common, and have in other places piled the pebbly mass into the conical mounds so characteristic of it. Elsewhere, again, the currents have left mounds of various shapes outstanding from the plain they belong to, by their gyratory and deflected erosion. In proof of this view of the origin of the features described, we invariably find them most to abound in the seaboard belts of the drift where the general continental inundation, after just depositing the drift below the then existing sea-level, was thrown into the wildest eddyings by surging to and fro above it. Hence the prevalence of the phenomena on the S. coasts of Long Island and of Massachusetts. The same feature of conical hills and hollows is met with very abundantly in the plains among the mountains of New England under precisely those conditions of the topography which admit of the same explanation, that of conflicting waters thrown into strong whirling and eddying currents.

It is only in Northern Pennsylvania that the drift stratum exists at all within the State, and even there it is so near its extreme S. margin, and is consequently so thinly spread over the upland tracts, that the features referred to are by no means as marked as they are in New England and New York. Wherever the deposit possesses an ample thickness, as in the river-valleys and the plains enclosed by the S. barriers which arrested the drift, it exhibits these phenomena; but the features which especially characterise it are the so-called *river terraces*, a description of which has been already given.

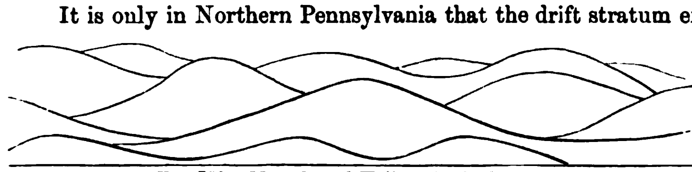


FIG. 750.—Mounds and Hollows in the Drift.

b. *Where the Strata alternate in Hardness.*

Of course, the contours impressed on any tract of the surface by the erosion of an approximately horizontal set of strata of various degrees of hardness and softness, will vary with every variation in these relationships of firmness in the rocks. Where the contrasts are great in this respect, the convex contours or projecting outcrops of the harder beds will be prominent and steep, and the concave slopes of the softer masses very gentle and retreating; where, on the other hand, these differences in cohesiveness are small, the convex and concave lines of the ground are much less distinct. An extreme disparity in the texture of the beds produces an alternation of precipitous escarpments and horizontal terraces, whereas a trivial inequality shows itself in no more than a slightly-undulated continuous slope.

1. *Terraced Hills, or Camp-like Eminences on Surfaces of the Plateaus and Plains.*—This feature occurs perhaps most conspicuously in the bituminous coal-fields, where the coal-beds and their attendant shales and marls are very soft, and in strong contrast, as respects erosibility, with the harder sandstones and grits. Where the terraces or gentle slopes are easily traceable through a district, they constitute a very admirable guide to the outcrops of the various coal-beds and layers of soft fire-clays; in fact, in a country which has its geology thus defined in its topography—and this is the case with all the United States coal-fields not buried under drift—the position and range of all the members of the formation may be learned and recorded by the geological explorer, if aided by minute and accurate maps, and by sufficient time, with the greatest facility.

If the strata are almost perfectly horizontal, the benches on the hills curve in and out with each recess and projection, precisely like so many water-lines at different levels, as if the sea had subsided successively from one station of erosion to another. They will follow pretty accurately the contour-lines of a map of the district. Where the hills are insulated, and either conical or irregular in shape, these terraces pass entirely round their upper insulated portions.

If the strata, on the other hand, are not absolutely horizontal, the benches marking the margins of the coals and other soft layers will enclose the upper parts of the hills, not symmetrically, but somewhat obliquely. Where there is more than a trivial inclination, we have the conditions of local erosion of monoclinal belts, to be considered in another section.

The annexed cut shows a body of nearly horizontal coal strata thus benched in the slopes and hills.—(Fig. 751.)

2. *Terraced Ravines and confluent Valleys.*—Where a plain or plateau composed of alternately harder and softer strata is cut off by terminating escarpments, or intersected by long and deep valleys, these escarpments, and the borders of these valleys, are trenched by steep ravines, or by steep branching or confluent shorter valleys, which are more or less terraced. If the strata are quite level, these terraces maintain the same levels on the opposite sides of the ravines, otherwise they change their heights on the hill-sides just in proportion to the space of the ravines and the degree of inclination in the strata. A careful measurement of their elements, and a little calculation, will enable the explorer at all times to discover the position of any stratum across a ravine or valley, and he will usually be much assisted in the identification, by recognising in their new positions the corresponding slopes and benches of the previously familiar beds. It is thus that he traces the coal-seams from hill to hill across the ravines and wider river-valleys which they skip.—(Fig. 752.)

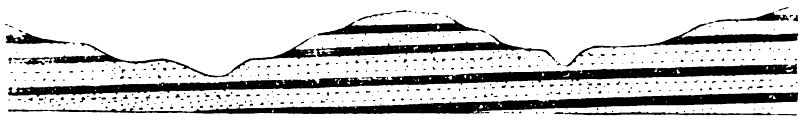


FIG. 751.—Benched Outcrop of Coal Strata.

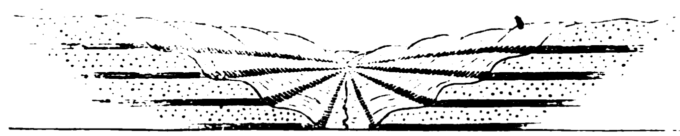


FIG. 752.—Terraced Hill-sides.

VI.—LOCAL EROSION OF MONOCLINAL STRATA.

a. *Transverse Ravines.*

These are of various forms, and variously deflect the outcrops of the strata obediently to their forms, and to the parts of the monoclinal belts which they intersect. They may cross the strata either perpendicularly or obliquely, and they may be either level ravines or sloping ones; and again, they may slope *with* the dip, or *against* it. Furthermore, the strata intersected may outcrop to form a plain, a ridge, or a valley. The more important varieties of these transverse trenches seem to be the following:—

1. *Level Ravines perpendicular to the Strike.*—The ravines or trenches of this class are apt to have the slopes of their two sides alike, and when this is the case, they cause precisely the same amount of deflection in the outcrops of the dipping strata. This deflection, of course, is greatest, or it amounts to a right angle in the dipward direction when the borders of the ravine are perpendicular; or, in other words, when it is a precipitous gorge. And it is less and less just in proportion as the slopes are more and more gentle. By deflection is here meant the angular change of direction from the *horizontal* line of outcrop of a stratum. The rapidity, then, with which *oblique* lines of outcrop will descend along the sloping side of a ravine or valley will depend on these two elements—the inclination of the stratum itself, and the inclination of the hill-side which intersects it; and the angle of descent along this hill-side can be readily calculated for every case by the methods of descriptive geometry which define the laws of the intersections of planes.

To render this effect of deflection of the line of horizontal outcrop clearer by an example, let us imagine a stratum—a bed of coal, if we choose—to dip, say to the S., at an angle of 45°; and let us suppose that the ravine crossing it, and running N. and S., has its E. bank sloping W., also at 45° to the horizon; then the line of intersection of these two planes, or that which marks the deflected course of the outcrop descending to the bed of the valley, will dip exactly towards the S.W. If, again, the sloping side of the valley be not of one constant declivity, but a curvilinear surface, then the line of outcrop will itself become a curve by the intersection of this curved surface with the plane one of the stratum. But further still, it frequently arises in nature that both the dip plane of the stratum and the sloping side of the ravine are curving planes, either both concave surfaces or both convex, or the stratum convex and the surface concave; or, fourthly, the surface convex, and the stratum concave. From all of which it will be seen that the actual lines of sloping outcrop in these, the simplest of ravines, being the intersections of such variously-related surfaces, are by no means easily traced, or even theoretically calculated. The best practical sagacity of the mining engineer and geologist is constantly put in requisition to trace the outcrops of the coal-seams, and other strata of our anthracite basins, turned from their normal courses into the most subtle curves by this intersection of curving planes of erósion with curving planes of dip.

I here append (Fig. 753) a simple topographical sketch—a bird's-eye view—of this variety of ravine, showing the deflections it produces.

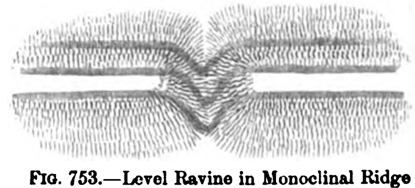


FIG. 753.—Level Ravine in Monoclinal Ridge viewed from above, perpendicular to Strike.

2. *Level Ravines oblique to the Strike.*—In these ravines and valleys the two opposite sides have seldom the same inclination to the horizon; and the reason for this is obvious. In those which intersect the strata at right angles, the waters have pressed with nearly equal force on both borders of the excavated trench; but in those which cut the beds obliquely, the erosive impulse has been strongest on that side towards which

the ravine has been deflected, leading to more under-cutting, and therefore to a greater steepness than on the opposite border. Of course, the amount of deflection of the strata from their lines of horizontal outcrop is greatest on that side of the ravine which adjoins the acute angle formed between the general course of the ravine in the dipward direction and the line of strike; and from two causes—the acuteness of this angle, and the superior steepness of this side of the valley.

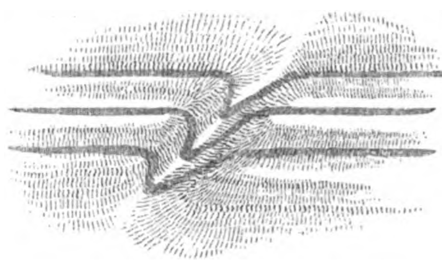


FIG. 754.—Level Ravine in Monoclinal Ridge, oblique to Strike.

A simple topographical sketch (Fig. 754) will sufficiently explain this obvious feature, which the unpractised explorer of strata may, nevertheless, easily overlook.

3. *Sloping Ravines descending in the Direction of the Dip.*—These are either perpendicular in direction to the strike, or more or less oblique—that is to say, they either coincide with the line of dip, or with some line between this and that of the strike. Those which intersect the sides of monoclinal ridges are very generally perpendicular to the strike; this being the natural course of the waters breaking over the crests of such ridges, and dashing down their flanks. It will suffice to consider this class.

These ravines on the dipward or face side of monoclinal belts are of two varieties—very different in their effects in deflecting the outcrops of the strata which they cut—according as they have a steeper or a gentler inclination than the strata themselves.

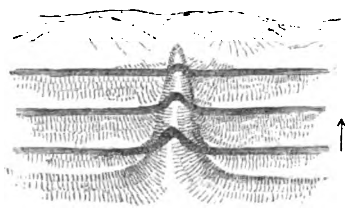


FIG. 755.—Sloping Ravine, descending in the direction of the dip more rapidly than the strata do, towards the observer.

1*st Variety.*—Where the ravines descend more *rapidly* in the direction of the dip than the strata do.

In monoclinal belts cut by such ravines there are necessarily two outcrops, a lower and an upper, of the strata intersected, and the *lower* outcrops are deflected *up-hill*—the steepness of the sides of the ravine and the degree of inclination of the rocks controlling the extent or degree of the deflection. In such deflections along the sides of the ravine, the edges of the beds converge as they ascend the ravine and unite in succession at different heights in its sloping bed to form **V**-shaped outcrops, the points of the **V** being directed upwards. This effect of sloping ravines on sloping strata has been neatly illustrated by Sopwith in his models of some of the simpler conditions of the denudation of imbedded rocks.

Instances of it are very numerous on both a large and a small scale in the deeply-channelled districts of our Western bituminous coal-fields, where the rocks have a low degree of dip.

The feature is here indicated in a topographical sketch (Fig. 755.)

2*d Variety.*—Where the ravines descend more *gently* in the direction of the dip than the strata do. This condition of things is connected with but one outcrop to each stratum—a natural consequence of the greater steepness of the dip over that of the intersecting valleys. The ravines not cutting through the upper beds as in the other case, but only trenching their higher outcropping margins, these edges are deflected in this instance *down-hill,* precisely in the manner in which they are along the sides of level ravines intersecting similar monoclinal belts. The **V**'s therefore point with the dip. The degree of the deflection of the horizontal outcrop of each stratum will depend on the steepness of the sides of the trench, and its more or less trumpet-like expansion; and the extent of the deflection, or the length of the **V** to its point at its water-level in the bed of the ravine, will mainly depend on the less or greater difference between the slope of the ravine and the dip of the stratum; the less this difference, the more tapering and longer, of course, the convergence of the two edges of each intersected bed.

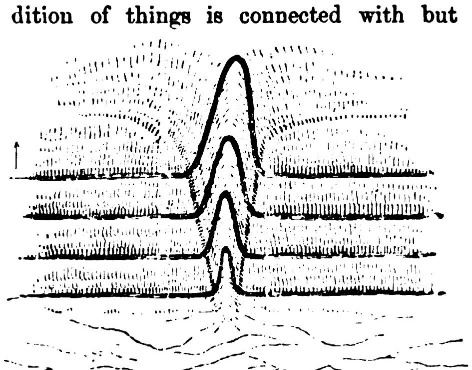


FIG. 756.—Sloping Ravine descending in the direction of the dip, more gently than the Strata do, towards the observer.

A sketch of this very common variety of ravine with its outcrops is here given (Fig. 756.) It is the form characteristic of the ridges and hill-sides of all the anthracite basins where the angle of dip is considerable.

3. *Sloping Ravines cutting Terraces on the dipward side of a Ridge.*—Wherever a ravine or trench descending a ridge on either its dipward or cropward side, crosses longitudinal terraces, these terraces are eroded more or less in their longitudinal direction, and are deflected downward into the ravine; and so likewise are the outcrops of the harder strata which divide the terraces or support them. Each such ravine is therefore composed of a main stem and lateral curving branches, and may in many cases be likened to a great expanded plant lying on the slope of the hill. Upon the relative breadth of the terraces denuded, and on other elements, such as the dip, will depend the magnitude, and indeed the shape, of these side-ravines, swinging in graceful sweeps from the benches in which they originate, down into the beds of the main transverse trenches. Where the mountain-side chances to include strata

of very unequal hardness in few alternations, and the soft ones are thick, and susceptible of deep erosion, and the whole erosion is on a great scale, the ravines being sharp and profound, these lateral enlargements at each terrace become great oval valleys. Usually the ravine originates or has its head in a terrace in one of these dish-like slanting excavations in the flank of the ridge. The sloping, shallow, oval valley gathering the drainage from a wide circumference on the mountain platform, pours it inward and forward, and finally through a contraction of the ravine, or, it may be, a mere narrow notch in the hard formation which forms the lower front edge of the terrace. Such are the *cirques* of the Alps, the great feeders of the upper glaciers. A topographical sketch (Fig. 757) is here annexed of this character of mountain ravine or valley.

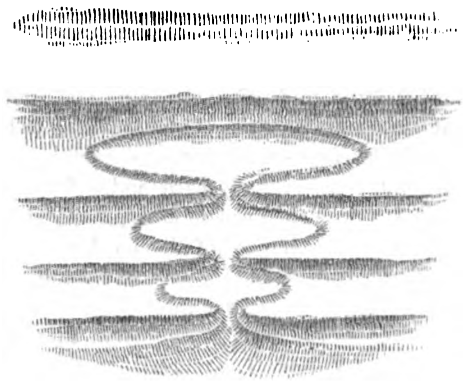


FIG. 757.—Sloping Ravines cutting Terraces on the dipward side of a Ridge.

4. *Sloping Ravines descending against the Dip*, or on the back or outcrop sides of monoclinal ridges :—

1*st Variety : descending Ridges but little terraced.*—Ravines in this position, widening, of course, as they descend, in a direction opposite to that of the dip of the strata trenched, deflect their outcropping edges in V-shaped descending lines in the direction of the dip, or from the mouth of the ravine. The lowest strata exposed endwise in the sides of such a ravine are those nearest its mouth, while the lowest thus accessible from the bed of a trench on the *face side* of a monoclinal ridge, where the dip exceeds the angle of descent of the channel, are those farthest in from the mouth.

The ravines of the class now considered are extremely numerous on the external sides of the monoclinal mountain ridges which enclose the anthracite coal-basins of Pennsylvania, and indeed belong, as an invariable feature, to all our monoclinal ridges composed of a hard crest-rock, and of some softer underlying formation.

2*d Variety : descending from Terraces on the Outcrop Side of a Ridge or Plateau.*—This is an interesting species of the ravine descending the cropward side of a raised monoclinal belt of strata. If the terrace which it crosses is wider, and supported by a very hard resisting stratum, we are sure to find the terrace itself denuded longitudinally on each side of the ravine in a long descending tributary trench or valley. Where only one such wide terrace occurs on the side of the ridge, the ravine usually has its source or head in a wide oval expansion, embracing these side-ravines as wings. These are common on the cropward slopes of the ridges of the Levant sandstones, the ravines breaching the lower or Levant grey sandstone, and commencing in the terraces of the softer Levant red sandstone above it. They present themselves on a grand scale in the Alps, where they terminate upward in one variety of the cirques or oval dish-like hollows high on the slopes of those mountains at the sources of their glaciers. Other cirques, it has been shown, are similar expansions of the upper parts of the class of ravines belonging to the dipward flanks of those mountains.

A topographical diagram (Fig. 758) is here offered of the usual form of the ravines of this species in our Levant sandstone ridges.

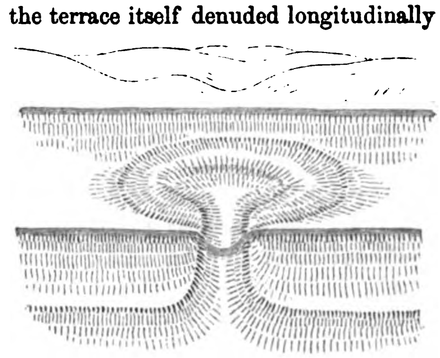


FIG. 758.—Sloping Ravine descending against the Dip.

5. *Gaps or Ravines intersecting Monoclinal Ridges.*—A ravine of this class, in its fullest development, is a deep sloping notch or cleft cutting the ridge to a low level, often to its base.

In many instances the breach is confined to the narrow crest or summit of the ridge, and prolongs itself down each flank in a sloping valley. Such are many of our mountain-passes in the Appalachians. Where it is a thorough cut, penetrating to the mountain's base, and giving passage, as it then so usually does, to some bold stream or river, it is called in Pennsylvania a *Water Gap* and when it indents only the upper part of the ridge, it is termed a *Wind Gap.*

These gaps present sundry minor characteristics, dependent chiefly on the special conditions of hardness and softness in the strata, on their relative dimensions and their steepness of dip, and on the direction of the ravine through the ridge, whether perpendicularly or obliquely transverse.

Where the strata of the mountain possess a very steep dip, the point of greatest contraction in the bed of the gap is only a small distance from the centre toward the dipward side; where, on the other hand, their inclination is comparatively gentle, the narrowest spot is much nearer the end in the same direction. This arises simply from the descent to that side of the hard resisting rocky rib which forms the crest. From this point of least width, where the hard middle rock reaches the water-level, the bed of the pass usually expands trumpet-like in both directions. Upward, the notch dilates, sometimes by steep straight slopes, sometimes by concave ones, and not unfrequently its profile, on one or both sides, is a convex curve.

Many of these gaps in the Appalachian chain are much encumbered on their slopes with fallen blocks dislodged from the edges of the harder rocks ascending towards the summits. Some of these great slanting floors of angular fragments of sandstone—familiarly termed by the people *Stone Slides*—extend from the bottoms of the gaps midway, or even much higher, towards the crests.

The two most obviously distinct varieties of the monoclinal notches are—

1st Variety: Simple Monoclinal Gaps in single-crested ridges, where the slopes into the ravine are approximately straight and regular, but steeper or flatter, as the case may be. The essentials to this structure are merely a middle hard stratum, and softer overlying and underlying masses. The most contracted part of the pass is where the hard stratum comes down to the water-level, or bed of the notch (Fig. 759).

2d Variety.—Complex or curved monoclinal gaps of steeper or gentler slopes, intersecting ridges composed of five or more alternately hard and soft strata, two at least of which are hard, and form two or more crests. The ravines of this class are oftentimes not straight, but wind with a double or even still more complex flexure through their ridges. If one of the hard formations has exceeded the other considerably in resisting strength, it very frequently throws itself nearly across the opening of the pass in a low ridge or spur breached at one end to the water-level of the other parts of the notch. Such is the feature of the gap in the Mahoning Mountain at Mauch Chunk, and from like causes that of the notch in the Little Shamokin Mountain, at the passage of the Shamokin Creek. At page 29 of Volume I. a pictorial view of the first of these scenes is presented.

Of course, all the conditions of deflection of the outcrops of the strata of the ridge will exhibit themselves in one of these deep thorough gaps, which we encounter in any other level transverse ravine; every outcrop will be turned

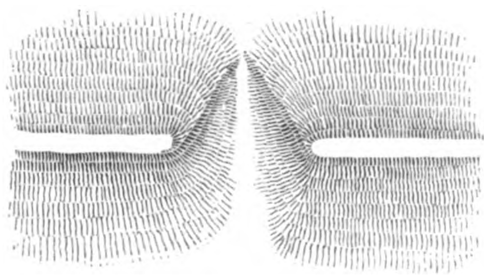


Fig. 759.—Gap in a Simple Monoclinal Ridge.

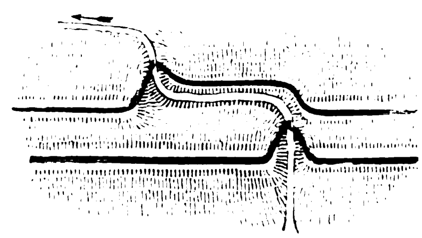


Fig. 760.—Gaps intersecting Monoclinal Ridges.

from its level line, both on the back and on the dipward side of the ridge, and carried down at a more or less abrupt plunge as the dip of the bed and the slope of the ravines may affect it until it reaches the bed or water level of the notch; there it will cross on a level, in a line parallel to its position on the mountain-side, and reascend the opposite side of the gap in a corresponding sweep, until it resumes its first position on the ridge.

It seems unnecessary to dwell further on the special features of the ravines of this class, as these have all been considered under previous heads. It remains simply to present a topographical picture (Fig. 760) of one of these gaps.

b. *Longitudinal Ravines in Monoclinal Belts.*

Local longitudinal ravines or trenches in monoclinal strata occur wherever the eroded tract is elevated above the general plain of the country, or intersected by deep transverse channels of drainage.

Thus they abound in the ends of ridges, but especially in the vicinity of the thorough gaps which cleave the monoclinal mountains. Their magnitude and depth will be found to depend mainly on the relative width and softness of the less cohering beds in which they lie, and on the height of the outcrops which they trench above the beds of the valleys and notches into which they descend. They are straightest and sharpest, and most nearly in the line of the strike, where the raised belt of alternately hard and soft strata has a perpendicular or very steep dip. Such is the posture of the rocks in some of the monoclinal ridges of the Levant sandstones between the Susquehanna and the Potomac on the N. sides of the great anticlinal limestone valleys—for example, in the Muncy or Bald Eagle Mountain; and there these longitudinal ravines in the softer Levant middle red argillaceous sandstone and shale are very conspicuous features in the orography. Where, on the other hand, the inclination of the beds is less, the ravines do not descend in the line of the strike, nor are they straight, but they follow the dip, as we have already seen, and usually with more or less of curvature. In both cases they are but prolongations of the horizontal terraces or benches which are deflected partially, but not exactly, in the direction of the dip, from the circumstance that while the erosion has followed in great part the softer strata, the eroding descending currents have at the same time been rushing somewhat more directly down the hill-side in obedience to their gravity. In the instances where the inequality in the firmness of the materials is at all excessive, and where both kinds are comparatively thick, conditions which prevail in the lower Coal-measures, or Seral conglomerate group, around the margin of the Shamokin coal-basin, these obliquely-descending ravined benches are separated by more or less boldly-jutting craggy ribs or ledges of the alternating harder rocks, which in the gaps of the Shamokin basin are massive, tightly cemented, coarse silicious conglomerates and sandstones, the interposed softer measures being coal shales and thick beds of friable anthracite.

It is not needful to dwell longer on the features of local longitudinal erosion, since all the essential phenomena have been described either in this paragraph, or in preceding ones treating of the modifications of the "transverse ravines."

I pass next to the various kinds of local denudations incident to anticlinal belts, especially to anticlinal ridges.

VII.—ANTICLINAL RIDGES.

a. *Local Erosion of Anticlinal Ridges.*

The first case is that of erosion upon the descending ends of anticlinal ridges, curving the denuded outcrops of the strata in a convex sweep round the subsiding spur, from one flank to the opposite across the axis, and presenting the terminating inflected lesser crests and terraces in sharper relief than where these are prolonged on the sides of the ridges. In the phraseology of the anthracite region, such outcrops, or the gangways below them, are said to "wind round the ends of the saddles."

b. *Gaps or Notches in Anticlinal Ridges.*

The features of these gaps are variously modified by the nature of the strata transversely breached and eroded.

1. One variety is where the whole of the interior rocks of the anticlinal, from the axis at the water-level to the crest of the ridge, are hard and cohering, and the flanking strata comparatively soft. In this case the gap is usually a simple trough-like cut (Fig. 761), with more or less steep plane-slopes, and is narrowest in the middle of the gorge, widening in trumpet-shape towards either base of the ridge or mountain.

2. Another variety is where there are three sets of rocks in the ridge, the arching crest ones hard, and the inner lower set at the axis soft for some height above the water-level, or bed of the notch. In such case the form of the gap is more complex, being dilated and circular or oval in the centre, and contracted towards either outlet by the obliquely-descending converging ribs of the hard formation. Where the hard rocks span, as they often do, the whole anticlinal, in one unbroken majestic arch of craggy precipices receding in a semicircular sweep at the crown of the curve, and approaching closely as they plunge on either flank to the level of the pass, we have the simplest, but perhaps the most picturesque, of all the forms of oval anticlinal valleys. These are the cluses of the Jura chain of Switzerland, where, composed of massively-bedded limestones, the finest of cliff-forming strata, and being of grand height and span, they constitute some of the most impressively wild and beautiful natural amphitheatres which water has anywhere carved out of rocks. In some instances the great rocky arches on each side of the pass are nearly a mile in span, their precipitous walls are many hundred, or even a thousand, feet in vertical height; and from the base of their beetling crags descends on each side a very long and concave mountain-slope or *talus* of huge fallen fragments of

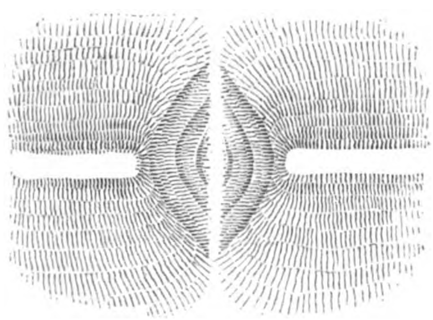


FIG. 761.—Gap in an Anticlinal Ridge of hard strata.

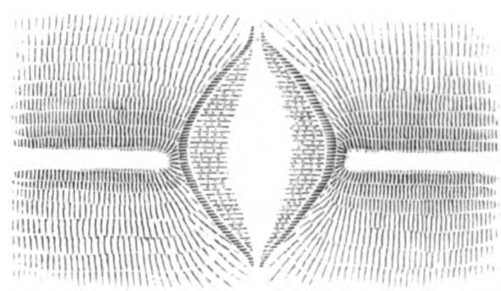


FIG. 762.—Gap or Oval Pass in an Anticlinal Ridge, the lower stratum being soft.

the cliffs, bringing down the ruggedness of the upper scene to the very margin of a smooth verdant meadow or oval plain. This stretches the length of the notch, is watered by a sparkling river, enlivened by a furnace or a mill, and is shut entirely in from the outer country by the jaws of a contracted rocky gorge or mere gateway, leading into and out of it between towering, jagged, perpendicular crags, which, in several cases in the Jura, are crowned by the fitly-placed ruins of some old baronial castle, or "feudal robber's nest."

In the anticlinal passes of the Appalachians, this species of mountain-gap, in virtue of the greater hardness of all the strata, and the absence of limestones as the mountain-rocks, is decidedly more tame in its scenery, but its constituent features are essentially the same as those I have here described as characterising the passes of the Jura Mountains.

The accompanying cut (Fig. 762) is an illustration of one of these oval passes.

A modification of this form of notch in an anticlinal ridge, somewhat frequent in the Appalachian chain, especially between the Susquehanna and the Potomac, is where the breach is not entirely through the mountain, but is confined to one side of it; or, what is the same thing, to one abutment only of the arch. The oval valley called Mosquito Cove, in Bald Eagle Mountain, and even the longer and more open elliptical Nippenose Valley in the same ridge, may be cited as cases of this sort. They are deep oval hollows scooped in a broad flattish anticlinal mountain by whirling waters, which cut for each but a single outlet through the N. or steepest, thinnest, and most shattered abutment of the arch. Many others of this type occur as high oval valleys on the backs of the anticlinals, not only in both the Appalachian and the Jura, but in other undulated chains. One instance is the small mountain-valley midway along the crest, in the highest part of Tuscarora Mountain, on the line of Perry and Juniata counties, Pennsylvania. A lateral gap of this sort, breaching only one of the monoclinal barriers or wings of an oval valley of denudations, is called in Switzerland a *ruz*, in contradistinction to a *cluse*, which is a double gap cutting the whole arch. Between these anticlinal gaps and the elongated oval anticlinal denuded valleys, there occur examples of every intermediate form, from such as are mere narrow transverse notches at their bases, through the transverse oval, and the nearly circular kettles, to the longitudinally oval valleys in all proportions; and it will be found, on generalising our survey of them and their attendant features, that they are all the offsprings of the same conditions of structure and the same physical forces—namely, a transverse rupturing by one or several cracks of the most distended parts of the anticlinals, and the passage of tremendous sheets of water across the ridges, and through the weakened and ruptured lines where the currents were necessarily deflected into irresistible vast excavating whirlpools by the obliquity of the barriers encountered or produced.

Thus it has come to pass that so many of the more largely excavated oval anticlinal valleys in the Appalachian chain between the Susquehanna and the Potomac, both the narrow high ones of the anticlinal ridges and the deeper wider ones exposing the soft Matinal and Auroral rocks, are provided with more than one pass through or into them. In fact, the number of the notches which give access to them is very various, from a single gap or depression confined to one, and that always the weaker side, to a thorough-cut or gap in both barriers—the normal type of these mountain-passes—or to even several monoclinal openings, sometimes all of them in one, sometimes in both barriers. An inspection of the topography of the mountain-chain S.W. of the Susquehanna will show these notches, both in the anticlinal ridges and in their monoclinal branches, in a great variety of combinations and situations.

It will be seen how very frequently a notch occurs—especially the single ones, or those in the monoclinal ridges—*near the ends* of the longer class of denuded anticlinal valleys. The causes of this prevalence of position, and of the still more marked excess in the number of these openings in the Northern over those in the Southern monoclinal barriers of the valleys, will appear distinctly in a future chapter, where an attempt will be made to discuss fully the mode of action of the forces which undulated the strata, and which, in arching the anticlinals, rifted them transversely, and most frequently and severely, towards their subsiding ends.

3. Another and distinct variety among the passes or gaps in anticlinal ridges occurs where there are FOUR or more separate sets of alternately soft and hard cohering strata, the lowest rising at the axis above the bed of the notch or valley in an interior arch, while the third rock, or upper hard one, still spans the breadth and height of the ridge, only covered low on its flanks by the softer and uppermost of the series. In this case, when the denudation is regular, as it is apt to be where the anticlinal wave is broad and of gentle curvature at the summit, we have an oval or circular deep cavity in the mountain, with a narrow outlet at one or both sides, just as in the variety previously described; but some of the internal features of the gorge are essentially different. The same semicircular steep cliffs or concave slopes sweep round each side of the amphitheatre, ascending and receding from each other with the climbing of the arch, and redescending and approaching again with its curving downward to its opposite abutment; but the *talus*, or long concave inclined plane of blocks and fragmentary rubbish dislodged from this steep upper encircling wall or slope, and covering the underlying softer stratum on each side of the notch, does not here descend to the bed of the valley, but only to the top of the second or interior arch formed by the hardness of the lower rocks, exposed in all the gaps of this class, in the centre or axis of the anticlinal. In mountain-passes of this form, the grand enlarged amphitheatre of the higher harder rocks is lifted, as it were, on the back of an inner and lower anticlinal ridge, which is itself transversely breached or notched to the water-level in the centre. This inner anticlinal arch repeats, often on a scale almost as large, the shape of the variety of anticlinal pass first specified (Var. b. 1), which is that of a simple trough-like cut, narrowest in the very middle of the pass, and expanding trumpet-like towards either side; but exterior to it, yet still within the mountain, is the great encircling oval or circular valley, with its talus on each side, and its double semicircle of cliffs or high craggy slopes lifted on the back of this interior saddle, and filling the span of the mountain. The ground-plan of the bed of an anticlinal pass of this description—where the denudation is synclinal, as in some cases it is, especially in the Jura—bears no remote resemblance to two lancets united at their shanks, or to the double-leaved paddle of an Esquimaux's canoe. Expanding from the middle of the hard inner arch in both directions, and widest at each side of it, where the easily-denuded softer strata descend both ways to the level of the gorge, the two ends are pinched again by the descent and convergence of the great outer upper arch of hard material, until, in some examples, they become merely the narrowest defiles, allowing space for only a stream and a roadway before they dilate into the open plains outside.

Instances of this class of notches in anticlinal ridges are not unfrequent in the Appalachian chain. On a relatively reduced scale they are even common in the anthracite coal-fields of the Schuylkill and Shamokin basins; but for the best-defined, most symmetrical, and most picturesque examples of this class, we must again turn to the limestone ridges of the Jura (Fig. 763).

4. There yet remains to be described a fourth modification of the anticlinal pass, or oval mountain-notch; it is where the anticlinal ridge or mountain embraces five sets of strata of different susceptibility to erosion—the *first* or lowest, the *third*, and the *fifth* being shales, or slates, or other soft rocks; and the *second* and *fourth*, sandstones or other firmly-cemented and resisting formations (Fig. 764). A gap or valley of this description differs from those of the type last defined only in its innermost or central features, which in that variety were those of a simple trough-like cut or notch in a central anticlinal arch of hard materials, but which in this are the features of the second type of anticlinal gaps or simple cluses repeated over again, but enclosed within a larger higher cluse or amphitheatre, saddling and embracing the inner and lower one as a larger conical oval funnel with a vertical upper rim would embrace and rest above a smaller similar funnel inserted in its truncated conical apex.

It is a circular or oval pot, opening upwards into a wider and higher circular or oval pot, whose bottom and upper lip or rim are neither of them flat or in a horizontal plane, but saddle-shaped or arching. Of course this form, where it is on a large and perfect scale, presents all the elements of scenery of the preceding or third variety of anticlinal pass in the upper and enclosing amphitheatre, with all the features characteristic of the second, in its lower interior or central cluse or valley; for this latter, when fully developed, as it is in one or two very striking instances in the Jura chain, has on either hand the encircling arching precipice, the long steep concave talus, or rugged "stone slide," and the smooth more or less dilated oval plain between in the bed of the notch. In the Appalachian anticlinals, between the Susquehanna and Potomac, and in Virginia, nearly all the examples of this concentric or double denudation, on the large scale, are cases of elongated anticlinal valleys of erosion of the type described (page 933) as of the group **b**, second

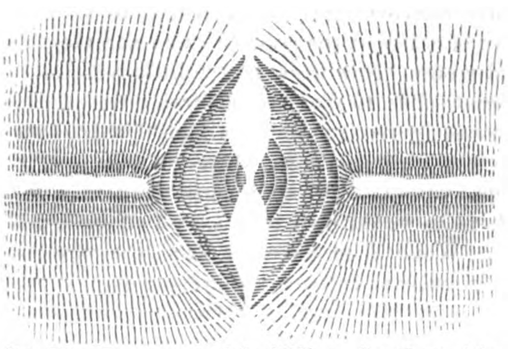


FIG. 763.—Gap in an Anticlinal Ridge. Complex variety arising from two hard and two soft strata.

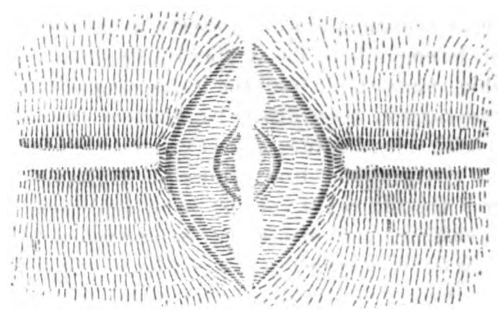


FIG. 764.—Gap in Anticlinal Ridge. Complex variety, produced by three soft and two hard strata.

variety, so common where the erosion has reached the Matinal and Auroral rocks. Even where these valleys have a gap at each side in their monoclinal barriers, as in the instance of Friend's Cove, in Bedford County, Pennsylvania, their great length in the direction of the anticlinal axis removes them from the class of mountain notches or passes, or that even of expanded cluses, though in reality they retain all the features of these at their two withdrawn extremities, and are to be viewed in a structural light as but extreme extensions of the same elements, and the products of the combined action of the same whirling erosive currents and crust-undulations—differing in degree, but not in kind—in the extent of the denudation along the anticlinals, and not differing in the nature of the actions, or the relations of the strata acted on.

The features of the four several varieties of anticlinal notches or circular gaps, above described, are much modified in their pictorial characters, first by the qualities of the strata eroded, and, secondly, by the style of the anticlinal curve. Their impressiveness or their tameness, as the case may be, will be found to be mainly connected with the greater or less difference of liability in the strata to erosion or degradation by water; but the degree of such susceptibility, let it be observed, is not dependent solely on differences of cohesion between the particles, or on mere hardness or softness, but is materially influenced by other conditions also, especially the absence or presence of joints and cleavage fissures, affording a grasp to the waters, and by the less or greater destructibility of the fragments torn away from the outcropping beds. Each region, therefore, however similar to others it may be in its undulated structure—in the form that is, of its anticlinal and synclinal flexures—will yet possess some distinctive characters in its scenery, some peculiar tone in its landscapes, even where these contain the elements of construction, traceable on examination to one or more of those circumstances that control the cutting and removing power of the waters in their action on the rocks. And these minor features of expression, so apt, from their very uniquetness, to lead away the attention of the student of nature from the generic identity of the scenes with others of their class, are especially distinctive in the gorges and passes of mountains, where whatever is individual to the region, in the composition of its rocky framework, will, from the stronger conflict there of the eroding and resisting agents, be all the more conspicuously developed. Therefore it is that the points of dissimilarity in the rocky constitution of the Appalachian and the Jura chains, so analogous in their general dynamic structure, or features of undulation and rupture, are most obvious precisely in these mountain gaps and clefts, whose construction, class for class, is so identical in the two mountain-regions. In the Appalachians the different features melt more into each other, and the whole scenery is tamer than in the Jura, because, in the former, the sandstones and slates of the ridges, and limestones and shales of the valleys, are less contrasted with each other in facility of erosion, than are the massive limestones of the latter chain, with its soft marls and clays. Besides, all the rocks of the Swiss chain are softer, and far more easily trenched and denuded, than the corresponding ones of the American range. Indeed, the valley-rocks of the Appalachians are altogether as difficult of erosion as are the mountain or harder masses of the Jura; they are, in fact, of the same chemical nature—limestones chiefly in both instances. If any difference does prevail, it is a superior cohesion on the side of these Appalachian softest formations over those Jurassic hardest ones, the one group being tough sub-crystalline limestones and indurated sandy slates of the Palæozoic age, the other compact and earthy limestones of the Oolitic period. This difference of resisting strength in the strata has evidently been of itself a most influential source of the sharper and deeper excavation of the Jura anticlinals, and of the consequently higher picturesqueness of its scenery. But it has been stated above that the topographical features of a denuded mountain-zone depend no less on the character or style of its anticlinal or synclinal flexures, than upon any or all of these relations of the strata to each other affecting their relative vulnerability to erosion. To a brief review of the influence of this element of form in the crust-undulations I will now proceed.

It is obvious that the shape or style of the anticlinal curve or sweep of the arch which the strata span, must of necessity modify more or less the form and structure of the notches and oval valleys carved in the ridges by the waters. These convex flexures possess, as we have seen, very various styles of curvature, some of them being nearly symmetrical waves, while others are of unequal incurvation on their opposite sides, having, like the billows which roll in over a constantly-shoaling bottom, a steep and a gentle slope. They have, moreover, further differences, in the comparative flatness of the summits of some waves, and the more angular turn of others at the crest or axis; and these important variations belong to both the symmetrical and the unsymmetrical groups. Now it needs very little reflection upon the forms which must result from the intersections of differently-curved solids, to show us that each series of circular and oval excavations in these dissimilar kinds of anticlinals, will necessarily receive from the special characters of their curves special subordinate modifications of their distinctive structural features. Thus, where the wave is both symmetrical and gently rounded on its back or crest, the hollow scooped within it will approximate to a regular oval or a circle; and the rim of the pot-like valley, and those of all the terraces within it, if it be excavated in an alternating group of soft and hard strata, will be approximately horizontal. While if, on the other hand, the wave is sharply crested, the denudation will result, not in two evenly-curved semicircular or half-oval valleys, one on either side of the transverse notch, but in two ascending and sharply-pointed valleys, making together a rhombic or diamond-shaped hollow, longest generally in the direction of the ridge's crest. And again, where, with either of these conditions of flatness or sharpness of summit, the anticlinal wave is unsymmetrical, or bends more or less steeply down on one side than on the other, there is a proportionate departure in the gorge or valley from either the regular circular, the oval or the rhombic figure, the side carved out of the more inclined flank of the wave being invariably and necessarily straighter and lower than the opposite. Such is the very general character of the hollows, whether mere notches or long denuded valleys in the anticlinals of the Appalachians; and such, indeed, will be found to be the very prevailing type of the pot-like gaps and valleys eroded in anticlinal ridges in all mountain-chains.

We have in the deep water-gap of the Juniata River, at its passage through Jack's Mountain, in Huntingdon County, Pennsylvania, a very good example of extensive denudation on the crest of a rather sharp and unsymmetrical anticlinal mountain-ridge. Here the S.E. flank of the wave is gentle, dipping about 30°, while the N.W. is at its abutment almost perpendicular. The crest is, moreover, abruptly turned. The denuding waters working upon this form, through the four successive great strata which build up the mountain, two great hard and massive sandstones, and two softer argillaceous strata, a hard one at the summit, and a soft one at the base in the axis of the ridge, have carved a great anticlinal hollow or rude cluse of the *double type*, in which each lateral recess or cove is pointed or angular in the direction of the crest, rather than rounded or oval, as it would have been had the curvature of the top of the wave been more flat or gently rounded. Being of the fourth variety of anticlinal notches described by me, where there are two hard formations, each to send down its two projecting spurs to the water-level, to make, when perfect, an outer and an inner amphitheatre, and in this case the arch being deeply cut to its abutments, and the inclinations of its sides being steep, there stand out four separate ridges, coming down from either mountain end toward the middle of the pass at the river.

VIII.—FEATURES OF LOCAL EROSION OF SYNCLINAL BELTS.

a. *Erosion of the Ends of Synclinal Ridges.*

The extremities of elevated synclinal belts, both ridges and narrow plateaus, are very generally much denuded, especially where the materials forming the base of the ridge are comparatively soft, as in that case their deeper excavation, by causing a superior steepness in the sides and ends of the ridges, has given to the final local currents a greater perpendicular pressure in rushing down the slopes.

Two features of erosion of the ends of such ridges are worthy of attention.

1. *Truncations of the Ends of Synclinal Ridges.*—A very common mode of ending of the ridges of synclinal structure, is by an abrupt cutting-off or truncation of their tapering points. Where the denudation of the mountainous zone has been very equable or chiefly longitudinal, the raised synclinal belts taper gradually off, both in width and height; but wherever strong transverse currents have swept across the terminations of such ridges, these are sure to be thus abruptly, and more or less squarely, cut away. In these cases the synclinal ridge, usually forming the ending of a mountain trough or basin by the coalescing of two monoclinal barriers, rises above the general level of the monoclinal crests into a high terminal knob, the crest-line of which suddenly gives place to a steep transverse slope, cutting the mountain from this high point to its base. Such is the feature in which the Terrace Mountain, near Huntingdon, ends against the valley of the Juniata; and very similar is the termination of the Mahanoy Mountain, on the Susquehanna. Many other examples could be adduced from the Appalachian chain in Pennsylvania and Virginia.

This abrupt arrest of the synclinal ridges is in striking contrast with the beautifully gentle and gradual tapering and curving down of the expiring anticlinal crests; and the erosive conditions productive of the two phases were not less dissimilar. In the instance of the synclinal belts, the waters were enabled, by the rising out above the general water-level of the country of the lower softer strata, to exert against them, just where least protected by the overlying firmer rocks, their fullest amount of excavating power, resulting in a tendency to steep cutting, or even, in certain cases, to absolute under-cutting, from the everywhere inward dip of the strata. But in the opposite case of the anticlinal belts, the harder crest-rocks of the ridges buried and sheltered the softer subjacent beds, and the more effectually the nearer the terminations of the crests, thereby giving the form of the anticlinal wave itself a constantly-increasing influence, and the erosive force of the water a diminishing one, to the end of the axis. It is only necessary to compare the profiles or crest-curves of the synclinal and anticlinal mountains exhibited in the illustrations in this work, to perceive at a glance the remarkable and characteristic differences of outline left by the waters on the ends of the two kinds of waves.

2. *Longitudinal Erosion of the Ends of Synclinal Ridges.*—In many instances the ends of synclinal ridges, and narrow synclinal table-lands, are much gashed by sharp sloping ravines. Where the crest is narrow, and formed by steeply-dipping hard strata, these trenches, scooped in the ends and flanks of such ridges, often radiate downward quite regularly in a sort of fan-like arrangement from the terminating knob. A feature of this kind presents itself in the terminal spur of the Shamokin coal-basin, seen from the W., from near the mouth of Zerbe's Run. It belongs likewise to the similar spur prolonged from the Wiconisco Coal-basin, and is more or less characteristic, indeed, of the synclinal spurs of the anthracite coal-basins generally. Where, on the contrary, the ridge is not a mere narrow crest, but a slender table-land, truncated, as such generally are, at its extremity, these ravines are confined more strictly to the end, and are more truly longitudinal in their direction. The narrow plateaus composed of the lower Levant sandstone, supporting the Levant red shale, which form so striking a feature in the great anticlinal limestone valleys of Centre and Mifflin counties, especially those in Kishacoquillas Valley, present us with fine instances of this terminal ravining, showing most unequivocally how the last localised currents of the retreating waters rushed lengthwise down the newly-truncated ends of these picturesque terraces. A glance at the picture of the Kishacoquillas ridges (Vol. I., page 476), looking E., will make this feature understood.

b. *Erosion of the Ends of Synclinal Valleys.*

The characteristic or usual form of the head or end of a synclinal trough—such as the termination of one of our wider coal-basins, the Shamokin, for example—is that of a symmetrically spoon-shaped valley, ascending at its very extremity to the level of the bounding converging crests. But this regular structure is departed from in many instances, by the presence of features of local erosion, which it is proper here to advert to. These, as in the denudations of synclinal ridges, are both transverse and longitudinal.

1. *Transverse Denudation of the Ends of Basins.*—A not unfrequent termination of a synclinal valley, bounded by narrow ridges of steeply-dipping rocks, is by an open longitudinal pass, caused by the entire obliteration of the synclinal ridge or knob which ordinarily forms the end of the basin. The destruction of the prow of the boat, and the scooping out of its contents at the broken end, must be imputed, in most instances, primarily to some great transverse fault or fissure weakening what is usually, from the close convergence or union of the monoclinal bounding ridges, the most massive and strongest portion of its rim. The cutting away of the dislocated end by a powerful transverse current would be necessarily followed or accompanied by the sweeping of a lesser longitudinally deflected lower current through the jaws of the newly-opened gap. Thus it has arisen that such truncated ends of basins are often deeply eroded, and their contained softer rocks—a body of coal-measures, perhaps—are almost completely washed away from the bed of the trough. There are several cases of this kind on a small scale in the anthracite region, and some approximations to it among the larger basins. The extremity of a synclinal valley, so nipped off and scoured out, resembles much in form as, at the time of its final shaping, it did in actual function, a great *spout*, like that of a pitcher. The W. end of the Wyoming Basin at Shickshinny is an example of both transverse and longitudinal erosion.

2. *Longitudinal Erosion of the Ends of Basins.*—It has just been shown that a longitudinal erosion, or scooping out of the end of a basin, accompanies generally its truncation; but it also occurs in cases where the termination is not abruptly nipped off, but only extensively worn down, as happens when the protecting harder rocks have been of

insufficient firmness to withstand the longitudinal currents through the valley. This feature prevails usually where the synclinal dips are rather gentle.

3. *Features of diffused Erosion of the Ends of Synclinal Valleys or Basins.*—The precise form in which a basin composed of hard strata, supporting and embracing softer ones, usually terminates, depends mainly, of course, on the two elements of the dip of the beds, and their relative degrees of resistance to erosion. In the simplest case of three formations—a-middle-hard one, forming the rim of the synclinal valley, and a soft lower, and another soft upper, deposit—all carved into a mountain-trough standing above the general level of the outer country, the more gentle the dip, and broader the synclinal wave, the rounder or blunter will be the outline of the spoon-shaped end of the basin; and the steeper the dip, the more slender. The anthracite fields of Pennsylvania present numerous examples of both of these types, and display this connection perfectly. Where the strata are synclinal at a moderate angle, and their dips on the two sides of the axis nearly equal, and where the synclinal line or keel of the boat rises perceptibly or considerably, we will find, if there exist no terminal nor lateral gap, the nearest approach to perfect symmetry in the beautiful concave oval sloping valley. While such is the contour of the interior of the basin carved out of the soft upper strata, that of its rim or barrier is a curve-line surface of not less grace. The converging monoclinal bounding ridges, gradually expanding and rising in their crests as they swing into each other to enclose the head of the trough, form, where they blend together to fill the synclinal space, a most noble and peculiar style of mountain swell; an elevated, ample, egg-shaped knob or summit, higher considerably than the monoclinal crests, keeping high watch over the comely valley which it terminates, and a still loftier outlook over the external country. Gracefully and largely convex in all its upper lines, this terminal synclinal hill, when regular, invariably sends downward into the exterior plain or valley in which it rests, a series of concave flattening and dilating slopes, which are no less marked for their ampleness of sweep than the exquisite delicacy of their flowing curvature. The highest and widest point of one of these knobs is generally not in the centre of its length, but nearer the basin which it closes up—precisely as the broadest and highest point of an egg resting on its side is between its centre and its blunt end. Summits of this description, of course, send off a declining spur, more or less pointed, in the direction of the synclinal line, and branch into the two other directions of the monoclinal crests, out of the union of which they arise.

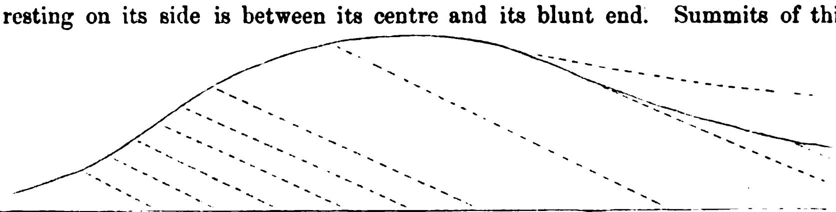


FIG. 765.--Profile of a Synclinal Knob.

The profile or longitudinal contour-line here presented (Fig. 765), will serve to aid the conceptions of the reader, not familiar by close observation with the structure of the Appalachian chain. It is a perpendicular section of the end of a basin along the synclinal axis.

c. *Local Erosion of Synclinal Belts, connected with transverse Gaps or Notches.*

Just as in the instances of the breaching of anticlinal ridges by transverse notches, give rise, under different phases of uplift of the anticlinal wave, to different forms in the gaps, so in the several types of synclinal ridges and raised basins we meet with special modifications in the notches by which they likewise are cleft. As the gorges of this class are, however, of more rare occurrence than the anticlinal ones, except perhaps the simplest varieties, and as there is less that is remarkable in their structure demanding detailed description, it will suffice merely to indicate their several features, and the conditions under which they have been produced.

1. *Simple Gaps in Synclinal Ridges or narrow Plateaus, composed of a harder Series of Strata reposing on a softer.*—Though all of the notches of this simplest and most common class have a generic form and one definite character, the proportions and scenery of their parts are modified by the special circumstances of the dip of the rocks, and their relative thickness and degrees of cohesion. The essential features of such gaps are these. The opposing ends of the ridge, which form the slopes or jaws of the notch, approach nearest in the middle of the gap, and round rapidly off at their sides both *outward* and *upward*—the converse of the converging arching of the harder belts in the cluses or oval gaps of simple anticlinal ridges. This style of pass is to be met with occasionally in the narrow plateau basins of the anthracite country of Pennsylvania; that of Rattling Run in Broad Mountain, opposite Ashland, is nearly of this structure. No sketchis needed to assist the conception of this simple structure.

2. *Complex Gaps in Synclinal Ridges or narrow Plateaus.*—These exist in their most completely developed character where the ridge or plateau in which the notch occurs, consists of at least four alternately hard and soft groups of strata. If the dips or basining be considerable, and the cleft, from the easy erosion of the softer strata, be sharp and steep, this form of gorge which under these conditions is invested with its boldest and most distinctive outlines, displays often a scenery of much picturesqueness. The extent of its pictorial beauty and impressiveness will depend largely, however, on the character of the harder strata intersected in the pass, as on their being vertically jointed and craggy, like many varieties of limestone. If they are susceptible only of rounded surfaces of erosion, like many of our tough, cohering, silicious conglomerates and sandstones, the defile will be deficient in wild grandeur.

The complex notches here referred to, cutting several alternating hard and soft strata, are a species of terraced gaps, in which all the formations exposed endwise by the denudation display inverted arches or trough-like curves, the hard ones in precipitous walls or steep slopes, as the nature of the materials determines; the softer beds, in gentler, talus-covered, slanting platforms of various inclinations. Conversely to the *receding rising* sweep of the upright arches of harder strata in the anticlinal gaps, the same harder beds, in these inverted arches, *approach, descending*, towards the centres of the synclinal notches. Hence, a structure of cliffs and slopes, or of steep slopes and terraces, ascending and retreating outward in both directions from the middle of the pass, until they curve round and upward into the flanks of the ridge or plateau.

A configuration of this sort is not at all rare, on a small scale, in the ravines which cross the narrow subordinate basins in the Great Pottsville and Shamokin coal-fields. In our Pennsylvanian mountain-ridges and plateaus it is of less frequent occurrence.

This structural feature is to be seen, but not in the conditions of proximity, to constitute a mountain pass or gap in the relations of the two opposing terraced spurs of the N. side of Kishacoquillas Valley, as the map and the sketches in this work will show. A clear conception of the essential features of these complex synclinal gorges will be found to be serviceable in tracing coal-beds and other strata from the flanks of synclinal ridges into and out of the gaps which intersect them.

d. *Lateral Gaps and Breaches in Synclinal Basins.*

It has been already shown that the Anticlinal Valleys of the Appalachian and other mountain chains, and the anticlinal notches likewise, both frequently exhibit gaps on one side only, or in but one abutment of the arch. Such of these gaps as appertain to the larger valleys have been described as monoclinal notches, while those connected with the shorter transverse excavations have been alluded to under their Swiss name of *Ruzes*. Among the local erosions of anticlinals, corresponding monoclinal notches and ruzes occur in the barriers of the synclinal valleys, and in some of the more local erosions in synclinal *cirques*. No further special allusion need here be made to the more ordinary variety in the central portions of the monoclinal rims of the mountain-basins, for they are but one series of the common monoclinal gaps; but a more distinct mention is demanded of the class of these breaches situated very near the ends of the synclinal valleys, high on one or other of the bows of the boat. To these latter, and to the lateral notches in the oval synclinal cirques, we shall therefore now give our attention, and to those of the cirques first.

1. *Lateral Gaps in small oval Synclinal Valleys.*—From the prevalence of a very elongated form in the crust-undulations of the Appalachian chain, the instances of short oval synclinal valleys or kettles wholly enclosed, or breached only on one side, are comparatively rare. The chief part of those met with are cirques, denuded in an upper series of soft rocks by virtue of a local whirling and scooping action of waters, deriving their power from a crack or breach in one rim or barrier of a long narrow mountain-trough, and not in a short one. Yet a few, under the latter circumstances, do occur, and these are the equivalents, under a converse structure, of the anticlinal single-notched cluses, or monoclinal gaps entering anticlinal cirques. Their essential conditions are, a short oval basin or synclinal mountain-valley, composed necessarily of three sets of strata—a soft external lower series; a hard middle one, forming the oval mountain-lip of the basin; and a soft upper series enclosed within the valley, denuded through the opening in one side of the rim. A considerable degree of synclinal dip on one side at least of the axis is indispensable to the existence of this structure.

Of examples, we may mention McCauley's Mountain, a small insulated elevated coal-basin near the Catawissa Valley. It is a short mountain-trough of shallow anthracite Coal-measures, girt by a rim of the hard Seral conglomerate, breached by a steep ravine or crest-gap on the S. side, where the dip is steep, and the barrier was consequently comparatively weak against the general rush of waters from the N.W.—(See the Geological Map of the Anthracite Region.)

Another instance which may be cited as belonging, perhaps, most appropriately to this class, is that of Scrub Ridge in Bedford County, a somewhat elongated mountain-basin of the soft *Umbral red shales*, supported within an oval barrier of hard *Vespertine sandstones*. Here likewise, in accordance with the prevailing law of the Appalachian flexures, the S.E. barrier of the synclinal trough is steeply dipping, and is therefore the side which has been breached; the breach in this case being not in the middle, but near the S. end.—(See the General Geological Map.)

2. *Lateral Gaps or Breaches at the Ends of Basins.*—These have been already alluded to as occurring high on the bow of the boat. Their very general position in the Appalachian chain, as seen extensively in the anthracite basins, is on the S.E. or S. side; and this from an obvious cause, before adverted to—the superior steepness, and consequent slenderness, of the outcropping strata of that margin. Frequently these outlets in the lower more denuded S.E. wall of the basin are not narrow deep gaps or gorges, but rather long and ragged breaches, such as that in the E. end of the Pottsville basin in Sharp Mountain above Mauch Chunk, and that in the S.W. end of the Shamokin basin, three miles from Trevorton. Such breaches are usually worn down to the high level of the bed of the valley within; but as the enclosing mountain-rim is under this proximity to the head of the basin, invariably of small altitude above this bed, the notch-like depth and form do not exist. On the exterior of the mountain, the breach prolongs itself down the flank in a wide and more or less deep ravine or great gulley, the channel through which the currents making the break in the barrier above carved their course to the plains outside, carrying with them the wreck of much of the coal strata of the head of the basin, and that of all the other rocks that lay across their track.

In other instances, confined mountain-notches do occur, near the extreme ends of the basins, especially in the anthracite region; but these, as in the examples of the Bear Gap of the Wiconisco Basin, the W. gap of the Mahanoy basin, and others, exist only where the monoclinal barrier breached is strong and massive from the moderate degree of dip of its hard strata. In all such cases there is likewise an external gulley or great trench, prolonged from the bottom of the gap down the slope of the mountain, and even in these instances of deeper notching, the height of this ravine, or difference of level between the coal-basin above and the outside valley of Umbral red shale below, amounts to several hundred feet.

There is yet another modification of this lateral outlet at the ends of synclinal valleys, examples of which are to be recognised in the anthracite country. It is where there is no positive notch or even shallow breach in the barrier of the basin; but a rising up of the bed of the spoon-shaped trough to the very level of the mountain-rim, or a general cutting-down of this to meet the high point of the basin, and on the outside of the mountain a trench or ravine through the hard barrier-rocks, and its lower softer strata down to the external plain. Such is the E. termination of the South Mahanoy Coal-basin, where the ravine of Pine Creek is exterior to the rim of conglomerate, and does not notch it; and such very nearly at least is the outlet at the extreme Western end of the Mahanoy basin, where the old Minersville Road passes across the tip of the basin, and over, but not through, the S. boundary of conglomerate, and down the exterior mountain-side through a long ravine, to a lower level of several hundred feet.

e. *Modifications of the Phenomena of General and Local Erosion dependent on wide Deviations from Symmetry of Structure in the Anticlinals and Synclinals.*

In the preceding sections of this chapter on the General and Local Features of Erosion, those phenomena chiefly were considered which have resulted from the erosion of symmetrical anticlinal and synclinal belts, or such as possess approximately equal degrees of incurvation, or of dip on both sides of the axes. It was felt that it might complicate too much the description of structures not very easily made intelligible in words, even with the most methodical treatment, to give the abnormal or deviating forms dependent on unsymmetrical flexures, under the same heads with the regular ones, and that the reader's conceptions would be clearer if they were reviewed in a group by themselves.

A strictly exact symmetry in the external features of the ridges and valleys, and their gaps, can of course nowhere prevail even under the most equable conditions of the erosive action; for, as already shown, the undulations of the strata, which determine the whole character of the orography, are very seldom, if ever, themselves equilateral—that is, symmetrical on both sides of their axes, or highest and lowest points. But a moderate amount of inequality in the two slopes of the waves is not usually productive of any very striking topographical irregularities; and as such moderate inequality is really the normal condition of the flexures of the crust, the features arising therefrom have been viewed as regular. Only the wider departures, therefore, from this merely approximate equilateral symmetry of the denuded anticlinals and synclinals, connected with the more extreme aberrations from an equal balancing of the dips, will be here submitted to review. For the sake of greater precision, the normal or only moderately inequilateral flexures may be here defined as those in which the average difference in the two sets of dips does not exceed 25° or 30°, as when the one side dips 30° or 40°, and the other 60° or 70°, and all waves of more unequal slopes than this are to be viewed as inequilateral, and productive of unsymmetry in the topography. These may be classed and described as follows, restricting our attention to the more characteristic only of the abnormal forms immediately connected with anticlinal and synclinal belts and their accidents. After the foregoing full account given of the various regular forms of external structure, these less symmetrical ones need not detain us long.

IX.—DENUDATION OF UNSYMMETRICAL ANTICLINAL BELTS.

The anticlinal tracts, in which there prevails a marked inequality between the dips of the opposite slopes of the waves, may, as respects their features of denudation, be conveniently divided into such as are simple ridges, and such as are elevated belts, denuded along their axes into valleys.

a. *Erosion of Unsymmetrical Anticlinal Ridges.*

All anticlinal ridges, whether curving or straight, will be seen, where there is a very obvious excess of steepness in the dips of one flank over those of the other, to have the anticlinal line or axis not in the orographic crest, but more or less down on the steep slope of the side of greatest dip, and therefore often not far in horizontal distance from that base. And they may be observed, furthermore, in their declining ends, still carrying the axis more to one side than to the other, to taper down much more sharply on the steep than on the gentle side, and to end somewhat like the point of a well-shaped quill, where the plumelets on one border of the shaft, being long, come bluntly round to the tip, while the shorter opposite ones prolong their curving margin more acutely out. In a horizontal section, therefore, of such a ridge, or the rudely horizontal one made by denuding waters, the curve of the outcrops, winding round the end from one side to the opposite, resembles much in its difference of rapidity of flexure on the two sides of the axis the curve of the dip itself, or the form of the wave as cut by a vertical section. A nice estimation of the form or style of this curve of outcrop in its two wings or branches is of essential importance to the field-geologist in tracing strata round the ends of anticlinals.

Where the dip on the steeper side of the axis is perpendicular or inverted, the abruptness of the turn in the outcrops at the axis is extreme—so rapid, indeed, as frequently to elude attention, the more especially as it very often happens in such cases, that the axis where this turn occurs below the crest of the hill is covered and concealed by a load of fallen fragments from above. It is not an uncommon occurrence in the Appalachians, where the strata on one side of the axis are much inverted, to find this saddle-line at the actual foot, or very low on the flank of the mountain, the whole of the upper rocks of the inverted set being in these cases crushed and cut away by denudation to the level of the adjoining valley.

b. *Erosion of Unsymmetrical Anticlinal Valleys.*

As in the instance of many anticlinal ridges, the axis or line of sharpest bend in many anticlinals denuded centrally into valleys is not a medial line, but lies near to one side. This condition prevails where one leg of the crust-wave is very steep compared with the other, or the whole flexure approaches to a fold with inversion. In all such cases where the strata of the steep-dipping side are perpendicular or overturned, the harder rocks of this border of the valley are greatly more eroded or cut down than the flatter-dipping ones of the other flank of the wave. So much is this the condition, indeed, in many of the larger Appalachian anticlinals, that while one of the monoclinal bounding ridges is a bold and massive mountain, the other, with the vertically-dipping beds, is often a low, narrow, and broken crest, or a mere line of ragged hills. Where such is the structure, the anticlinal valley is of course not a regular oval one, but it is straightest on the side of the steep dips; and the bed of the valley slopes, moreover, laterally towards that margin, from its being the side of easiest and deepest erosion. It also generally happens that the barrier on this side, even where it is not greatly broken down, is pierced by one or several gaps, while that of the opposite flank, massive and resisting, from the wide breasts of hard strata above the general valley-level in consequence of gentler dips, is entire, or without a notch. This state of matters exists in Milliken's Cove, an anticlinal valley of Will's Mountain, near Bedford.—(See Plate at p. 368, Vol. I.)

The annexed Sketch, accidentally omitted at page 774 of this volume, where it appropriately belongs, represents a naked surface of Umbral Red Sandstone, smoothed and striated by the passage of the boulder-drift. The locality is the Wilkesbarre and Easton turnpike road, nearly S. of the "Prospect Rock," on the S. side of the Wyoming Valley. It exhibits a condition of the abraded rocky floor of the drift, abundantly met with throughout this mountain-slope, and which is very instructive. The rocky surfaces dip from 30° to 45° towards the N.W., or into the Wyoming Valley, and the boulder-scratches point obliquely *up* the mountain-slope towards the S.W., as indicated in the cut, as if produced by fragmentary debris violently propelled against the sloping mountain-wall of the valley from the N., and deflected up and along the inclined plane out of the normal course of the unimpeded drift, which, except where thus obstructed and turned aside, observes a somewhat constant direction of S.S.E. The extensive prevalence throughout Northern Pennsylvania, and many other districts, of this *ascending* striation, effectually refutes, I conceive, the Glacial Theory of Drift, as far, at least, as it essays to explain the phenomena in North America. The striæ if caused by Glaciers should *descend* this mountain, which is as high as any within a wide space around it.

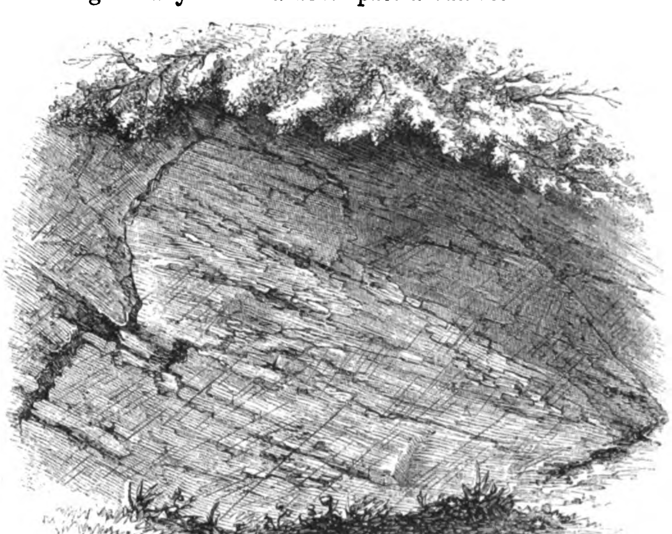


FIG. 766.—Diluvial Scratches deflected up and along the South Mountain barrier of the Wyoming Valley.

COAL-FIELDS OF THE UNITED STATES AND BRITISH PROVINCES.

HAVING presented in Books VIII. and IX. as accurate and complete a description of the Coal-fields of Pennsylvania as the information derived from the Geological Survey of the State admits, I propose, before quitting the subject of Coal, to furnish the reader with a general account of all the other great Coal-fields of the United States and the British Provinces, that the relative wealth and industrial capacity of our own favoured region may be correctly estimated in comparison with those of other districts of North America.

With a similar view of comparing or contrasting the resources in Fossil Fuel of Pennsylvania, and other parts of the United States, with those of other countries, I shall in a later division of this work introduce a somewhat analogous synoptic sketch of the chief Coal-Basins of Europe.

The reader will derive much assistance in the perusal of the following descriptions, from a frequent inspection of the Author's Geological Map of the United States, upon which he will find all the Coal-fields of the country carefully delineated, and their relations shown to the other formations.

CHAPTER I.

DESCRIPTION OF THE COAL-FIELDS OF THE PROVINCES OF BRITISH AMERICA.

THE Coal-formation of that portion of the British Provinces which encircles the Gulf of St Lawrence occupies numerous detached areas. According to Professor J. W. Dawson, to whose interesting description of the geology of Nova Scotia and neighbouring provinces, entitled *Acadian Geology*, we are indebted for the chief facts embodied in the following statement, the formation consists of two groups of strata, the upper composed of greyish and reddish sandstones and shales, with beds of conglomerate, and thin beds of limestone and coal, the latter not economically important—in all more than 3000 feet thick; the lower of dark-grey sandstones and shales, with occasional reddish and brown beds of bituminous limestone, and valuable seams of coal and ironstone, all possessing a thickness of more than 4000 feet.

These Coal-measures are underlaid by a lower carboniferous group called the Gypsiferous Formation: this is composed of rèddish and grey sandstones and shales chiefly in the upper part, conglomerate in the lower part, and thick beds of limestone, with marine shells and beds of gypsum—the whole group being more than 6000 feet thick.

The Upper Coal-measures contain the usual vegetable remains of the coal-formation in its more terrestrial type, the fossils being ferns, calamites, coniferous wood, &c. The Lower Coal-measures exhibit, on the other hand, mingled with this characteristic vegetation, the remains of shell-fish, ganoid fishes, and of three species of reptiles. The Lower Carboniferous, or Gypsiferous formation, displays a blending of the fossil vegetation distinctive of the coal strata, with numerous shells, corals, and other relics of a decidedly marine type.

The general area occupied by the Carboniferous rocks of Nova Scotia is subdivided, by belts of the more ancient rocks, into eight separate coal-fields :—

1. The Cumberland coal district, bounded S. by the Cobequid Hills, and united on the N.W. with the great coal-field of New Brunswick.
2. The Hants and Colchester district, including a long strip S. of the Cobequids, and another in the valley of the Musquodoboit River.
3. The Pictou district, uniting W. with both of the preceding.
4. The Sydney district, bounded by metamorphic rocks.
5. A belt of carboniferous rocks, probably without Coal-measures, extending from the Straits of Canseau, West through the County of Guysborough.
6. The Richmond and South Inverness district.
7. The Inverness and Victoria district.
8. The Carboniferous district of Cape Breton County.

The reader will observe that the above is rather a classification of the geographical distribution of the carboniferous formation generally than of the upper half of it, the lower group of which alone contains any valuable coal-seams. Condensing the descriptions of the author of the *Acadian Geology*, I shall proceed to sketch the principal geological features of these carboniferous basins in the order here presented.

The Cumberland carboniferous area is a somewhat regular synclinal trough; its S. side exhibits the lower carboniferous rocks stretching along the base of the Cobequids, and dipping N. towards the middle of the basin, and upon these rest the strata of the Lower or productive Coal group, observing the same dip. In the centre of the trough, the Upper or unproductive Coal-measures are seen to basin, inclining first to the N. at a gradually-subsiding angle, and then dipping S. The N. side of the basin displays the older Coal-measures, and the Lower Carboniferous group elevated in a bold anticlinal flexure, and finally dipping N. again into the broad coal-field of New Brunswick. One of the finest natural sections of the carboniferous series to be met with on the Continent is that which is presented by the truncated Western end of the Cumberland trough, in the cliffs facing Chiegnecto Bay. According to Sir William Logan,—the first to give a detailed description of this locality,—the part of the section called the South Joggins exposes nearly the N. side of the basin, showing the strata for about 10 miles under dips varying from 19° to 25°. It has been computed that the strata here exposed possess a vertical thickness of at least 14,000 feet, measuring from the top of the coal strata to the marine limestones of the lower carboniferous group; and it is said that seventy separate seams of coal are to be counted, each with its roof-slate and under-clay.

The oldest beds of the Lower Carboniferous series, better studied near Amherst, consist of sandstones and marly clays, imbedding thick layers of marine fossiliferous limestone and gypsum. The limestone group is overlaid by a succession of sandstones and shales; among these beds, some of which are reddish, occur layers of gypsum and sandy limestone, and some of the grey sandstones contain fragments of fossil trees in a coaly state.

The next group, estimated to be 3240 feet thick, contains nine thin seams of coal, in all only 10 inches thick ; also several layers of hard bituminous black limestone, distinguished by small enamel-like shining scales of ganoid fishes ; the grey sandstones are full of fossil plants. It is from some of these layers that the United States derive their chief supply of the well-known Nova Scotia grindstones, in such extensive use throughout the country.

Overlying the group last described occurs a group of strata 2082 feet thick, containing no coal-beds or bituminous limestone, and but little fossil vegetation, but abounding in reddish shales, and reddish and grey sandstones. The top of this group brings us to the base of the true Coal-measures, the estimated level of which is 7636 feet above that of the base of the lower carboniferous rocks. These Coal-measures have been divided by Professor Dawson into twenty-nine groups, estimated by him to possess an aggregate vertical thickness of 2819 feet. The total number of coal-seams of all dimensions in this division of the formation is forty-seven ; of these there are forty of all sizes, from a thickness of half an inch to one of 14 inches. Of the remaining seven beds, the thinnest is 18 inches thick, and the thickest 5 feet ; their aggregate gross bulk is 23½ feet, but only five of them are of a size adapted to economical mining : their aggregate thickness is about 20 feet, and the nett quantity of coal, rejecting the slaty partings, is probably about 16 feet.

Some of the groups or subdivisions of the productive Coal-measures are unusually interesting for their organic remains ; not a few of them contain sandstone-casts of the stumps and stems of the tree-like plants of the coal period, standing athwart the strata, or in an upright attitude in relation to the originally horizontal bedding of the deposits. In one thick series of beds, Group XIII., there are not fewer than thirteen distinct forest surfaces marked by erect trees, or the under-clays of the coals, deemed to be the soils of as many swamps or jungles ; and alternating with these are five layers, imbedding marine fossil shells, all implying as many periods of submersion beneath the sea. Some of the limestone-beds contain numerous remains of Modiola, a delicate shell ; Cypris, a small crustacean animal ; the scales of fishes ; and even *coprolites*, the fossilised dung of probably some aquatic reptile. One group, No. XV., is especially interesting, as containing the bones of a curious reptile, the *Dendrerpeton Acadianum*, and the shell of a snail or land-shell, all found in the interior of an upright stump of a tree mixed with sand, decayed wood, and fragments of plants, which seem to have fallen into the tree after it became hollow. These curious evidences of an ancient dry-land, discovered in 1852 by Sir Charles Lyell and Professor Dawson, were incased in a bed of argillaceous sandstone 9 feet thick, imbedding numerous other erect plants.

Sir William Logan conceives that the physical conditions attending the production of the coal strata exposed at the Joggins, were " gradual and long-continued subsidence, with occasional elevatory movements going on in an extensive alluvial tract teeming with vegetable life, and receiving large supplies of fine detrital matter. On the one hand, subsidence tended to restore the original dominion of the water ; on the other, elevation silted up, and vegetable and animal growth built up, successive surfaces with dry land. For a very long period these opposing forces were alternately victorious, without effecting any very decided or permanent conquest ; and it is very probable that the locality of our section was, during this period, near the margin of the alluvial tract in question, where the various changes of the conflict were more sensibly felt and more easily recorded than nearer the open sea or farther inland."

The whole series of carboniferous strata exposed at the Joggins has been subdivided by Sir William Logan into the eight following groups :—

Nos. I. and II.—Grey and yellowish Sandstones and Conglomerates, and dark-red, chocolate-coloured, and grey argillaceous and sandy Shales. Remain of drifted and some erect coal-plants. Thickness 2267 feet. Professor Dawson regards these groups as identical with the upper coal-formation at Pictou.

No. III.—Grey and reddish Sandstones and Shales, carbonaceous shales, under-clays, and 22 seams of coal; erect plants at two levels. Thickness, 2134 feet.

No. IV.—Grey and reddish Sandstones, and grey, reddish, and chocolate-coloured Shales—the grey most abundant. Carbonaceous shales, bituminous limestones, under-clays, and 45 seams of coal; erect plants at 18 levels. *Modiola and fish-scales.* Thickness, 2539 feet.

No. V.—Reddish and grey Sandstones, and red and green Shales, red beds predominating. Calcareous concretions; remains of carbonised plants. Thickness, 2082 feet.

No. VI.—Grey, drab, and reddish Sandstones two-thirds of the mass, grey and reddish Shales, under-clays and Bituminous Limestones; 9 seams of coal, drifted plants abundant, and upright stems at one level. *Modiola and fish-scales.* Thickness, 3241 feet. (Groups Nos. III., IV., V., VI. are regarded by Sir William Logan as representing the productive Coal-measures of Pictou and Sydney, and some of the underlying sandstones.)

Nos. VII. and VIII.—Reddish and grey Sandstone, red Conglomerate, red and chocolate-coloured Shales, concretionary Limestone, and two beds of Gypsum; plants. Thickness, 2308 feet.

These rocks, together with a thick underlying bed of limestone, represent the lower carboniferous or gypsiferous series of Winsor, Pictou, and other localities.

The whole coal-series, measuring, according to Sir William Logan, 14,570 feet vertical thickness, embraces 76 beds of coal, all, with two exceptions, resting on Stigmaria under-clays. There are, besides, 16 similar under-clays without coals above them; erect plants occur at 22 horizons; and there are 24 bituminous limestones, of which 17 are closely associated with seams of coal.

Clay ironstone, in balls and irregular bands, occurs among the strata at the Joggins, but not in sufficient abundance to be valuable. Grindstones, a useful product of these strata, are quarried on a large scale, 36,712 tons having been exported from Cumberland in 1851. Limestone and gypsum abound in the belt of country stretching from Minudie to Pugwash. Some of the beds of black bituminous limestone abound in scales and bones of fishes, and contain therefore a sufficient quantity of phosphate of lime to constitute the material a valuable manure.

COAL-FIELD OF NEW BRUNSWICK.

The extensive coal-field of New Brunswick is divided from that of Cumberland, just described, by an anticlinal belt of the older Carboniferous rocks, the axis of which passes through Chiegnecto Bay. North of this axis, the coal-rocks occupy a rather slender basin, bounded on its N. by a range of metamorphic strata culminating in Shepody Mountain, the synclinal centre of the trough crossing Shepody Bay. This basin heads towards the W.S.W., and expands between the Petitcodiac and the sea-coast at Northumberland Strait. North of the zone of older rocks of the Shepody Mountain spreads the main carboniferous area of the province, Northward as far as the Bay of Chaleurs, and Westward as far as Oromucto Lake. This is a broad triangular tract, 150 miles long from S. to N., and 100 miles wide from the sea-coast Westward. We may infer from its wide extent, and from the undulated outline of its Western border, that it is not one simple basin, but a succession of broad and shallow troughs, and intervening anticlinal flexures.

It would appear, from the researches of the Canadian geologists, that the basin of Shepody Bay is wanting in the middle and upper Coal-measures, its highest strata appertaining to the lower Coal-measures and the lower carboniferous series. Professor Dawson alleges that such, indeed, is the character of the entire coal area of New Brunswick, where lower carboniferous rocks, closely resembling those of Nova Scotia, seem to underlie a large portion of the basin, usually coloured in the geological maps as one continuous coal-field. The productive Coal-measures are evidently developed on a comparatively limited scale in this province; no actually valuable bed of coal has yet been brought to light, though beds of cannel coal, resembling bituminous shales, and thin seams of ordinary coal, do occur. The most important, certainly the most curious, mass of fuel in this district is the bed or vein of the Albert Mine near Hillsborough. This substance, the chemical nature and geological relations of which have occasioned much discussion in connection with a legal definition, does not wear the aspect of an ordinary coal, but is a much more fusible substance of a splendent resinous lustre, and a perfect conchoidal fracture. It is destitute of the lamination of coal, but has the structure of a pasty substance, which has been stirred while in a plastic state before consolidation. Its powder and streak are black, and it is very brittle; its specific gravity, about 1.10, is less than that of the lightest varieties of common coal; it emits a bituminous odour, puffs when exposed to flame, evolves a copious volume of gas, and melts in a close vessel, but not in the open air. In these properties it resembles jet or pitch coal. As this substance contains the unusual proportion of 57 per cent of volatile inflammable matter, it is admirably adapted for the economical production of illuminating gas, for which it has been successfully employed.

As exposed in and near the Albert Mine, this material would seem not so much to constitute a true bed or layer conformably imbedded between the strata, as to fill an irregular fissure or fissures connected with a dislocation of the strata. Professor Dawson supposes it to have been a bed of true coal disturbed and contorted while soft, and with the enclosing rock bent into a sharp arch, the arch to have been dislocated and denuded in its upper part, making the strata on the one side of the coal to abut against it, and to squeeze it while in a plastic state into the adjoining fissures: if so, the carbonaceous mass must eventually resolve itself in the progress of mining into a regular coal-seam, with conforming floor and roof. The question here arises, will it then possess the abnormal chemical and physical properties which it at present exhibits? It is difficult to conceive how these can have arisen from mere mechanical pressure, however energetic, upon a bed of ordinary coal, even though softened and rendered plastic by heat; and this objection becomes stronger when we reflect that hitherto no instances of a change in the nature of a coal have ever been found to accompany the faults and squeezes so common in nearly all coal-fields. It is barely possible that this bed of carbonaceous matter, originally very hydrogenous, and easily softened or rendered plastic by heat under an excessive squeeze exerted at a line of flexure or fault, may have extruded its more fused or liquid portion from out of the more solid part of the bed into the vacant fissure, very much after the manner in which the fluid oils separate from the solid fatty bodies with which they are associated in animal structures.

But this modified form of the hypothesis lacks support upon the ground already mentioned, that the history of mining has hitherto failed to exhibit any instances of such exudation of the bituminous portions of coal-seams, or indeed any change of chemical composition from mere compression. While, therefore, we cannot doubt that the material exposed within and around the Albert Mine was in a pasty state at the time it assumed its present position between the rocks, we can hardly assume it to be either a metamorphosed condition of true coal, or a derivative part of a genuine coal-seam, but itself an original product or formation; in other words, a genuine coal elaborated by chemical action from vegetable matter, and thrown while soft, or after it had been rendered plastic, into its present posture by forcible disturbance of the strata. To account for its peculiarities of composition, we must look rather to conditions under which the deposit was originally collected and elaborated, than to any subsequent changes attributable to geological forces. Regarded from a geological point of view, this much-discussed hydro-carbon must rank therefore as a genuine coal, using this word to designate not a specific mineral or chemical compound, but a genus of substances having a common or similar geological history, possessing carbon for their base or principal constituent, traceable to a similar origin in vegetable matter, and applicable to similar uses in the arts.

CARBONIFEROUS DISTRICT OF COLCHESTER AND HANTS.

There is an extensive irregular basin of carboniferous rocks on the S. side of the Cobequid Hills, which possesses as large an area as the basin of Cumberland; its general Southern boundary is the Northern base of the Horton and Ardoise Hills, against the ancient rocks of which the lower carboniferous beds lean at a high angle. This tract appears to have the structure of an undulating trough, the main synclinal axis of which ranges E. and W. through the basin of Minas, passing South of the Pictou coal-field; it contains but a very limited tract of productive Coal-measures, by far the largest portion of the district consisting of only the lower carboniferous series, which are to be found here as well exposed, and under as full development, as the Coal-measures are at the Joggins.

These lower carboniferous rocks consist for the most part of grey sandstones and dark shales, some of the former containing well-preserved coal-plants. At Horton Bluff there occur also many layers of coarse limestone among grey and red sandstones and marls. The enamelled scales and pointed conical teeth of *Palæoniscus* and other ganoid fishes are abundant in some of the shales in this locality, while other beds contain the trunks, branches, and leaves of *Lepidodendron* and other coal-plants. The Horton shales are regarded as the geological equivalents of the strata of Hillborough, but they have not disclosed any seam of the remarkable bituminous matter exposed at the Albert Mine. One stratum exhibits stems of *Lepidodendron* rooted in an erect position across the strata; older relics of a fossil forest are nowhere known. In the same group of strata it is not uncommon to find the *Coprolites*, or fossilised excrements of fishes; and even the footprints of a small reptile have been noticed. No seam of coal has been met with in these lower strata. Many of the strata of this basin are of a strictly marine type, being flaggy limestones, imbedding numerous fossil-shells belonging to species of *Productus*, *Spirifer*, and *Terebratula*, which are indicative of a marine origin, and characteristic of the early carboniferous ages. Associated with the marls and limestones of this group is much white crystalline gypsum, which makes a conspicuous display from its whiteness. This valuable material is developed on a large scale at Windsor, where there are great quarries of it. A very striking natural exposure of the gypsum occurs on the St Croix River, where the material stands forward in glittering whiteness from the face of a long range of cliffs.

The Coal-measures of this broad basin occur chiefly in the neighbourhood of the Folly River, across which they stretch from near Cape Chiegnecto to the upper part of the Salmon River. These coal-rocks repose on the oldest grits of the lower carboniferous series, without being underlaid by any intervening marine limestones. The group consists of grey sandstones and dark shales, imbedding a few thin layers of coal. On the Salmon River they contain a bed of coal about 2 feet thick, accompanied by shale imbedding characteristic coal-fossils.

The carboniferous district of Colchester divides into three sub-basins E. of the Shubenacadie, by the intrusion of narrow belts of metamorphic strata. The most Northern follows the valley of Salmon River into the Pictou district; the other two sub-basins do not contain the coal-formation in their extension E.

It is stated that nearly 80,000 tons of gypsum were quarried and exported in 1851 from Windsor, Shubenacadie, and other localities of the gypsum-bearing strata accessible to shipping.

Iron ore, but not in quantities sufficient for smelting operations, is to be met with near the entrance to the Shubenacadie, among the lower carboniferous strata.

Coal, but in thin seams, none of them exceeding 18 inches in diameter, occurs, according to Professor Dawson, at Salmon River, North River, Chiganois River, De Bert River, Folly River, and Great Village River, and appears at intervals as far W. as Cape Chiegnecto.

CARBONIFEROUS DISTRICT OF PICTOU.

The carboniferous basin of Pictou, bounded on the S. by the older schistose rocks of the N. slopes of the Blue Mountain and the Cobequid Mountain, contains a full development of both the lower carboniferous series and the productive Coal-measures. The lower carboniferous rocks half enclose it in a crescent-shaped belt, extending from the coast a little West of Arisaig, S.W. and N.W. to Tatmagouche Bay. This group of strata consists in this basin of conglomerates, with interstratified beds of amygdaloidal trap-rocks as a bottom group, and upon these a succession of reddish and grey sandstones and shales—a thick limestone, with characteristic fossils, forming the upper part of the series; while associated with the limestone are layers of marl and gypsum.

The Coal-measures consist of the very same materials as they do at the Joggins, except that instead of containing a multitude of thin seams of coal and bituminous shale, they here enclose only a few beds of comparatively great thickness. They are well exposed on the East River of Pictou, especially around the Albion Mines. At this locality the strata, according to Professor Dawson, have a thickness of about 800 feet, and are chiefly black shales, with *Cypris* and ferns, and other fossil plants. The number of coal-seams is five or six, the two largest measuring respectively 37½ and 22 feet: the thicker of these, called the Main Seam, is traceable by its outcrop for several miles, and has already been extensively wrought. A serious fault, or line of disturbance, cuts off the Coal-measures towards the N., or on the coast, by causing a downthrow of a thick bed of conglomerate which overlies the coal. This conglomerate, unlike that of the lower carboniferous group, is composed of large pebbles cemented by calcareous matter: it is imagined by Professor Dawson to represent an ancient gravelled beach, contemporaneous with the Albion Coal-measures, and isolating them from the wider area of coal strata on the N. towards Pictou. He "conceives that the Albion coal was formed in a depressed space separated by a shingle bar from the more exposed flats without," accounting thus "for the great thickness of the deposits of coal and carbonaceous shale, the absence of sandstones, and the peculiar textures and qualities of the coal, as well as the association with it of remains of fish and *Cypris*, since modern analogies show that such an enclosed space might be alternately a swamp and lagoon, without any marked change in the nature of the mechanical deposits."

It would appear that the synclinal axis of the Pictou coal-field cannot be far from the town of that name, since, according to Professor Dawson, "the strata to the N. and W. of Pictou Harbour dip gently towards the S.E." Near the town of Pictou a bed of sandstone is seen with erect stems of *Calamites* rooted in the spots in which they grew; relics of the other ordinary coal-plants in their usual condition abound.

The N. side of the coal-field between Pictou and Cape John is traversed by an anticlinal axis ranging from near the mouth of Carribou River across French River at Tatmagouche; beyond this axis there would seem to be another lying still farther N., producing S. dips in the lower carboniferous strata forming the N. side of the Cumberland coal-field. It would thus appear that the Pictou and Cumberland basins occupy separate troughs of the strata, divided from each other by the Carribou anticlinal.

The Main Pictou coal-seam is composed as follows:—

Roof, slate fragments, 3 inches; Coal, shaly, 6½ inches; Coal, laminated, thin layers of mineral charcoal, 2 feet; Coal, cubical, 3 feet 2 inches; Carbonaceous Shale and Ironstone; Remains of large Fishes and Coprolites, 4½ inches; Coal, laminated and cubical, 9 feet 3 inches; Ironstone and Carbonaceous Shale, with Lepidodendron, Ulodendron, Sigillaria, &c., 8 inches; Coal, laminated, a line of ironstone balls, 1 foot 2 inches; Coal, laminated and cubical, 6 feet 7 inches; Ironstone and Pyrites, 3 inches; Coal, laminated and cubical, 10 feet 3 inches; Coal, coarse, with layers of bituminous shale and pyrites, 1 foot; Coal, laminated, with a fossil trunk in pyrites, 2 feet 1 inch; Coal, laminated and cubical, 2 feet 3 inches; Under-clay, 10 inches. Thickness perpendicular to horizon, 40 feet; vertical thickness, 38 feet.

The actual thickness of good coal is about 24 feet. The chemical constitution and physical properties of this coal will be found in the General Table.

Another coal-bed of the Pictou basin—the "Deep Seam," so called—lies about 150 feet below the main seam; it contains about 12 feet of good coal in three benches, the best of which is said to be superior to any part of the main seam, but owing to subdividing layers of shale, it cannot be mined as economically as the large bed. It yields much illuminating gas, and an excellent vesicular coke, and produces but a moderate amount of ashes. These ashes, Professor Dawson states, "are for the most part of a reddish colour, whereas those of the main seam are invariably white or light grey;"—a reverse relationship, it will be remarked, to that which obtains in the anthracite basins of Pennsylvania, where whitish ashes characterise, with but one or two exceptions, all the lower coal-seams, while reddish ashes everywhere prevail in the upper.

Other good coal-seams occur in the Albion Coal-measures; "one of them, similar in quality to the main seam, but containing more ashes, is 6 feet thick; another, yielding 8 per cent of ashes, a good vesicular coke, and 56.6 per cent of excellent illuminating gas, lies 450 feet below the main seam; it is said to be only 14 inches thick. There are several small seams of coal at New Glasgow, Merigomish, Middle River, South Pictou, Carribou, and elsewhere, but they are too thin to be profitably mined; those of the Albion Measures, already referred to, are the only thick seams at present known within the Pictou basin.

Clay iron-stone is to be met with in the Albion Coal-measures in sufficient abundance, and of fit quality, it is said, to warrant the erection of smelting-furnaces.

A grey freestone, now in some demand in the Atlantic cities of the United States for architectural uses, is quarried on a large scale at the head of Pictou Harbour; it has the requisites of durability and an attractive colour.

Fossils.—A curious fossil was discovered by Professor Dawson in 1850, in a seam of coaly ironstone in the Albion Coal-measures; it is the upper part of a skull, supposed by Professor Owen, to whom it was submitted, to have belonged to a gigantic frog-like reptile or *Batrachian*, of a type not previously found in rocks as ancient as the Coal-measures. The specimen is 7 inches broad and 5 long, and along its semicircular margin it is provided with strong, conical, finely striated, and slightly-curved teeth. It is one of sundry curious relics of frog-like reptilian life already recovered from the American Carboniferous formations.

CARBONIFEROUS DISTRICT OF SYDNEY COUNTY.

A wide basin of the carboniferous strata occupies a triangular area in Sydney County, Nova Scotia, extending W. from the Gut of Canseau, and the S.W. shores of St George's Bay, to the stream called the Ohio River. It is bounded on the S. by the older crystalline rocks of the Cape Porcupine range of hills, and on the W. by the similar formations of the Antigonish Mountains, terminating on the N. by the Cape St George; this would appear to be a broad synclinal trough, deepening and widening rather rapidly N.E. towards St George's Bay. All its marginal tracts adjoining the bounding hills are occupied by the lower carboniferous series constituted of the usual conglomerate, and sandstone, limestones, and gypsiferous beds of the formation; the latter materials existing in great abundance. The gypsum alone is stated by Professor Dawson to be at least 200 feet thick, and to form at one place a beautiful cliff fronting the sea.

The Coal-measures occur in the central parts of the basin, inland from Pomket and Tracadie, but only thin seams of coal have hitherto been met with. It does not appear probable that any valuable seams of coal occur.

CARBONIFEROUS DISTRICT OF GUYSBOROUGH.

South of the belt of metamorphic and crystalline rocks, and between it and a similar range, extending W. from Cape Canseau, there lies another trough of Carboniferous strata, encompassing the head of Chedebucto Bay, and stretching thence due West past Glen Elbe, and along the upper valley of St Mary's River. This basin appears to contain no Coal-measures, being too narrow and shallow for their reception; but it embraces some valuable beds of limestone both N. and S. of the town of Guysborough.

CARBONIFEROUS DISTRICT OF RICHMOND AND SOUTH INVERNESS.

East of the Gut of Canseau and St George's Bay, the carboniferous strata re-occur in the island of Cape Breton, the North-dipping lower members of the formation of Tracadie coalescing with the South-dipping corresponding rocks of the N. side of Chedebucto Bay, by the sinking under of the igneous axis of Cape Porcupine ; an anticlinal flexure probably traverses the district from Cape Porcupine N.E. towards the head of Bras d'Or Lake. Apparently none but lower carboniferous rocks occur N. of this anticlinal in South Inverness ; but these lower strata there developed are interesting for their abundance of gypsum. The Richmond portion of the tract, which is a prolongation of the Guysborough basin, does contain a patch of Coal-measures ; but no coal-seam has yet been mined in it. There is a thick bed of mixed coal and shale immediately on the coast in Carribou Cove ; it measures 11 feet 8 inches, stands vertically, or indeed a little overturned, dipping 80° W., 57° S. The coal is crumbly and soft, and is evidently not in a workable condition. Coal likewise appears at Little River, a small tributary of Carribou Cove.

The lower carboniferous series is admirably displayed in the neighbourhood of Plaister Cove, on the Gut of Canseau. Professor Dawson thus describes them :—

Group 1.—Thick beds of grey conglomerate, under a nearly vertical dip, form the base of the carboniferous series. These appear at McMillan's Point, between which and Plaister Cove occurs

Group 2.—Composed of black and grey shales alternating with hard sandstones, altered by heat, and intersected by white veins of calc-spars. Overlying these is

Group 3.—This consists of a bed of dark sub-crystalline limestone, 30 feet thick, also traversed by many thin cracks, filled by calcareous spar ; and upon the limestone are layers of greenish marl and gypsum, somewhat contorted. Next succeeds

Group 4.—Composed of greenish marl, with grains of red foliated and fibrous white gypsum, and a few slender ones of calc-spar ; the greenish marl contains sulphuret of iron. Above the marl reposes

Group 5.—A bed of gypsum, estimated to be 50 yards thick. This great mass of sulphate of lime forms a cliff about 80 feet high, shaped grotesquely by the action of the weather. Two-thirds of the bed consist of crystalline anhydrite, the remaining one-third of common gypsum forming a base, imbedding the anhydrite in minute crystals. The mass is perforated perpendicularly by slender tubular holes or channels, called "Plaister Pits," caused by the solvent action of surface water trickling down the steeply-inclined joints.

Group 6 embraces a few layers of limestone, resting at a steep angle on the gypsum. One of these is a curious mixture of grey limestone and gypsum, the result, apparently, of the cementing together of fragments from the two rocks.

Group 7 is a thick bed of marl like that underlying the gypsum ; it is partly homogeneous, partly brecciated, and some layers of it are highly gypseous.

Group 8, the highest in the series, is a thick succession of dark calcareous shales, overlaid by a thick mass of hard grey and brownish sandstones and shales.

The dark shales are overlaid by true Coal-measures, the same which at Little River and Carribou Cove imbed regular seams of coal.

The chemical composition of the coals of Carribou Cove will be found in the General Table.

CARBONIFEROUS DISTRICT OF NORTHERN INVERNESS AND VICTORIA.

A long and irregular tract of carboniferous rocks extends the whole way from the W. shore of St George's Bay to Cheticamp. Between Plaister Cove and Port Hood it is but a narrow strip of the lower members of the series facing the sea. Between Port Hood and Margarie the Carboniferous area widens, spreading from the sea Eastward to the waters of Bras d'Or and St Ann's Bay, but broken by the intrusion of spurs and ridges of the igneous rocks; and between Margarie and Cheticamp it is again only a narrow strip restricted to the coast. The chief part of this long tract embraces the lower carboniferous series, under its usual Nova Scotian type: the lower beds consisting of conglomerates and limestone, in some localities much altered by igneous action. Associated with the carboniferous limestone is much gypsum; these valuable materials are largely developed to the N.E. of Port Hood, and thence N. to the Mabou River, where the limestone may be identified by characteristic fossils. Like some parts of the Carboniferous or Umbral limestone of the United States, a portion of it is oolitic. According to Professor Dawson, there is an enormous bed of gypsum near the mouth of Mabou River. These rocks are also largely developed at Ainslie Lake, and on Margarie River, its outlet. According to descriptions of Mr Brown, in the *Proceedings of the Geological Society*, the lower carboniferous rocks of the East coast of Cape Breton have a total thickness of about 1000 feet, which is much less than their average thickness.

The Upper Carboniferous series or Coal-measures occur on only two or three limited patches within this large area: one locality is Port Hood, where these strata much resemble those of the Joggins. The formation consists of grey sandstones, grey and brown shales, black and calcareous shales, and thin beds of coal, with the usual fossil vegetation. Professor Dawson speaks of superb examples of stumps of Sigillaria, with roots and rootlets attached, imbedded where they grew, and exposed by denudation over a broad horizontal surface, permitting a full view of the subdivisions of the roots, and their junctions with the stems. Some of these stumps are 2½ feet through, and show the Stigmaria roots diverging from them in four directions, at right angles to each other, each main root forking into two, and each branch-root also into two, and so on. Other beds of the group contain characteristic marine fossils, *Modiolæ, Cypris, fish-scales, coprolites,* &c.

Another locality of the Coal-measures is Margarie; but here the strata are very limited. It would appear from the seaward dip of all the strata, that the main coal-field lies to the N.W., beneath the Northern parts of Northumberland Straits, the small patches of the formation at Port Hood and Margarie being merely marginal portions of it which have escaped submergence. All the coal-beds are stated to be small, the largest seen by Professor Dawson, *not exceeding one foot in thickness.*

CARBONIFEROUS DISTRICT OF CAPE BRETON COUNTY.

The only remaining tract of carboniferous rocks, in this part of the British Provinces, is that which constitutes an irregular triangular area in the Northern and central parts of Cape Breton County; it may be called the Sydney Basin, as that town lies somewhat centrally within it. It is bounded N. by the sea, W. by the waters of the Great Bras d'Or, Little Bras d'Or, and Bras d'Or Lake, and Southward by a belt of igneous and metamorphic rocks, extending Eastward from the last-named sheet, to the open Atlantic at Cape Breton. This irregular triangular area, which includes Boulardarie Island, is penetrated and made irregular by the tidal estuaries of Bras d'Or, Sydney Harbour, and Miré River, and by a band of crystalline rocks in the Sunacadie Hills. The geology of the district has been well explored by R. Brown, Esq. of Sydney, from whose written description the following condensed account is mainly derived.

It embraces both the Lower Carboniferous series and the productive Coal-measures : its general structure is that of a wide undulated trough, spreading and deepening in a N.E. direction from Miré River towards the sea : it is apparently traversed by several anticlinal flexures ranging N.E. and S.W., by virtue of which the strata are disposed into as many intermediate sub-basins, the largest of which occupies the peninsula between Sydney Harbour and Miré River, Boulardarie Island apparently constituting a lesser one.

The Lower Carboniferous group consists of very nearly the same materials as it possesses elsewhere in Cape Breton and Nova Scotia—that is to say, conglomerate, sandstone, shale, limestone, and gypsum, disposed in their usual order. These rocks lean in many places on the steeply-dipping edges of the older slates. The limestones abound, in some localities, in well-preserved fossils ; and gypsum is developed on a large scale, though it is nowhere extensively quarried.

The Coal-measures occupy all the Northern or seaward front of the county, extending, in fact, from Great Bras d'Or across the N. end of Boulardarie Island, the Northern half of the peninsula between Little Bras d'Or and Sydney Harbour, and all the Northern part of the wider peninsula between the latter and Miré River. Mr Brown conceives "that this great area of Coal-measures is probably the segment only of an immense basin extending towards the coast of Newfoundland—a supposition which is confirmed by the existence of Coal-measures at Neal's Harbour, 30 miles N. of Cape Dauphin." The same authority states that "the productive coal strata cover an area of 250 square miles, and he thinks they possess a thickness of 10,000 feet. One continuous section, on the N. shore of Boulardarie Island, exposes a thickness of 5400 feet ; and other sections, nearer the middle of the field, display between 1000 and 2000 feet more, referable to a higher place in the series."

A natural section, on the N.W. side of Sydney Harbour, exhibits, in 1860 feet of strata, thirty-four seams of coal, and forty-one Stigmaria under-clays ; the coal-beds measuring, in the aggregate, 37 feet. There are eighteen distinct courses of erect trees, chiefly Sigillaria, and many of these exhibit their roots of Stigmaria very plainly. These were among the first instances anywhere cited of the true nature and mode of growth of Stigmaria.

In the fifth volume of the *Geological Journal*, Mr Brown describes a specimen of *Sigillaria alternans* with Stigmaria roots attached, subdividing and having conical tap-roots penetrating downwards into a thin bed of shale overlying a coal-seam. This coal-bed, "like the main seam at the Joggins, supported, when it was a bed of soft peat, a forest of *Sigillaria and Lepidodendron*, many of which still remain erect in the overlying shale, with all their roots and long spreading rootlets attached." In one instance the roots dip gradually downwards until they come in contact with coal at about 18 inches from the centre of the tree, and then spread out over its surface. The horizontal roots branch off in a remarkable manner, the base being first divided into four equal parts by deep channels running from near the centre. An inch or two farther on, each of these quarters is divided into two roots, which, as they recede from the centre, bifurcate twice within a distance of 18 inches from the centre of the stump. There are four large tap-roots in each quarter of the stump, and about 5 inches beyond these a set of smaller tap-roots striking perpendicularly downwards from the horizontal roots, making forty-eight in all—sixteen in the inner, and thirty-two in the outer set; and, what is a still more remarkable feature in this singular fossil, there are exactly thirty-two double rows of leaf-scars on the circumference of the trunk. This curious correspondence in the numbers of the roots and vertical rows of leaf-scars surely cannot be accidental?

Besides erect trees and other forms of the Carboniferous vegetation, the Sidney Coal-measures contain many layers of shale imbedding *Modiola, Cypris, Spirorbis, Fish-scales,* and other aquatic animal-remains.

Only four out of the 34 coal-seams of the Sydney Harbour section are of workable dimensions; one, the Indian Cove Seam, is 4 feet 8 inches thick; the Main Seam, 450 feet above the Indian Cove bed, is 6 feet 9 inches thick; the Lloyd's Cove Seam, 730 feet higher than the Main Seam, is 5 feet thick; and the Cranberry Head, or top seam, 280 feet higher than Lloyd's Cove Seam, is 3 feet 8 inches thick. For the chemical and physical characters of the Sydney Main Seam, the reader is referred to the General Table.

Valuable beds of coal have been opened on Boulardarie Island, but these are not at present wrought. Other beds, important for their size, are seen at Bridgeport; one of these, about 9 feet thick, appears to be an excellent coal.

CHAPTER II.

GENERAL DESCRIPTION OF THE GREAT APPALACHIAN COAL-FIELD.

LIMITS AND DIMENSIONS.

The longest, and in area the most extensive, of the five great coal-fields of the United States is that which I have designated the Great Appalachian Basin. Extending as it does in a S.W. direction, from Northern Pennsylvania to Middle Alabama, parallel with the Appalachian Mountains, many of whose great ridges rise within its borders, and insulate valleys of the coal-bearing strata, it seems fairly entitled to the name here conferred on it. This great coal-field, almost the largest expanse of continuous Coal-measures in the world, possesses a length of about 875 miles, and a maximum breadth, between its E. outcrop in Southern Pennsylvania, and its W. in Northern Ohio, of about 180 miles; while it covers about 56,000 square miles of the earth's surface. Its general outline is that of a short rough club, the slender part, the table-land of the Cumberland Mountain in Tennessee, representing the handle.

The S.E. border of the coal-field may be defined as commencing in Lycoming County, Pennsylvania, in the summit of the Alleghany Mountain, and as pursuing a general S.W. course, coincident with the N.W. slope of that ridge or table-land, obliquely across the State to the head-waters of the Youghiogheny in Maryland. Near the S. boundary of Pennsylvania it offsets Westward, and, continuing its course S.W. through Virginia, ranges on coincident with the N.W. slope of the Briery Mountain, Laurel Hill, Rich Mountain, Big Sewell, Mountain, Great Flat-Top Mountain, and Cumberland Mountain, to the border of Tennessee. From the Northern line of Tennessee, it extends across that State to Alabama, coinciding nearly with the South-eastern escarpment of the Cumberland Mountain, and its Eastern spur the Lookout Mountain. From the Tennessee River, near the Northern line of Alabama, to the termination of the coal-field E. of Tuscaloosa, the boundary pursues the same S.W. direction, following the summits of the ridges immediately West of the Coosa River.

The N. and W. border of the coal-field is traceable from Lycoming County westward through Northern Pennsylvania, in a winding and very broken line, through Tioga, Potter, M^cKean, Warren, Crawford, and Mercer counties to the State-line of Ohio, crossing which, it takes a more Southerly trend to the Ohio River, through Turnbull, Portage, Summit, Wayne, Holmes, Coshocton, Licking, Fairfield, Hocking, Vinton, Jackson, and Sciota counties. From the Ohio River, the line ranges across Kentucky in a S.W. direction, passing through Greenup, Carter, and Morgan counties to the head-waters of the Tygert River, and thence by the W. boundary of Morgan and Laurel counties, and down the Rockcastle River to the Big Narrows of that stream, beyond which it runs to the Cumberland River, in Pulaski County, near the Shoals. Its course thence is winding through Wayne County by Slone's Hill and the Wallace Mountain, where it enters Tennessee; in which State it winds with still more tortuous bendings through the spurs of the Cumberland Mountain in Fentress, Overton, Putnam, White, Van-Buren, Grundy, and Franklin counties, and enters Alabama. In this latter State, the margin of the coal-field, still conforming to the summit of the W. escarpment of the Cumberland Mountain plateau, ranges irregularly through Jackson, Madison, Morgan, Bench, Hancock, Marion, Fayette, and Tuscaloosa counties, to the termination of the coal-field N. of the town of Tuscaloosa.

This extensive coal-field is, in its general structure, a broad comparatively flat synclinal trough, undulated in many wide low flexures, or gentle anticlinal and synclinal waves, of great length and continuity. These flexures are both straight and curved in the lineation of their axes. Like those of the more folded portions of the Appalachian chain, they are parallel with the general trend of the coal-field and with each other, and display a prevailing declension in the steepness of their slopes, as they succeed each other from S.E. to N.W. They are most numerous and conspicuous in Pennsylvania and Virginia. It is to the influence of a powerful and deep erosion upon a terminal group of these undulations that the coal-field is subdivided, in Northern Pennsylvania, into six long slender synclinal mountain-spurs or fingers, extending N.E. between deep valleys of older strata. From the superior hardness of the sandstones supporting the Coal-measures, compared with the subjacent clayey rocks, the margin of the coal group is very generally the edge of a mountain table-land, so that the whole field may be viewed as carved in relief out of the general plane of the country, by excavation of the circumjacent softer strata.

Many extensive rivers intersect and drain the basin. The Ohio River, and its main upper tributary the Alleghany, water it longitudinally from near the S. border of New York to the N. frontier of Kentucky, and it is drained transversely in the N.E. by the West Branch of the Susquehanna, centrally by the Great Kenawha and Big Sandy rivers, and near its S.W. extremity by the Tennessee River. The deep valleys of these and other great streams serve as so many trenches across the basin to promote in a most fortunate manner a wide intercourse and commerce between the interior of the table-land and the external country; and the general elevation of the basin, especially of its marginal portions above the bordering valleys, and these intersecting river-channels, places an enormous body of the mineral wealth of the coal-field in positions of unusual fitness for mining, and for transportation to the external markets.

COMPOSITION OF THE COAL-MEASURES.

The full and minute description of the Coal-Measures of Pennsylvania presented in this work will suffice to convey a sufficiently clear and accurate knowledge of the type which they wear in the N.E. portion of the basin, and may serve as a standard for comparison with the other parts. They consist of grey and yellowish quartzose grits, and sandstones, argillaceous sandstones, sandy and micaceous slates and shales, argillaceous shales and fire-clays, calcareous shales or marls, argillaceous and pure calcareous limestones, occasionally layers of chert, thin layers of argillaceous iron-ore, in continuous plates and in detached balls, and seams of coaly slate, and of more or less pure coal. These constituents are not interstratified in the same proportions throughout all parts of the deposit, nor do the same subdivisions of the formation retain a very constant character throughout wide geographical limits. As a general rule, the coal strata of this great basin graduate from a littoral to a more marine type as they spread toward the W. or N.W.; that is to say, the sandstones become fewer, thinner, and less pebbly, finer-grained, and more argillaceous; the shales and slates less sandy and more calcareous, the limestones purer, thicker, and more abundant; and the organic remains—the most significant of all—less exclusively terrestrial, or more aquatic. This gradual modification of type obtains as strikingly in the middle or Virginia and Kentucky division of the coal-field, as in the N.E. or Pennsylvania portion; but whether it is noticeable to the same degree in the S.W. or Tennessee and Alabama subdivision, has not been ascertained, owing chiefly to the narrower dimensions of the basin in that quarter. A far more rapid change in the materials may be observed in crossing the coal-field in an E. and W. direction than in passing an equal distance in the direction of its length—a fact true, indeed, of nearly all the Appalachian formations. We shall see hereafter, when examining the composition of the Western Kentucky or Illinois coal-field, that the same law of a more marine type towards the W. is as discernible in crossing from the one great basin to the other, as it is in traversing the Appalachian coal-field alone. Perhaps in this circumstance we may discern an indication that the two great basins were originally connected and continuous, and that their insulation has arisen simply from an extensive denudation of all the upper strata at the wide anticlinal zone, which extends from the limestone district of Cincinnati to the limestone tract of Lexington and Nashville. A similar and even more striking Westerly increase of the marine type, so far as this is indicated by an augmented proportion of limestones and marine organic remains, is discernible when we compare the composition of the Illinois coal-field E. of the Mississippi River, with that of the Missouri basin W. of it. Similarity of mineral constitution, but especially this fact of its gradation, when taken together with other geological considerations, almost compels us to believe that these two coal-fields were once conjoined, and that their separation was produced by a wave-like disturbance of the crust, and a deep and wide erosion of the carboniferous rocks in the valley of the Upper Mississippi.

It has been shown that the bituminous Coal-measures of Pennsylvania are divisible into five groups; a lower group, consisting of the Seral conglomerate, and two or three imbedded coal-seams;

a productive group of older Coal-measures; an unproductive mass of coal-shales; a second productive group of newer Coal-measures; and a second unproductive mass of shales, which terminate the formation. These groups are discernible in Western Virginia as well as in Western Pennsylvania; but it is not at present known how much farther in the S.W. direction they maintain themselves. The lower or conglomeritic group seems indeed to encompass and underlie the entire coal-field; but the two upper ones—the upper productive Coal-measures, and the still higher upper unproductive or Barren shales—are restricted to the widest and deepest part of the general basin, not extending, apparently, beyond the Guyandotte River. It is probable, therefore, that the coal-beds of the Cumberland Mountain, in Kentucky and Tennessee, belong chiefly to the lower Coal-measures, and to the Conglomerate series underneath them. For a general representation of the Coal-measures of Western Pennsylvania, the reader is referred to the column on page 475, and for a view of those of Western Virginia to the figure (767).

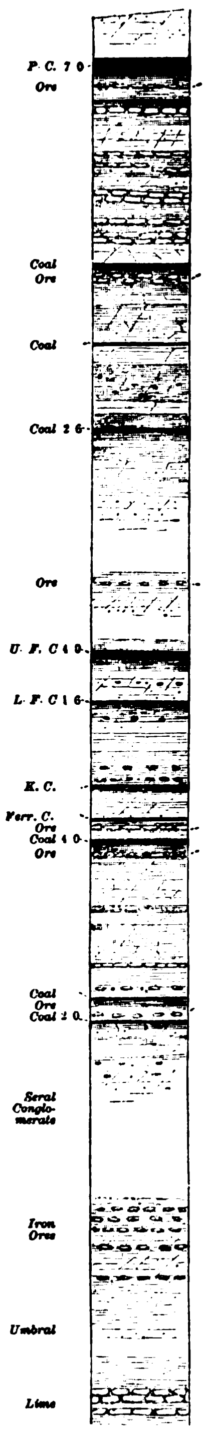


FIG. 767. — Section of Strata N. W. side Laurel Hill, Cheat River, Virginia. — 1 *inch* = 200 *feet.*

COAL-BEDS.

When treating of the anthracite basins, in our general descriptions of the Coal-measures of Pennsylvania, it was shown that the deepest of these, the Southern or Pottsville Field, embraced not less than fifty coal-seams, including beds of all dimensions, of which about *twenty-five* are of workable size. In the account of the bituminous coal strata of Western Pennsylvania, some nine or ten workable beds are shown to exist in that district, in a thickness of less than 2100 feet of strata; the same number can be identified in North-western Virginia, and probably in South-eastern Ohio, where the strata crop out on the opposite side of the Great Basin. A less and less number will be found to prevail as we trace the coal-field S.W. to the intersection of the Tennessee River. It will appear hereafter that the Coal-measures of Western Kentucky, belonging to the S.E. end of the Great Illinois basin, contain about *seventeen* workable coal-beds in a thickness of more than 3400 feet of Coal-measures; and it will also be seen that the still more W. coal-field of Missouri and Iowa exhibits, on the Missouri River, where the formation is obviously in full development, not more than *seven* or *eight* coal-seams of a size fit for mining, and that these are included in about 700 feet of strata.

This striking interruption to the law of a declining gradation W., in respect both of the aggregate depth of the Coal-measures and the number of included coal-seams presented by the Western Kentucky coal-district, is not a little anomalous, and suggests a doubt whether an error may not have been committed by the explorers of that coal-field, leading to an over-estimate of the thickness of the formation. It is a region intersected by a series of dislocated undulations of the strata, and by several faults of considerable magnitude; and it is quite possible that through one or both of these sources of fallacious measurement certain parts of the Coal-measures may have chanced to be counted more than once.

The reader will find the composition of the coal strata of the Appalachian basin described at length in the Introduction to Book VIII. of this work, and again in the introductory Chapter of Book IX., on the Bituminous Coal-measures of Western Pennsylvania.

The limits of the several groups of the bituminous Coal-measures are indicated minutely on the Geological Map of Pennsylvania. To trace them in detail through the basin would demand a much more elaborate description than is compatible with the plan of this general outline. It will suffice for the present purpose to sketch the general boundary of the base of the upper productive group, or that which, in the ascending order, commences with the Great Pittsburg Coal-seam.

The basin or area of the Pittsburg Coal, and of all the Coal-measures which overlie it, has its Northern boundary in Western Pennsylvania, a little North of latitude 40° 30′. This boundary extends from Saltzburg, on the Connemaugh River, W. across the Alleghany River below Tarentum, and the Ohio River, near Little Sewickly Creek, in Alleghany County; and bending a little Southward, it recrosses the Ohio a short distance N. of Steubenville.

From the river-hills near Steubenville the margin of the upper productive group pursues a very nearly S.W. course to McConnellsville, on the Muskingum River, ranging through Jefferson County, the S.E. corner of Harrison, the N.W. corner of Belmont, and through Guernsey into the centre of Morgan. From the Muskingum it trends more nearly S., encroaching gradually towards the Ohio River, passing a little East of the town of Athens, and through the S.W. corner of Meigs County, and through Gallia County to the Ohio River, which it reaches a little above Burdington. The outcrop of the Pittsburg Coal-seam crosses the Ohio River near Brownsville, between the mouths of the Sandy and the Guyandotte rivers, and, curving rapidly towards the E., it sweeps across the Guyandotte, near the falls of that river, taking a nearly due East course thence to the Great Kenawha, the valley of which stream it passes below Charleston. Before reaching the Great Kenawha the line we are tracing turns N., and pursues an undulating N.E. direction parallel to the general course of the Elk River as far as Sutton in Braxton County, Virginia. From Elk River its general course is nearly N.N.E. to Pennsylvania; but the precise line of the outcrop is excessively winding, in consequence of the deeply-excavated character of the high sloping table-land through which it meanders E. of the valley of the Monongahela River; in this part of its course it traverses Braxton, Lewis, Barbour, Taylor, and Monongalia counties. From the point where it enters Pennsylvania, this margin of the upper Coal-measures pursues a very nearly straight course close along the base of Chestnut Ridge or West Laurel Hill, passing a little East of Uniontown, McConnellsville, Youngstown, and Blairsville, near which last-named place it reaches the N. boundary at the point from whence we set out.

The Pittsburg Coal, or main upper seam which constitutes the lower limit of the upper Coal-measures, evidently underlies every part of the large area thus defined: and this area appears to amount to about 14,000 square miles, of itself a very noble coal-field. Of course, each of the overlying coal-beds of the upper group possesses successively a less and less extent. It is probable that more than one of the thicker coal-beds of the lower Coal-measures have a continuous elliptical outcrop like the Pittsburg Seam, but this latter is at present the only member of the formation, the continuity of which has been positively established over so wide an area; and it is on this account particularly interesting—not merely as the widest seam of pure coal hitherto brought to light, but as manifesting in its broad extent and in the singular persistency of its characters and subdivisions, the wonderful uniformity of all the physical conditions under which its materials were accumulated. This prodigious floor of coal does not hold everywhere the thickness it possesses in South-western Pennsylvania, but undergoes a very gradual progressive reduction of size as it advances S.W. and S.; it declines, indeed, to a thickness of little more than 3 feet near the S. end of the oval basin which it occupies.

It is worthy of note that these upper Coal-measures bear the marks of having been formed under a considerably more uniform and tranquil condition than that which attended the deposition of the groups beneath them. Thus, not only do the sandstones, shales, and limestones maintain a more constant type, but the individual coal-seams themselves appear to fluctuate less in their dimensions and composition. This greater constancy of character is probably connected with a more marine or less littoral origin, as evinced in a larger proportion of limestones and other oceanic deposits, in a finer state of comminution of the land-derived sediments, and especially in a greater abundance of marine forms among the fossils. The evidences of these differences between the upper and lower Coal-measures may be abundantly seen in the detailed descriptions of them as they appear in Pennsylvania.

CHAPTER III.

ILLINOIS AND INDIANA COAL-FIELD.

General Description.—This great coal-field, embraced between the wide anticlinal area of the middle and older Palæozoic rocks of Indiana and Middle Kentucky on the E., and the anticlinal belt of Carboniferous limestones of the Upper Mississippi on the W., is an immense tract of coal strata occupying the S.W. counties of Indiana, the Green River country of Kentucky, and a very large area of the extensive State of Illinois. The Coal-measures, or proper coal-formation, thus geographically defined, fill a tract of a somewhat regularly oval form, the longer diameter of the ellipse extending in a N.W. direction from near Morgantown in Kentucky to the Mississippi River, below Rock Island—a length of 375 miles. The greatest breadth of the elliptical coal-field is from Greencastle, W. of Indianapolis, to St Louis on the Mississippi, a distance of 200 miles. A careful estimate of its surface, as it is represented on the Geological Map, gives it an area of not less than 51,000 square miles.

According to Dr Norwood, workable beds of coal do not underlie the whole area thus estimated, and usually indicated on the maps as Coal-measures: he says,—

"Illinois is not one 'great coal-field,' as has been represented in maps and geological reports made previous to the commencement of the State Geological Survey. While it contains within its borders more coal than any other State in the Union, with, perhaps, the exception of Pennsylvania, the coal does not rest in one great basin. So far as the State Survey has thrown any light on the subject, it has been found that the rocks beneath the Coal-measures, instead of showing a nearly horizontal section from E. to W., as was formerly believed by some of our geologists, have been in reality as much disturbed by internal convulsions as those of any volcanic district in the United States. The beds of the lower formations, including the mountain limestone and millstone grit, are found, at various localities, displaced and tilted up at every angle from a few degrees to the vertical. These displacements are not confined to any one section: they occur in every district, from the N. limits of the coal-beds to the S. border of the State. In the irregular valleys and basins formed by these disturbances, our lower Coal-measures were formed. Subsequent to that period, the then existing coal-beds were displaced and eroded, forming new valleys and new basins which have been filled with new deposits of coal, and so on, up to the termination of the carboniferous epoch. An outline of these basins and valleys, so far as ascertained, will be given in the Geological Report. It must, however, remain imperfect for years to come, as every re-examination of a coal-field develops new facts, which no reasoning from previous data could have brought to light." *

As regards the coal-field itself, it has the structure of a comparatively shallow and rather symmetrical oval basin, or broad synclinal trough, with a general inward dip of the strata from all parts of the periphery towards the centre; but it is, as we have seen, not exempt from local undulations, containing, on the contrary, especially near its S.W. border, several wide anticlinal waves.

The greater part of the margin of the Illinois coal-field is bordered by a concentric outcrop of the Upper Carboniferous limestone, which, commencing N. of the Illinois River near La Salle, sweeps round the N.E. corner of the coal-field in a narrow belt, gradually widening in a S.E. direction until it crosses the Ohio River into Kentucky. From the Green River of Kentucky this limestone girdle trends in an undulating course W., N.W., and N., to the vicinity of Iowa City, passing the Ohio River in Hardin County, the Big Muddy River in Jackson, and the Mississippi River near the mouth of the Missouri; thence the belt runs N. between the coal-field and the Mississippi, which it crosses just above the Iowa River to enter the State of that name. The N. border of the coal-basin does not appear to be similarly confined by an outcrop of the carboniferous limestone, but is in contact with Palæozoic strata of the age of the Vergent or Chemung rocks, equivalents of the Middle Devonian strata of Europe.

The precise limits of the coal-bearing strata, for every part of the circumference of the basin, have not yet been established with precision; but we shall not err very widely if we define their boundary as ranging S.E. from the Illinois River, near the towns of Morris in Grundy County, Middleport, Iroquois, Covington, Greencastle, and Spencer, and thence, in a more nearly Southward line, to Rome on the Ohio River, and to Hardinsburg and Morgantown in Kentucky. From Morgantown, its general course is N.W., passing S. of Greenville and N.W. of Marion. Re-crossing the Ohio River into Illinois, it passes near the Sulphur Springs in Williamson County by Waterloo in Monroe, and near to Alton and Carrolton, until it crosses the Illinois River; beyond this it passes Beverley, and runs E. of Carthage and a little W. of Monmouth, until it meets the Mississippi River near Muscadine. Here the margin of the Coal-measures appears to deflect suddenly towards the E., and to extend parallel with the S. bank of the Mississippi River nearly to Rock Island, where, leaving the river, it stretches almost due E. across the State of Illinois to a point on the Illinois River a little N. of Ottowa, passing in its course a little N. of the town of La Salle.

The more prominent undulations in the S.W. boundary of the coal-field adjoining the Mississippi River would seem to be produced by tongues of the carboniferous limestone penetrating Northward into the general area of the coal-rocks, resulting from an undulation of the formations before the deposition of the coal.

* See *Abstract of a Report on Illinois Coals*, page 91. By J. G. Norwood, M.D., State Geologist.

I shall now proceed to offer a more detailed description of two or three of the better-explored local districts of this wide coal-field, commencing with a sketch of the strata as they are seen in Kentucky, the part nearest to the Great Appalachian coal-field already described.

WESTERN KENTUCKY COAL-FIELD.

Limits.—According to the Geological Report of Dr David Dale Owen, who has made a systematic survey of this coal-field of Western Kentucky, the portion of the Great Basin lying within that State covers the whole of eight counties, and a part of four others. The following is his description of its approximate boundaries :—

"Commencing at the Ohio River, at the mouth of Tradewater, it runs up the valley of that stream, whose course very nearly coincides with its S.W. limits. From near the sources of Tradewater, in the N. part of Christian County, its S. boundary runs by the head-waters of Pond River, near the lines dividing Muhlenburg, Todd, Logan, and Butler counties, crossing Muddy River near its forks; thence through the S. part of Butler County, crossing Barren River between the mouth of Jasper River and the junction of Barren River and Green River; thence E. along the divide between those rivers, through Warren and Edmondson counties, to near the mouth of Nolin Creek; thence nearly N. to the mouth of Dismal. Either an outlier or tongue of the Coal-measures appears to stretch away to the E., to the confines of Grayson and Hart counties, and even on to the waters of Roundstone; but the main boundary takes from Dismal Creek a N.W. course S. of Grayson Springs, near the sources of Clay Lick and Caney Creeks, towards the falls of Rough Creek; thence N. by the sources of Panther Creek, nearly along the line dividing Hancock and Breckinridge counties, until it strikes the Ohio River again at the Great South Bend, near the limits of the above counties."

The formation is divisible into two groups, an upper and a lower set of Coal-measures; these are separated by a conspicuous sandstone called the "Anvil Rock." They are also geographically divided by a dislocated anticlinal axis, extending in a S.E. direction from Gold Hill, in Illinois, across the Ohio River at Shawneetown to Bald Hill in Union County. This dislocation casts off the Upper Coal-measures to the N., and the Lower to the S.

The subdivisions of the formation have been ascertained with approximate accuracy by surface measurements and borings, the general results of which are as follows: The estimated total thickness of the carboniferous strata in this coal-field is 3429 feet; the Lower Coal-measures, including the "Anvil Rock," being 1029, and the Upper Coal-measures about 2400 feet.

The number of coal-seams in the lower group amounts to *ten*, and all of these, excepting one called the "Curlew Bed," are workable. There are eight workable seams in the upper group, distributed through a thickness of about 2000 feet of strata. The upper 600 feet of the formation contain but one workable bed situated near the base of this division, which, however, includes nine other very thin bands of coal.

The united thickness of all these coal-seams, counting the thin ones with the thick, is upwards of 40 feet.

The accompanying columnar sections (Figs. 768, 769) will serve to convey a correct general notion of these Coal-measures.

In the W. portion of the coal-field the strata are thrown into "a series of waves or wrinkles, or into elongated dome-shaped vaults and corresponding depressions." One synclinal fold exists in the valley of Hines Creek; another trough or fold of depression enters the productive coal-field between Locust-Lick Creek and Tradewater River, and another at Half-Moon Lick on the Tradewater, extending nearly E. to Crab Orchard Creek. Between these are anticlinal flexures, forming with them a succession of waves.

Composition of the Coal.—The coal of this field is, for the most part, a tolerably pure bituminous coal, varying in specific gravity from 1.28 to 1.40, yielding generally from 50 to 60 per cent of coke. The average amount of volatile matter exceeds 40 per cent, and that of the ashes 5 or 6 per cent. The *colour* of the ashes or earthy matter of the lower group of coals is various, being, according to the seam, light-grey (corresponding to the white-ash of the lower anthracite beds), reddish-grey, and pale flesh-colour. A solid cubic foot of the coal weighs about 80 lb., and a cubic foot in lumps about 45 lb. The coal of some of these seams approaches in its qualities the splint coals of Scotland, having their dull aspect, and retaining, when coked, nearly the original shape of the coal. The reader will find the composition of several of these Kentucky coals in the table of "Analyses of Coals" in a future chapter.

"The compact slaty varieties of coal, like the Breckinridge Cannel Coal, yield about 60 per cent of volatile matter; the parrot coal, and even the bituminous shales, afford a vegetable tar, or thick crude oil, from which two products can be obtained; one of an oily consistence, which may be clarified into a nearly colourless oil, that, for certain purposes, may be substituted for other more expensive animal and vegetable oils; the other a transparent, scaly, crystalline substance, of a white colour and waxy lustre, which melts at 110° into a transparent oil, and at a still higher temperature takes fire and burns with a white flame, without smoke, and leaves no residue. This substance was called by the discoverer, M. Reichenbach, of Blansko, paraffin, from its little tendency to combine with other bodies.

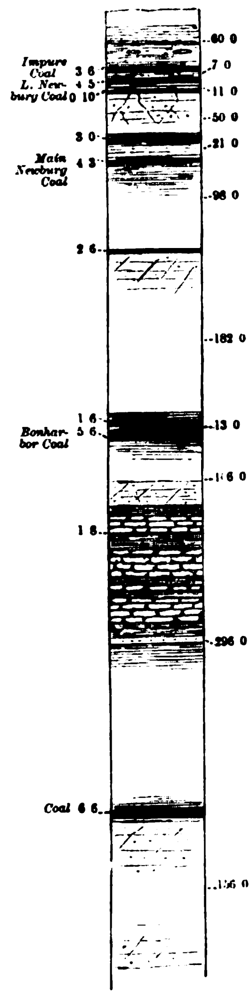


FIG. 768.—Upper Coal-measures, Holloway's Borings, Henderson County, Kentucky. From D. D. Owen. —200 *feet* = 1 *inch.*

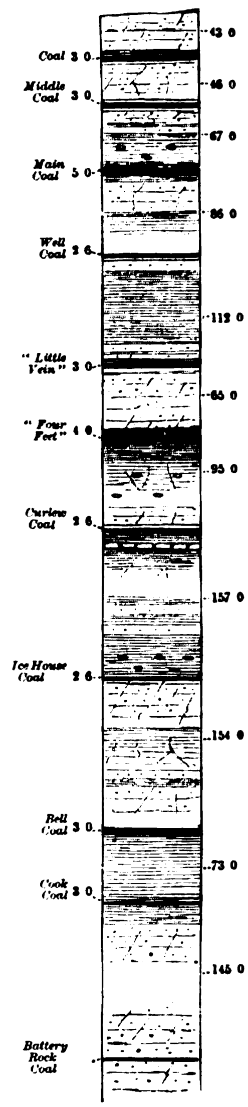


FIG. 769.—Lower Coal-measures of Kentucky. From D. D. Owen.—200 *feet* = 1 *inch.*

"It is supposed that the Breckinridge Coal may yield 25 per cent of refined oil, and 18 per cent of paraffin."

Iron Ores.—The intercalated shales of the Western Kentucky Coal-measures contain a fair proportion of the argillaceous iron-ores or clay iron-stones generally characteristic of Coal-measures. As generally in the Appalachian coal-field, these iron ores are most abundant in the lower group. They occur in the form of bands and flattened or kidney-shaped lumps. One stratum, a 10-feet-thick bed of shale, overlying a coal called the "Ice-House Seam," includes seven or eight thin bands of such iron ore, estimated to amount, in the aggregate, to a thickness of 16 inches. This ore is slightly calcareous, and well adapted to smelting, and promises to yield between 30 and 40 per cent of iron.

Other important beds of iron ore occur in the lower Coal-measures in Muhlenburg and Hopkins counties. "Considerable quantities of carbonate of iron are interstratified in the shales overlying the 'Thirteen-inch Coal' near low-water mark at Coal Haven and the head of French Island."

Limestones.—Bordering the Ohio River, the upper 400 feet of the Coal-measures are rich in limestones, there being five or six separate beds in this space; one of these, 8 feet thick, appears in the bank of the river one mile below Uniontown; another, 7 feet thick, occurs opposite Diamond Island; and a third bed, 8 feet thick, is in the hills of Green River near its mouth. Only two beds of limestone, worthy of note, are included in the lower 900 feet of the Coal-measures. One of these, 4 feet thick, lies below the "Curlew" Coal; the other overlies the coal next under the "Anvil Rock." It is stated that "the lower S. Coal-measures are richer in limestones than their S.W. equivalents."

The coal-seams of the Kentucky coal-field repose, in almost every instance, on a bed of fire-clay more or less pure, containing remains of the *Stigmaria ficoides*, or the roots of *Sigillaria*, one of the chief coal-producing plants of the coal period.

In 1857 there were eighteen coal-mines in operation on the Lower Ohio in this coal-field, though some of them were wrought on a very limited scale.

Undulations.—Two opposite views of the undulations of the Illinois coal-field have been entertained by the Western geologists, some explorers conceiving that the Coal-measures occur in detached basins, reposing unconformably upon the upturned edges of older Palæozoic strata, others believing that the basin structure is due to denudation upon the summits of anticlinal waves, embracing both those older rocks and the coal-formation. Both views would appear to be correct, for in the W. part of the Kentucky coal-field, the undulations of the Coal-measures involve the subjacent Middle and Lower Palæozoic rocks, whereas near La Salle, on the N.E. border of the Illinois portion of the basin, there prevails an actual unconformity of the Coal-measures to the subjacent strata. The probability is, that while some portions of the wide floor of the older rocks upon which the Coal-measures were deposited were disturbed from their original horizontality before the deposition of the coal, the whole coal-field was itself disturbed and undulated after the Coal-measures were formed, and the more exposed anticlinal waves were more or less denuded and separated.

Very little information has as yet been given to the world concerning the structure and contents of the middle tracts of this broad coal-field of Illinois. It has been stated that there exists in the interior of the basin a group of overlying strata referable by their organic remains not to the true Carboniferous formation, but to the still higher Permian series. But until the evidence from the fossils can be thoroughly sifted, we must remain in doubt whether to rank this upper group of strata as a higher division of the coal-formation, or as the representative of a separate and later age. According to Professor James Hall,* "the Coal-measures extend much farther to the N. than the Northern limits of the carboniferous limestones, and are spread out over the thinning and slightly-inclined edges of these beds, and over the more disturbed and more highly elevated edges of the rocks of the preceding periods, so that the Coal-measures rest respectively upon all the formations, from the lower Silurian to the carboniferous limestones." Dr J. G.

* See J. Hall "On Carboniferous Limestones of Mississippi Valley," in *Silliman's Journal*, vol. xxiii. p. 191.

Norwood reports that the coal-field is not a continuous one, but is broken into local patches by uplifts of the Carboniferous limestone. He describes the lower Coal-measures as deposited in basins thus produced, and as having undergone a subsequent disturbance, and states that this fracturing and filling up of the newly-formed valleys with fresh deposits of the coal strata, proceeded alternately to the end of the Carboniferous period.* According to Mr Worthen, the State Geologist, the general strike of the anticlinal axes disturbing the coal-field is N.W. and S.E.; parallel, that is to say, with the average longer diameter of the whole coal-basin, and not with the undulations of the Appalachian Chain. The same direction of the flexures has been noticed by Professor Hall in his traverse of the valley of the Upper Mississippi.

La Salle Coal-Field.—This N.E. division of the Great Illinois Coal-basin displays—according to Dr Norwood, who first made the discovery—the Coal-measures resting unconformably on the inclined strata of the Lower Silurian or older Palæozoic formations. The sandstone floor of the Coal-measures is in actual contact in some places with the Matinal (Trenton) limestone, identifiable by its fossils. The coal-field of La Salle is described by J. W. Foster, Esq.,† as occupying trough-like depressions in the older formations. The lowest seam sometimes reposes immediately on the edges of the older rocks, and at other times has a parting of shale. It is 3½ or 4 feet thick. An interval of 176 feet filled with shale, limestone, and thin beds of sandstone, separates it from the middle coal-bed, which is 6 feet thick, and contains a foot or more of cannel coal. Another space succeeds, containing a similar alternation of strata of 53 feet, surmounted by the upper coal-seam, which is nearly 4 feet thick. In this portion of the coal-field the strata dip at a very gentle rate, seldom much exceeding 5° towards the S.W. It is stated that these beds reappear in the cliffs of the Big Vermilion River.

According to Mr Foster, the coals of La Salle belong to the class of dry bituminous coals, their volatile matter amounting to from 25 to 30 per cent, uncombined water to more than 10 per cent, fixed carbon to from 50 to 60 per cent, and earthy matter 5 or 10 per cent.

The geographical positions of the Kentucky field in the S., and of the La Salle coal-field in the N., both occupying wide and comparatively unoccupied coal-markets, must promote the early and rapid development, by mining, of these interesting divisions of the basin; but the day cannot be distant when nearly every part of this great central coal-field of the Union will be much more thoroughly explored, and its vast stores of fuel made subservient to the demands of industry.

CHAPTER IV.

IOWA AND MISSOURI COAL-FIELD—GENERAL DESCRIPTION.

This very extensive coal-field stretches in a S. direction from the interior of Iowa across the Des-Moines and Missouri rivers to the lower valley of the Neosho in the Cherokee country, W. of Arkansas, where it appears to connect itself with the coal-field of the last-named State and the

* See *Abstract of a Report on Illinois Coals, &c.* Chicago, 1858.

† See *Report upon the Mineral Resources of the Illinois Central Railroad.* New York, 1856.

Indian territory. It is a rudely elliptical area, widest in the N., and contracting rapidly towards the S.W., in consequence of the S.W. trend of the older rocks which form its S.E. boundary in Missouri.

This coal-field is described by Dr D. D. Owen * as having in Iowa alone an average width from E. to W. of less than 200 miles; an average length of 140 miles, and an area of 25,000 square miles.

It is bounded, according to him, by an irregularly undulating line, as follows :—

"Commencing where the line between Iowa and Missouri crosses the Des-Moines River, near the W. border of Lee County; thence, nearly North, to the N.E. corner of Washington County; thence with a N.W. curve to the Iowa River, which it crosses in Township 81, North range 8 West, of the 5th Principal Meridian, not far from the line between Johnson and Iowa counties; thence up the valley of the Iowa some 25 miles, when it recrosses that river near the S.E. corner of Tama County; thence curving through Tama County, and again crossing the Iowa to near the centre of the E. line of Marshall County; thence along the water-shed of the Iowa and Cedar, recrossing the former near the N.E. corner of Township 87, North range 30 West, of the Principal Meridian; thence with a W. curve up the Iowa, and continuing W. of that river to the Big Woods, where it recrosses for a few miles, returning to the W. side of that stream, and running in a nearly due West course to the Des-Moines, which it crosses six miles above the Lizard Fork; thence with a S.W. curve towards the head-waters of the Three Rivers; thence down the valley of Neshnabotna to the State line.

"After crossing the Iowa boundary-line into Missouri, the boundary-line of this coal-field bears nearly S. through Clark, Lewis, and Marion counties, to near the junction of the Three Forks of Salt River. Thence through the W. part of Ralls County towards the head waters of Rivière au Cuivre, in the E. part of Audrain County, and N.W. corner of Montgomery County. Thence it sweeps in a South-westerly curve through Calloway County towards the Missouri River, which it crosses near its confluence with the Osage, leaving a belt of country, some 90 miles wide, between this coal-region and the outcrops at Charbonnière, and the coal-pits worked on Rivière des Péres, in St Louis County. These are, in fact, outliers of the Illinois coal-field. From the Missouri River the boundary bears, with a Westerly curve, up the valley of the Osage, N. of that river, which it crosses, but for a very limited distance only, at three points; in Camden County, near the mouth of the Niangua; in St Clair County, near the mouth of Sac River; and in Bates County, near the confluence with the main river of the Little Osage. Thence the line bears, with a Northerly curve, towards the W. confines of Fayette, recrossing the Missouri at Wellington, thence up the valley of that river to the State line, keeping from 10 to 25 miles from the river."

Later researches by the geologists of Missouri † indicate that the Coal-measures spread some distance into Nebraska and Kansas, or to the W. of the Missouri River, between the mouth of the Platte and the valley of the Neosho, but the W. limit of the productive coal-field has not yet been well defined.

Professor Swallow, in his Reports on the Geological Survey of Missouri, defines the area covered by the Coal-measures as bounded by a line drawn from the N.E. corner of Marion to the middle of the W. boundary of Jasper counties. This is the average boundary, "for the older rocks come to the surface in many places on the N.W. side of this line, as in the valleys of the Mississippi and Salt rivers, and of the Missouri as high up as Miami, in Saline County; while the coal strata are known to cover large areas in St Louis, St Charles, Calloway, Montgomery, Audrain, and Ralls counties to the S.E. of it." He estimates the area of the Coal-measures within the State as exceeding 26,887 square miles.

* See Owen's *Geological Survey of Wisconsin, Iowa, and Minnesota.* Philadelphia: Lippincott, Grambo, and Co.

† See *First and Second Annual Geological Reports of the Survey of Missouri*, by G. C. Swallow, State Geologist.

SUBDIVISIONS OF THE COAL-MEASURES.

Professor Swallow, in his Report, groups the coal-formation of Missouri into three subordinate series, the dividing rocks being two important sandstones. The lower series ranges N.E. from the S.W. corner of the State of Missouri, through Jasper, Bates, Sinclair, Henry, Benton, Morgan, Cooper, Boone, Calloway, Audrain, Monroe, Shelby, Marion, Lewis, and Clark, or from the Neosho to near the mouth of the Des-Moines, the S.E. margin forming one border of the coal-field.

It would seem that the Coal-measures, as they are intersected by the Missouri River, exhibit a prevailing Westerly dip, and do not present a regular synclinal structure or basin form, as indicated on the Geological Map of Dr D. D. Owen. The middle series, as a consequence, occupies the more central parts of the coal-field; it crosses the Missouri River between the mouth of the Kansas and the mouth of the Chariton, and ranges S. to Henry County, and N. and N.E. to the Grand and Chariton rivers. This middle group is well exposed in the sides of the Missouri Valley, near Lexington.

The upper or third division of the Coal-measures spreads along the Missouri River between Lexington and the mouth of the Platte, and is exposed at many localities between this last-named river and the Kansas, as at Parkville, Leavenworth, Weston, Elizabethtown, and Dallas.

Recent researches in Kansas have shown that these supposed Upper Coal-measures are overlaid in their turn by a still higher group of strata, recognisable by their organic remains as bearing an affinity to the Permian strata of Europe; but as no stratigraphical break or unconformity of any kind has been detected separating this later series of beds from the recognised Coal-measures, and as many of their fossils belong to the true Carboniferous species, the individuals of which, moreover, greatly exceed in number those of Permian analogies, it becomes us to be cautious in displacing these rocks from the proper Coal-measures to which they may possibly belong as a member of the American carboniferous system of deposits.

COMPOSITION OF THE COAL-MEASURES.

The *Lower Series* of the Missouri coal strata appear, according to the statements of Professor Swallow, to be inconstant in their lithological characters and their thickness. Between Booneville and the mouth of the La Mine their total thickness is about 150 feet; they there include six seams of coal, the lowest of which is 3 feet thick, and the fifth in ascending order 6 feet thick, while the other four are of dimensions less than 1½ feet. The other strata are chiefly bituminous shale, except that a bed of hydraulic limestone underlies the thickest of the coal-seams.

The Middle Coal-measures consist of brown and grey argillaceous sandstones, blue and yellow shales, and compact blue and buff limestones. Three permanent thin seams of bituminous coal occur in the shales of this group, and occasionally other still smaller layers. These rocks are less fossiliferous than the upper series. Their average thickness is about 200 feet.

The Upper Coal-measures consist of blue and grey bituminous shales, grey and buff limestones, and soft shaly sandstones, with several very thin layers of coal. Thin seams of coal occur also in the bituminous shales; but this division of the formation nowhere contains a coal-bed of sufficient thickness to admit of profitable mining. This series is estimated to have a thickness of about 300 feet.

It would appear from the foregoing statements that the total thickness of the Coal-measures on the Missouri River is 650 feet. On the line of the Hannibal and St Joseph Railroad their thickness is apparently 739 feet.

ORGANIC REMAINS.

According to the Report of Professor Swallow, the fossils become progressively more abundant as we ascend from the lowest to the highest strata of the Coal-measures; several species, however, *Fusulina cylindrica, Terebratula subtilita*, &c., are found throughout the three divisions.

The organic remains of these Missouri Coal-measures * consist of—

CRINOIDEA; 4 species of the genera *Echinocrinus, Poteriocrinus, Actinocrinus.*

ZOOPHYTES; 4 species of the genera *Chætetes, Zaphrentis, Campopyllum, Ceripora.*

BRACHIOPODA; 27 species of the genera *Productus, Chonetes, Orthis, Spirifer, Terebratula, Discina.*

ACEPHALA; 16 species of the genera *Allorisma, Myalina, Avicula, Pecten, Leda, Tellinomya, Cardiomorpha, Cardinia, Cypricardia, Arca, Pinna.*

GASTEROPODA; 12 species of the genera *Straparollus, Bellerophon, Turbo, Pleurotomaria, Loxonema, Murchisonia, Nerita, Fusulina.*

CEPHALOPODA; 5 species of the genera *Nautilus, Goniatites, Orthoceratites.*

CRUSTACEA; 1 species of the genus *Phillipsia.*

FISHES; teeth and bones of undetermined genera.

PLANTS; 4 species of the genera *Calamites, Sphæreda, Sigillaria, Lepidodendron.*

There are some remarkable deposits of coal and coal-shale in Missouri, detached from the general coal-field, and lying in very abnormal positions in ravines and excavations among the older formations as low as the Calciferous sandstone of the Auroral series; and it is a curious fact, that all the cannel coal hitherto discovered belongs to these insulated deposits. These outlying coal-beds, though usually circumscribed in extent, are in many cases of excellent quality, and of sufficient magnitude for mining.

IRON ORES.

The Coal-measures of Missouri are alleged to be generally deficient in the iron ores characteristic of other coal-fields. No deposits of clay iron-stone, or argillaceous protocarbonate of iron, have been met with of sufficient magnitude to be of any practical value.

CHAPTER V.

MICHIGAN COAL-FIELD.

THE next principal coal-field of the United States is that which occupies the interior of the Southern peninsula of Michigan. It is a broad, shallow coal-basin of an approximately circular outline, centrally situated between Lake Huron and Lake Michigan, and covering all the

* See Catalogue by Dr Shumard, page 16; *Geological Survey of Missouri.*

central counties of the State from Saginaw Bay on the E. to Wexford, Lake, Newago, and Kent counties on the W., and extending S. from the Manistee River to the head-waters of the Kalamasoo River. The E. margin of the Coal-measures, starting at Saginaw Bay in Huron County, runs S., trending a little W. through Tuscola County, passing the N.W. corner of Napier and the S.W. corner of Genessee, and through the W. side of Livingstone to the E. border of Jackson County. There the boundary curves W., and, crossing the S. portion of that county, deflects N.W., to maintain this latter direction through Calhoun and Barry to the Grand Rapids of the Grand River; passing which, its course is N. through Kent, Newago, and Lake, into Wexford, where it reaches the Manistee River. North of this stream it bends rapidly to the E., recrossing it in Kalkasta County, and extending through Crawford, near the E. border of which it bends again to run S.E. through Ogemaw and Losco counties to Saginaw Bay, which it reaches W. of Shawtimiog Point. The area of Coal-measures thus circumscribed is estimated at from 12,000 to 15,000 square miles. The S.E. and S.W. borders of the coal-field are marked by a narrow outcrop of the Carboniferous limestone, a formation which, in some localities, contains beds of gypseous shales, imbedding large cakes of plaster-of-Paris. Of the interior of the coal-field very little is known geologically. It is believed to embrace but few beds of coal of workable dimensions, probably only two or three. The strata, for the most part horizontal, or gently and widely undulated, consist mainly of shales and argillaceous sandstones. A general mantle of drift, or loose fragmentary matter, concealing the foundation-rocks of the country, and the surface being still further masked by a close covering of herbage and forest, the geological structure of this coal-field remains as yet very imperfectly known. We are led from general considerations, especially from the relationships of the strata underlying this coal-field to those which pass beneath the Great Appalachian and the Illinois basins, to conjecture that, at the termination of the coal period, or before the denudation of those lower rocks, these Michigan Coal-measures were continuous with those of the two other coal-fields; but more exact geological investigations are required before this and some other interesting questions in the geology of the country between Lake Erie and Lake Michigan can be satisfactorily settled.

It is stated that coal outcrops at three different points—namely, at Barry in Jackson County, at Red Cedar River in Ingham County, and at Shiawassee River. The coal is compact and lustrous, ignites easily, and burns with a light flame, leaving but a small amount of ashes.

TABLE

SHOWING THE CHEMICAL CONSTITUTION AND PHYSICAL CHARACTERS OF THE BEST-KNOWN COALS OF NORTH AMERICA.

(BRITISH PROVINCES.)

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific gravity.	Volatile matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.	Sulphur.		
"Main Seam," Sydney,	...	26.93	67.57	5.50	...	Prof. W. R. Johnson.	A bright free-burning coal, leaves a heavy reddish ash.
Carribou Cove, Richmond District,	...	25.2	44.7	30.1	...	Prof. J. W. Dawson.	A mixture of coal and bituminous shale.
Little River, Carribou Cove,	1.38	...	...	...	...	Do.	Hard, with uneven fracture, lamination rather indistinct; kindles quickly, and swells and cakes; ashes brownish.
Albion Coal, Pictou,	1.32	30.11	61.09	8.80	...	Do.	Is free from sulphur, but yields much light bulky ash; affords a good vesicular coke.
Pictou,	...	29.63	56.98	13.39	...	Prof. W. R. Johnson.	
Joggins Main Seam,	...	38.8	56.0	5.2	...	Prof. J. W. Dawson.	A bright coal; some iron pyrites and calcareous matter in its joints.
Springhill,	...	30.2	56.6	13.2	...	Do.	Compact, lustre rather dull, contains some sulphur.
Albert Mine,	1.09	57.6	42.4	.27	...	Hayes and Jackson.	Conchoidal, lustre resinous and shining, powder black, very brittle.
(UNITED STATES.)							
Hard Anthracites. — Rhode Island,	1.79	3.00	77.00	16.00	...	Hayes.	
PENNSYLVANIA.							
Nesquehoning, 10-feet vein,	...	6.40	86.60	7.00	...	Geol. Survey, Penn.	Columnar, conchoidal, greyish black, splendent; ashes, white.
Summit Mines of the Lehigh Company,	...	7.50	88.50	4.00	...	Do.	Massive, compact, black, brilliant; ashes, dull white.
Summit Mines, Lehigh Company,	...	6.60	87.70	5.70	...	Do.	Dense, laminated, somewhat conchoidal, black, splendent; ashes, white.
Tamaqua Coal D East,	1.57	5.03	92.07	2.90	...	Do.	Compact, slaty, conchoidal, greyish black, splendent; ashes, white.
Tamaqua Coal E East,	1.60	4.54	89.20	6.26	...	Do.	Compact, conchoidal, greyish-black, splendent; ashes, pure white.
Tamaqua Coal R, Sharp Mountain,	1.55	7.55	87.45	5.10	...	Do.	Compact, greyish-black, splendent.

	Names and Localities of Coals.	Composition.					Authorities.	Remarks.
		Specific gravity.	Volatile matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.	Sulphur.		
Hard Anthracites.	Tuscarora,	...	7.50	88.20	4.30	...	Geol. Survey, Penn.	Slightly laminated, compact, irregularly conchoidal, black, splendent; ashes, pinkish-brown.
	Beaver Meadow,	1.55	2.52	90.20	6.13	...	Prof. W. R. Johnson.	
	Schenoweth Bed, East Norwegian,	1.50	1.40	94.10	4.50	...	Do.	Compact, black, splendent; ashes, light brown.
	Third Coal, Nealy's Tunnel, near Pottsville,	1.55	5.40	89.20	5.40	...	Do.	Compact, iron-black, conchoidal, splendent; ashes, pale yellow.
	Forest Improvement,	1.47	3.07	90.70	4.41	...	Do.	
	Sharp Mountain, North of Pinegrove,	1.54	7.15	80.57	3.28	...	Geol. Survey, Penn.	Laminated, grey-black, splintery, splendent.
	Lyken's Valley,	1.39	6.88	83.84	9.25	...	Prof. W. R. Johnson.	
	Shamokin,	...	6.10	89.90	4.00	...	Do.	Massive, laminated.
	Black Spring Gap,	1.44	9.53	82.47	8.00	...	Do.	Friable, iron-black, somewhat splendent; ashes, yellowish white.
Semi-Anthracites.	Black Spring Gap, "Lea Vein,"	1.35	8.96	88.84	5.20	...	Do.	Laminated brittle black, shining; ashes, cream-colour.
	Black Spring Gap, "Grey Vein,"	1.44	9.78	81.62	9.20	...	Do.	Massive, black; ashes, light orange.
	Lyken's Valley, "Third Bed,"	...	8.85	88.25	2.90	...	Geol. Survey, Penn.	Laminated, brittle, fibrous, jet-black, shiny.
	Zerbe's Run,	1.40	7.31	84.25	6.11	...	Hayes, Mean of 5 Analyses.	
	Wilkesbarre, "Warden's Bed,"	1.40	7.68	88.90	3.49	...	Geol. Survey, Penn.	Compact, conchoidal, iron-black, splendent.
	Carbondale,	1.40	7.07	90.23	2.70	...	Do.	Laminated, compact, iron-black, brilliant; ashes, grey.
	Black Spring Gap, "Grey Band of Grey Vein,"	1.33	11.40	81.40	7.20	...	Do.	Fibrous, brittle, grey-black, smutty, dull, metallic lustre; ashes, pale ochreous yellow.
	Gold Mine Gap, "Peacock Vein,"	1.41	10.95	82.15	6.90	...	Do.	Massive, slightly columnar, black, shiny; ashes, pale orange.
	Gold Mine Gap, "Heister Vein,"	1.41	10.43	81.47	8.10	...	Do.	Massive, striated, jet-black, shining; ashes, pale yellow.
	Rausch Gap Dauphin, "Peacock Vein,"	1.45	10.57	77.23	12.30	...	Do.	Massive, friable, columnar, black; ashes, pale orange.
	Yellow Spring Gap,	1.41	10.95	79.55	9.50	...	Do.	Slaty, brittle, black, shining; ashes, pale yellow.
	Rattling Run, Dauphin,	...	13.75	74.55	11.70	...	Do.	Massive, fracture regular, black, shining, lustre feeble, yields a light and spongy coke.
Bituminous Coals. Semi-Bituminous, Cumberland (Maryland).	Big Flats,	...	15.06	76.94	8.00	...	Do.	Massive, laminated, striæ small, jet-black, much lustre, yields a good coal; ashes, orange.
	Broad Top (Hopewell Mine),	...	11.20	88.80	4.00	...	Do.	Somewhat columnar; yields a spongy coke.
	Blossburg,	1.32	15.27	73.11	10.77	0.85	Do.	
	Lycoming Creek,	1.38	14.48	71.53	13.96	0.03	Do.	
	New York and Maryland Mining Company,	1.43	14.10	73.50	12.40	...	Prof. W. R. Johnson.	
	Neffs,	1.33	15.13	74.53	10.34	...	Do.	
	Easby's "Coal in Store,"	1.30	15.65	76.27	8.08	...	Do.	
	Atkinson and Templeman's,	1.31	15.98	76.69	7.33	...	Do.	
	Easby and Smith's,	1.33	16.42	74.29	9.29	...	Do.	
	"Cumberland" (Navy Yard),	1.41	17.28	68.44	13.98	0.71	Do.	
	Lick Run, Lycoming County,	...	20.72	79.28	13.07	...	Do.	Laminated, somewhat brittle, shining, black.
	Queen's Run, below Farrandsville,	...	21.50	78.28	4.60	...	Do.	Irregularly columnar, brittle, jet-black, thin films of charcoal.
	Snoe Shoe Mine,	...	21.20	78.80	2.07	...	Do.	Massive, brittle, irregular, fracture tendency to columnar structure, jet-black.

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific gravity.	Volatile matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.	Sulphur.		
Bituminous Coals.							
Moshannon Creek, near Philipsburg, ...	...	29.50	70.50	6.10	...	Prof. W. R. Johnson.	Small columnar, somewhat fibrous, striæ distinct, jet-black.
Steed's Mine, 16 miles from Philipsburg, .	...	20.40	79.60	120	...	Do.	Friable, irregularly columnar, striæ distinct, jet-black.
Leech's Mine, 17½ miles from Philipsburg, . . .	...	20.32	79.68	11.75	...	Do.	Friable, structure columnar, jet-black.
Upper part of large bed, Ralston, ...	...	20.50	79.50	5.00	...	Do.	Columnar, irregular cubical, shining black.
Karthaus Lower Seam, . .	...	24.80	75.20	4.70	...	Do.	Columnar, cubical, friable, jet-black.
Reed's 6-feet Vein, Curwinsville, ...	...	27.00	73.00	5.30	...	Do.	Columnar, cubical, brittle, jet-black, with great lustre.
Bear Creek, Blossburg, . .	...	32.00	68.00	5.20	...	Do.	Columnar, somewhat compact thin seams of charcoal, lustre jet-black.
Warner's 5-feet Vein, Caledonia, ...	...	37.00	63.00	8.50	...	Do.	Laminated, cubical, brittle, jet-black.
Warner's 3-feet Seam, Caledonia, . . .	...	38.20	61.80	7.20	...	Do.	Soft, columnar, jet-black, fracture irregular.
Blairsville Large Bed, . .	...	31.00	69.00	4.00	...	Do.	Laminated, columnar, hard, compact, shining, jet-black.
Sandy Ridge, 4 miles from Shippensville, . . .	...	43.20	56.80	7.00	...	Do.	Massive, striæ indistinct, fracture cubical, black, lustre feebly shining.
Cannel Coal, from 6 miles East of Franklin, . .	...	52.78	47.22	17.68	...	Do.	Composed of laminæ, breaks with uniform cleavage, conchoidal, dull-black, with little lustre.
Cannel Coal from Greensburg,	...	36.00	64.00	33.88	...	Do.	Thick regular laminæ, cross fracture, conchoidal, surface smooth, dull black.
Conneaut Lake, ...	...	38.75	61.25	1.80	...	Do.	Slaty, laminated, somewhat brittle, jet-black.
Near Greenville, ...	...	40.50	59.50	1.7	...	Do.	Laminated, slaty, cross fracture, splintery, brittle, jet-black.
Near Orangeville, ...	...	43.75	56.25	2.80	...	Do.	Laminated, rusty between laminæ, black, sometimes iridescent.
VIRGINIA.							
Little Sewell, ...	...	17.48	80.24	2.28	...	Prof. W. B. Rogers.	Shining and dull-black laminæ.
East side of Big Sewell, Rogers' Seam,	...	22.32	75.88	1.80	...	Do.	Shining jet-black laminæ, some dull-black.
West flank of Big Sewell, Tyree's Bed,	...	30.08	67.84	2.08	...	Do.	Dull-black laminæ.
Between Big Sewell and Kenawha, Paris and Wood's Bank, Mill Creek, Fayette County,	...	26.20	71.88	1.92	...	Do.	Shining black laminæ, films of charcoal.
Valley of the Kenawha. Lower Coal Series. Keller's Creek, Lowest Seam,	...	37.08	60.92	2.00	...	Do.	Brilliant, compact.
L. Ruffner's Campbell Creek, or Second Seam,	...	32.44	55.76	11.80	...	Do.	
Noyes, Rand, & Co.'s Campbell Creek or Second Seam,	...	31.28	65.64	3.08	...	Do.	
Cox and Hannah's Third Seam,	...	42.55	51.41	6.04	...	Do.	Black, shining, compact.
Faure's Bank, Upper Seam, .	...	35.04	53.20	11.76	...	Do.	
Smither's Bank, ...	...	29.76	54.52	15.76	...	Do.	
Hughes Bank, ...	...	32.88	62.32	4.80	...	Do.	Brilliant, compact.
Daniel Ruffner's Upper Seam, .	...	35.08	57.28	7.64	...	Do.	
Brantzburg, Lower Seam, North Branch of Potomac,	...	19.72	72.40	7.88	...	Do.	
Oliver's Tract, 12-feet Seam, .	...	16.28	79.08	4.64	...	Do.	
Sigler's Mine, near Westernport, Maryland, 12-feet Seam,	...	15.76	82.60	2.64	...	Do.	

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific gravity.	Volatile matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.	Sulphur.		
Lonaconing, Maryland, 12-feet Seam,	...	19.37	77.43	3.20	...	Prof. W. B. Rogers.	
Kitzmiller's, Hardy County, .	...	15.48	79.76	4.76	...	Do.	
Falls of Stony River, Hardy County, Lower Seam, . .	...	15.52	79.16	5.32	...	Do.	
Stony River, 1 mile North of Turnpike, ...	...	13.28	83.36	3.36	...	Do.	
Colonel Fairfax's Kingwood Basin, Upper Seam, ...	...	31.75	53.77	14.48	...	Do.	
Do. do. Middle Seam, 2½ miles from Kingwood, ...	...	27.77	65.32	6.91	...	Do.	
Forman's Basin, South-East of Kingwood Basin, . . .	...	21.00	73.68	5.32	...	Do.	
Forman's Mill, Big Sandy, 1 mile from Brandonville, Preston County, Middle Seam, . .	...	22.40	67.60	10.00	...	Do.	
Mr Seaport's Big Sandy Basin, West side of Big Sandy River,	...	27.12	66.64	6.24	...	Do.	
Mr Hagan's Kingwood Basin, 1 mile West of Kingwood, . .	...	26.48	68.32	5.20	...	Do.	
Mr Cresap's, three-fourths of a mile South-West of Kingwood,	...	30.24	64.24	5.32	...	Do.	
Main Seam, Clarksburg Upper Coal series, ...	...	41.66	56.74	1.60	...	Do.	
Main Seam, near the middle, Clarksburg, ...	...	45.43	49.21	5.36	...	Do.	
Main Seam, Pruntytown (same with the Clarksburg Seam), .	...	39.00	57.60	3.40	...	Do.	
Main Seam, Morgantown (same with the preceding), . .	...	37.30	60.54	2.14	...	Do.	
Judge Summer's Bank, Coal Creek, Kenawha, . . .	...	41.85	55.55	2.60	...	Do.	Compact, thin laminæ, striated, shining, jet black.
Judge Summer's Vein, Grand Creek, Kenawha, ...	...	43.20	52.75	4.05	...	Do.	Compact, fracture irregular, jet black.
Wolf Creek, half a mile above the Burning Spring, Big Sandy, .	...	48.00	47.15	4.85	...	Do.	Laminated, shining, jet black, striæ indistinct.
Big Coal River, 5 miles above the junction of the two branches,	...	47.10	50.20	2.70	...	Do.	Cleaves into laminæ, jet shining black, striæ indistinct.
Three-Mile Creek, Kenawha County, ...	...	50.30	45.95	3.75	...	Do.	Semi-compact, laminated, dull-black.
Lawson's Opening, Logan Court-house, ...	...	39.50	58.35	2.15	...	Do.	Massive, shining jet black.
Traa Fork, Guyandotte, . .	...	42.00	56.50	1.50	...	Do.	Massive, columnar, dull-black.
Pigeon Creek, Big Sandy River,	...	41.00	55.00	4.00	...	Do.	Shining jet black, laminæ.
Coals of the Chesterfield, Powhatan, Goochland, and Henrico Basins. — Coals from South side of James' River: Clover Hill, . .	...	33.04	56.83	10.13	...	Prof. W. R. Johnson.	
Mid-Lothian, . .	...	32.09	63.11	4.80	0.99	Do.	
Stonehenge, . .	...	36.50	58.70	4.80	...	Prof. W. B. Rogers.	Ashes, light reddish.
Engine Shaft, Maidenhead, . . .	...	32.83	63.97	3.20	...	Do.	Ashes, strong red.
Engine Shaft, worked by Heth, Potts, & Co.,	...	37.65	62.35	2.80	...	Do.	Ashes, reddish yellow.
Wills's Pit, . .	...	32.50	62.90	4.60	...	Do.	Ashes, light brown.
Colonel Heth's deep shaft, bottom of the seam, . . .	...	35.82	53.36	10.82	...	Do.	Ashes, light pinkish-brown.
Powhatan Pits, . .	...	32.33	59.87	7.80	...	Do.	Ashes, pale buff.
Winterpock Creek, Appomatox River, Mr Cox's Mine, . .	...	29.12	65.52	5.36	...	Do.	
Coals from near the North side of James' River: Anderson's Pit, First Seam in Shaft,	...	28.30	66.78	4.92	...	Do.	Ashes, light grey.
Barr's Pits, First Seam, . . .	...	24.00	70.80	5.20	...	Do.	Ashes, faint red.
Deep Run Pits, .	...	25.16	69.84	5.00	...	Do.	

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific Gravity.	Volatile Matter in 100 parts.	Fixed Carbon in 100 parts.	Earthy Matter in 100 parts.	Sulphur.		
KENTUCKY.							
"Thirty-Inch Coal," near Racoon Creek, Greenup County,	1.32	41.20	50.20	8.60	1.44	Dr D. D. Owen.	Slaty, tough, dull-black. A splint coal.
Racoon Creek, under part of 8 to 10 inch Coal, near Racoon Furnace,	1.39	35.50	55.30	9.20	0.45	Do.	A dry splint coal; ashes nearly white.
Bottom part of Main Peach Orchard Coal, Lawrence County,	1.27	38.6	58.55	2.85	...	Do.	
Main Ashland Coal, below the clay-parting, Greenup County,	1.33	44.1	51.4	4.5	...	Do.	Ashes, reddish-grey.
Crawford's Cannel Coal, near Grayson, Carter County,	1.21	59.0	34.5	6.5	...	Do.	Ashes, flesh-colour.
Gairt's Main Coal, Big Sandy, 5-Mile Shoal, Lawrence County,	1.30	41.2	53.8	5.0	...	Do.	Ashes, light grey.
McHenry's Coal, Tugg Fork of Big Sandy, Lawrence County,	1.31	40.0	50.0	10.0	...	Do.	Ashes, whitish grey.
Aron's and Bogg's Coal, Big Sandy Coal, and Mining Company, Floyd and Johnson Counties,	...	35.2	63.8	1.0	...	Do.	Ashes, flesh-coloured.
Main Ashland Coal, above clay-parting, Greenup County,	1.28	38.30	57.90	3.80	0.73	Do.	Soft, "fat," bituminous, deep pitch-black, strong lustre; ashes, purplish grey.
Coal, with slate roof, first bed above Ashland Main Coal, Greenup County,	1.30	40.70	51.00	8.30	1.81	Do.	Intensely black coal, high lustre; ashes, lilac-coloured.
Kilgore's Coal, William's Creek, Carter County,	1.31	41.00	55.00	4.00	0.71	Do.	A splint coal, pitch-black, lustrous; ashes, pale grey.
Cannel Coal from Barrett's Creek, Carter County,	1.44	37.50	42.70	19.80	8.00	Do.	Dull, slaty, jet-like lustre; ashes, dark lilac colour.
Airdrie Coal, 6¼ feet thick, Muhlenburg County,	1.22	48.40	48.50	3.10	1.35	Do.	Pure, soft, friable, shining pitch-black; ashes, reddish grey.
Eade's Coal, 2½ miles S.W. of Greenville Muhlenburg County,	1.26	40.40	56.10	3.50	0.65	Do.	Ashes, purplish.
Clark's Coal, Pond River, Muhlenburg County,	1.34	33.30	59.20	7.50	0.55	Do.	Friable, dull, fragmentary; ashes, nearly white.
Todd and Crittenden's Coal, Owsley County,	1.29	36.80	57.10	6.43	0.33	Do.	Pitch-black, much lustre, fibrous, splint coal; ashes, nearly white.
Cannel Coal from Haddock's Mine, Owsley County,	1.21	50.00	47.00	3.00	0.24	Do.	Tough, pitch-black, conchoidal; ashes, buff-coloured.
Coal, Cumberland River, Whitley County,	1.29	39.00	57.00	4.00	...	Do.	Ashes, light grey.
Cannel Coal, Dorton's Branch, Cumberland River,	1.25	42.9	55.1	2.0	...	Do.	Close-textured, concentric-structured, brilliant, conchoidal; ashes, orange-coloured.
Coals of Edmondson County, First Coal,	1.29	40.0	40.0	20.0	...	Do.	
Coals of Edmondson County, Second Coal,	1.29	45.2	53.8	5.0	...	Do.	
Main Coal, Giger's Hill, Catlettsburg, Greenup County,	1.21	40.00	57.80	2.20	0.26	Do.	Bituminous, pitch-black, strong lustre; ashes, yellowish grey.
Coal from Hoskin's Mine, Short Mountain,	1.33	37.8	55.2	7.0	...	Do.	Ashes, purplish grey.
Coal, Kincheloe's Bluff, or Lewisport, Green River,	1.27	43.0	55.0	2.0	...	Do.	
Colonel Martins' Coal, above Prestonburg, Big Sandy,	...	38.0	61.0	1.0	...	Do.	
Pittsburg Coal,	1.29	31.70	65.30	3.00	0.05	Do.	Pure-looking, pitch-black, much lustre; ashes, yellowish grey.
Lower part of First Coal under the Anvil Rock, Union County,	1.36	39.6	47.4	13.0	...	Do.	Ashes, reddish grey.
Mr Hawes' Main Coal, Howesville, Hancock County,	1.39	47.0	46.0	7.0	...	Do.	Ashes, white.
Roberts' Coal, Muddy River, Muhlenburg County,	1.21	41.48	54.72	3.80	...	Do.	Ashes, white.

Names and Localities of Coals.	Composition. Specific Gravity.	Volatile Matter in 100 parts.	Fixed Carbon in 100 parts.	Earthy Matter in 100 parts.	Sulphur.	Authorities.	Remarks.
Captain Davis' Jakefield Coal, Hopkins County,	1.29	43.75	50.75	5.50	...	Dr D. D. Owen.	Ashes, nearly white.
Gamblin Coal, Hopkins County,	1.27	42.47	56 13	1.40	...	Do.	Ashes, pale flesh-colour.
Box Mountain Spring Coal, Hopkins County,	1.33	40.75	50.25	9.00	...	Do.	Ashes, light greyish flesh-colour.
Captain Davis' Pigeon Run Coal, Hopkins County,	1.28	46.8	49.7	3.5	...	Do.	Ashes, white.
Big Sandy Main Coal, Lawrence County,	...	35.2	63.8	1.0	...	Do.	
Cook's Coal, Green River, Henderson County,	...	44.5	47.0	8.5	...	Do.	
Bonharbor Coal, Daviess County,	1.27	48.3	46.7	5.0	...	Do.	Ashes, light grey, almost white.
Two inches of coal on the top of Bonharbor Coal,	1.52	38.0	37.0	25.0	...	Do.	Hard, close-textured, compact, cannel-like.
Wolf Hill Coal, Daviess County,	1.22	42.4	56.6	1.0	...	Do.	
Two-feet Henderson Coal, equivalent of the Little Newbury,	...	45.5	44.5	10.0	...	Do.	Ashes, grey.
Gallion's Coal, William's Creek, Carter County,	1.31	45.80	49.50	4.70	2.41	Do.	Pitch-black, strong lustre; ashes, dark lilac colour.
Keath's Coal, near Pond River, N.E. part of Christian County,	1.30	43.90	48.90	7.20	2.16	Do.	Soft, friable, dull, pitch-black; ashes, pale reddish grey.
Lacey's Atchison's Coal, Pond River, N.E. part of Christian County,	1.27	41.70	53.30	5.00	1.36	Do.	Soft, bituminous, pitch-black, lustrous; ashes, lilac-coloured.
Robert and A. G. Carter's, Bath County,	1.32	38.00	53.90	8.10	0.99	Do.	A splint coal, fibrous, pitch-black lustre; ashes, light-grey colour.
Mulford's Main or Five-feet Coal, Union County,	1.30	39.5	57.5	3.0	...	Do.	
Bell's Coal, Crittendon County,	1.27	39.4	57.6	3.0	...	Do.	Ashes, pale flesh-colour.
Mulford's Four-foot Bed of Coal, Union County,	1.28	42.4	50.6	7.0	...	Do.	Ashes, light grey.
"Little Vein," Mulford's Mine, Union County,	1.30	36.7	55.3	8.0	...	Do.	Ashes, light grey.
Little Vein, Cannel part,	1.36	40.3	47.7	12.0	...	Do.	
Mulford's Middle Coal, Union County,	1.40	38.7	51.3	10.0	...	Do.	Ashes, reddish grey.
Ice-House Coal, Union County,	1.34	36.5	58.5	5.0	...	Do.	Ashes, reddish grey.
Upper part of First Coal under the Anvil Rock, Union County,	1.28	51.3	42.3	9.0	...	Do.	Ashes, reddish grey.
Wright's Mountain Coal, Hopkins County,	1.28	41.40	56.30	2.30	0.10	Do.	Pure-looking, soft, friable; ashes, dark grey.
Robinson's Coal, Clear Creek, Hopkins County,	1.27	45.50	51.10	3.40	1.56	Do.	Soft, pitch-black; ashes, reddish grey.
Pond River Coal, near McNary's, Hopkins County,	1.29	40.30	53.50	6.20	1.12	Do.	Ochreous, pure, pitch-black, lustrous; ashes, dark brick red.
Tygert's Coal-bank, Hickory Camp Creek, Butler County,	1.29	38.60	56.90	4.50	0.29	Do.	Friable, pitch-black; ashes, light yellowish grey.
Pardon Sheldon's Coal, Welch Creek, Butler County,	1.24	38.70	60.70	0.60	0.26	Do.	Pure-looking, soft, pitchy-black, strong lustre; ashes, dirty salmon colour.
Sneed's Coal Mines, Tradewater, Crittenden County,	1.31	37.00	55.40	7.60	1.04	Do.	Very black, pure, bituminous; ashes, purplish grey.
Caseyville, Cannelton Coal,	1.39	31.82	44.49	23.69	...	Prof. W. R. Johnson.	
INDIANA.							
Cannelton,	...	38.16	58.34	3.50	...	Do.	
SOUTHERN ILLINOIS.							
Saline River, Galatin County, Upper Bed,	...	42.4	56.1	1.5	...	Dr Norwood.	
Saline River, Second Bed,	1.28	36.8	55.2	8.0	...	Do.	

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific Gravity.	Volatile Matter in 100 parts.	Fixed Carbon in 100 parts.	Earthy Matter in 100 parts.	Sulphur.		
Saline River, lowest bed worked,	1.29	40.8	55.5	3.7	...	Dr Norwood.	
Saline River, Upper Bed Lock Reserve,	1.30	39.2	57.8	3.0	...	Do.	
Eagle Creek, Galatin,	1.23	37.0	57.2	5.8	...	Do.	Ashes, grey.
Bowles,	1.30	39.8	53.2	7.0	...	Do.	Ashes, white.
Equality, Lower Bed,	1.29	35.8	52.2	12.0	...	Do.	
Equality, Upper Bed,	1.30	37.7	59.8	2.5	...	Do.	
Equality, Top Bed, Martin's,	1.27	40.66	51.92	6.7	...	Do.	Ashes, drab.
Coal Branch of Bankston Creek, Saline County,	1.28	39.08	50.6	9.6	...	Do.	
Hay's Mill, Little Saline River, Saline County,	1.49	32.04	57.6	10.0	...	Do.	Ashes, dark red.
Dr Smith's, Williamson County,	1.31	40.1	51.92	8.7	...	Do.	Ashes, reddish brown.
Spiller's, Williamson County,	1.28	43.1	54.9	2.0	...	Do.	
Joel Johnson's, Johnson County,	1.44	25.6	47.84	27.1	...	Do.	Ashes, white.
Murphreysboro', Jackson County,	1.29	37.7	60.8	1.5	...	Do.	
Shasteen, Hamilton County,	1.32	38.94	53.56	7.5	...	Do.	Ashes, pale brown.
Du Quoin, Perry County,	1.28	48.9	48.1	3.0	...	Do.	Ashes, grey.
Schneider's, Munroe County,	1.24	42.9	52.6	4.5	...	Do.	Ashes, white.
Schneider's, Lower Bed,	1.28	41.0	52.2	6.8	...	Do.	
Caseyville, Six-Feet Bed, St Clair County,	1.30	39.8	55.2	5.0	...	Do. Do.	Ashes, pale red.
Pfeiffers, St Clair,	1.29	44.3	51.2	4.5	...	Do.	Ashes, red.
Belleville, St Clair,	1.26	45.0	49.6	5.4	...	Do.	Ashes, grey.
Belsha's Middle Drift, St Clair,	1.29	43.66	47.74	8.6	...	Do.	Ashes, grey.
Dilg and Kempff's, Belleville, Middle St Clair,	1.38	42.38	49.02	8.6	...	Do.	Ashes, white.
Dilg and Kempff's Top Coal, St Clair,	1.28	45.54	47.66	6.8	...	Do.	Ashes, white.
Dilg and Kempff's Bottom Coal, St Clair,	1.35	39.63	36.77	23.6	...	Do.	Ashes, grey.
W. B. Churchill's, St Clair,	1.31	45.4	45.7	8.9	...	Do.	Ashes, white.
Jeffrey's, Madison County,	1.28	48.75	47.35	3.9	...	Do.	Ashes, grey.
Cartlidge's, Madison,	1.31	44.39	45.01	10.6	...	Do.	Ashes, grey.
Groshang's, Madison,	1.32	37.55	54.85	7.6	...	Do.	Ashes, brown.
Dumford's, near Alton, Madison,	1.25	47.26	47.44	5.3	...	Do.	Ashes, grey.
Emerson and Ryder's, Madison,	1.31	42.6	53.9	3.5	...	Do.	Ashes, reddish brown.
Wood River, Middle Bench, Madison,	1.31	50.0	42.7	7.3	...	Do.	Ashes, pink.
Wood River, Upper Bench,	1.29	55.3	37.2	7.5	...	Do.	Ashes, grey.
Cook's, Madison,	1.30	51.15	38.85	10.0	...	Do.	Ashes, grey.
Edwardsville, Madison,	1.34	46.85	49.75	3.4	...	Do.	Ashes, purplish.
MIDDLE ILLINOIS.							
Johnson's, Calhoun County,	1.26	45.7	49.1	5.2	...	Do.	Ashes, brown.
Near Carbinville, Macoupin,	1.27	43.48	48.72	7.8	...	Do.	Ashes, grey.
Houseworth's, near Pittsfield, Pike County,	1.22	49.5	45.5	5.0	... ...	Do.	Ashes, white.
Jackson's, near Pittsfield,	1.77	14.1	56.9	29.0	...	Do.	Ashes, grey.
Drake's, Green County,	1.30	40.47	48.93	10.6	...	Do.	Ashes, grey.
Sander's, North of Springfield, Langamon County,	1.24	48.14	42.86	9.0	...	Do.	
Springfield, Langamon,	1.28	53.9	42.8	3.3	...	Do.	Ashes, dark grey.
Puffenberger's, Langamon,	1.26	50.68	43.62	5.7	...	Do.	Ashes, dark brown.
Pleasant View, Schuyler County,	1.28	40.6	52.9	6.5	...	Do.	Ashes, deep red.
Rushville, Schuyler County,	1.30	41.6	46.1	12.3	...	Do.	Ashes, white.
Exeter, Scott County,	1.28	42.37	50.13	7.5	...	Do.	Ashes, red.
Barker's, Scott County,	1.23	42.8	52.2	5.0	...	Do.	Ashes, light brown.
Frost's, Scott County,	1.28	46.37	46.53	7.1	...	Do.	Ashes, red.
Higby's, Adams County,	1.33	48.4	41.2	10.4	...	Do.	Ashes, yellow.
Bassett's, Adams County,	1.26	42.52	51.48	6.0	...	Do.	Ashes, pale red.
Payne's, in entry, Vermilion County,	1.28	47.0	47.5	5.5	... ...	Do. Do.	Ashes, grey.
Payne's, in outcrop, Vermilion,	1.26	46.1	43.9	10.0	...	Do.	Ashes, grey.
Henson's, Vermilion,	1.31	43.5	50.0	6.5	...	Do.	
Lafferty's, Six-Feet Bed, Vermilion,	1.28	44.3	48.7	7.0	...	Do.	Ashes, grey.

Names and Localities of Coals.	Composition.					Authorities.	Remarks.
	Specific Gravity.	Volatile Matter in 100 parts.	Fixed Carbon in 100 parts.	Earthy Matter in 100 parts.	Sulphur.		
Carother's, Vermilion,	1.21	50.8	46.2	3.0	...	Dr Norwood.	Ashes, greyish white.
Gilbert's, Vermilion,	1.21	51.4	45.6	3.0	...	Do.	
Butler's, Vermilion,	1.39	40.1	47.9	12.0	...	Do.	Ashes, grey.
Leonard's, Vermilion,	1.31	45.57	48.93	5.5	...	Do.	Ashes, white.
William's, Vermilion,	1.22	49.15	45.85	5.0	...	Do.	
Alexander's, Vermilion,	1.26	43.5	40.5	16.0	...	Do.	
Russell's, Vermilion,	1.21	49.0	39.0	12.0	...	Do.	Ashes, grey.
Chicago and Danville Coal Company, Vermilion,	1.23	49.04	48.96	2.0	...	Do.	Ashes, bluish grey.
Cook's, Vermilion,	1.33	47.3	47.7	5.0	...	Do.	Ashes, reddish grey.
Eli Thornton's, Vermilion,	1.40	42.27	55.73	2.0	...	Do.	Ashes, red.
J. H. Blackmore's,	1.29	44.5	47.10	8.4	...	Do.	Ashes, reddish grey.
Colchester, McDonnough County,	1.29	41.2	56.8	2.0	...	Do.	Ashes, light grey.
Opposite Peoria, Tazewell County,	1.26	43.4	48.6	8.0	...	Do.	Ashes, grey.
Salem Hill, Menard County,	1.26	46.0	51.2	2.8	...	Do.	Ashes, very dark red.
NORTHERN ILLINOIS.							
Kickapoo, Peoria County,	1.28	47.7	46.3	6.0	...	Do.	Ashes, grey.
McMurtry's, Knox County,	1.21	50.5	45.5	4.0	...	Do.	Ashes, nearly black.
Loomis, Wataga, Knox,	1.28	44.4	51.1	4.5	...	Do.	Ashes, pink.
Loomis, Cannel Coal, Knox,	1.33	42.4	33.6	24.0	...	Do.	Ashes, grey.
Smith's, Warren County,	1.24	43.1	51.7	5.2	...	Do.	Ashes, red.
Tucker's, Warren,	1.22	44.8	51.0	4.2	...	Do.	Ashes, red.
Sheffield, Bureau County,	1.19	47.5	47.5	5.0	...	Do.	Ashes, white.
Tiskilwa, Bureau County,	1.36	43.0	48.9	8.1	...	Do.	Ashes, white.
Rock Island, Shale, Rock Island County,	1.44	31.3	46.7	22.0	...	Do.	Ashes, light red.
Carbon Cliff, Rock Island,	1.24	43.7	52.8	3.5	...	Do.	Ashes, white.
Corcoran's, Rock Island,	1.26	47.2	50.3	2.5	...	Do.	Ashes, black.
Robbin's, Henry County,	1.22	49.7	47.1	3.2	...	Do.	Ashes, blackish grey.
Aldrich's, Henry,	1.26	43.1	49.9	7.0	...	Do.	Ashes, brown.
Kewanee, Henry,	1.23	42.2	52.8	5.0	...	Do.	Ashes, grey.
Geneseo, Henry,	1.32	41.24	52.76	6.0	...	Do.	Ashes, brown.
Thornton and Park's, Mercer County,	1.24	45.8	49.7	4.5	...	Do.	Ashes, white.
Perley's Ottawa, La Salle County,	1.26	43.7	52.3	4.0	...	Do.	Ashes, white.
Ward's, Marseille's, La Salle,	1.31	45.6	33.4	21.0	...	Do.	Ashes, white.
Hitt's Vermilion Mine, La Salle,	1.29	46.9	40.3	12.8	...	Do.	Ashes, white.
Kirkpatrick's, Big Vermilion, La Salle,	1.20	48.2	49.3	2.5	...	Do.	Ashes, grey.
Ireland's, La Salle,	1.23	46.7	50.3	3.0	...	Do.	Ashes, grey.
Seeley's Lowell, La Salle,	1.22	42.6	41.4	16.0	...	Do.	Ashes, bright brick red.
Kirkpatrick's Cannel Coal, La Salle,	1.43	39.6	30.4	30.0	...	Do.	Ashes, grey.
Eagle Creek, La Salle,	1.22	46.7	45.8	7.5	...	Do.	Ashes, dark red.
Buffalo Rock, La Salle,	1.28	45.0	50.5	4.5	...	Do.	Ashes, pale red.
Big Vermilion, La Salle,	1.24	51.4	47.1	1.5	...	Do.	
Egleston's Cannel Coal, La Salle,	1.41	44.5	41.5	14.0	...	Do.	
Field and Round's, La Salle,	1.22	48.1	46.7	5.2	...	Do.	Ashes, red.
Kirkpatrick's Cannel Coal, La Salle,	1.26	45.2	40.1	14.7	...	Do.	Ashes, blackish grey.
Egleston's, La Salle,	1.21	48.25	48.45	3.3	...	Do.	Ashes, grey.
Hartshorne's, La Salle,	1.27	42.5	49.7	7.8	...	Do.	Ashes, brown.
Kentucky's Coal Mining Company, Upper Bed, La Salle,	1.25	52.51	40.49	7.0	...	Do.	Ashes, brown.
Gorbett's, La Salle,	1.25	45.18	47.12	7.7	...	Do.	Ashes, red.
Kentucky Shaft, La Salle,	1.26	42.93	50.07	7.0	...	Do.	Ashes, purplish.
Peru, La Salle,	1.53	28.68	40.32	31.0	...	Do.	Ashes, brown.
Watson's, Grundy County,	1.25	45.5	47.8	6.7	...	Do.	Ashes, pink.
Turner's, Morris, Grundy,	1.22	48.5	49.0	2.5	...	Do.	Ashes, white.
Eight Miles South-West of Wilmington, Grundy,	1.21	47.95	49.15	2.9	...	Do.	
MISSOURI.							
Osage River,	1.20	43.50	51.16	5.34	...	Prof. W. R. Johnson.	

BRITISH COAL-FIELDS.

The Carboniferous System of Great Britain occupies the Western and Midland parts of the Island, extending, with slight interruptions, from South Wales, or the Bristol Channel, to the estuaries of the Firth of Clyde in Scotland. This Carboniferous system succeeds the Devonian or Old Red Sandstone formation, which, in its turn, reposes on the older Palæozoic or Silurian system. In England the Carboniferous system is generally composed of five groups of strata, the whole of which, however, are not always present in particular localities. They are as follows, beginning with the uppermost :—

1. Coal-seams, alternating with sandstone and shale.
2. Millstone-grit.
3. Yordale rocks, shales, limestone, and gritstones.
4. Scar limestone, or mountain limestone.
5. Shales. ... ...

The Carboniferous or Mountain Limestone forms the base of the Coal-measures. In North and South Wales, in Derbyshire, Somersetshire, and Gloucestershire, it forms one unbroken band, with a thickness varying from 1900 feet to 400 and 500 feet, and frequently rises to the surface. As it passes N., however, through Lancashire, Cumberland, and Northumberland, to the Tweed, it becomes more and more divided by beds of sandstone and shales, till at Aldstone Moor no less than twenty of these bands, having an aggregate thickness of 470 feet, are found alternating with shales and coal-seams.

Throughout all this range, though the aspect of the limestone varies somewhat, yet it preserves nearly a uniform mineral character. It is nearly a pure carbonate of lime, of a greyish or bluish-grey colour, passing to blocks of considerable hardness, and with a conchoidal fracture. Many varieties, on being rubbed or bruised, exhale a fœtid odour. Sometimes it contains an admixture of clay and of carbonate of magnesia, at other times it forms with sandstone a brecciated mass. It is full of organic remains, chiefly *corals, encrinites, Producta, Spiriferæ, Terebratulæ,*— all indicative of its marine origin.

Solid bitumen is frequently found imbedded in this limestone. Chert nodules, and other silicified masses, are prevalent ; and in Derbyshire the limestone is intersected by an igneous rock called Toadstone.

The Yordale rocks, common in Derbyshire and Yorkshire, consist of shaly limestone of a black or brown colour, and a micaceous gritstone, with an average thickness of 500 feet. The dark argillaceous limestone contains an abundance of marine shells, *Goniatites, Orthoceratites,* and *Posidoniæ,* having their cavities filled with liquid bitumen. It is of importance to notice that the lower coal-shales of Ireland contain exactly similar beds of bituminous shaly limestone as the above.

Millstone-Grit.—This sandstone bed, immediately below the coal-seams, is a coarse-grained sandstone, identical in its component parts with the sandstones of the coal strata. It is made up of quartz pebbles, of various sizes under that of an egg ; of felspar, in small rounded masses, having internally a crystalline structure ; and of pale silvery fragmentary scales of mica sparingly intermixed ; the whole cemented by a soft, whitish, unctuous mass of decomposed felspar.

The millstone-grit of the S. of England is more compact, harder, and more cherty than the coarse pebbly conglomerate of the N. districts ; it furnishes a good building-stone in Yorkshire, Lancashire, and Derbyshire, and under the name of "Farewell Rock" in Dean Forest and South Wales, is a valuable stone for the construction of iron furnaces, as it is found to resist great heat.

The Coal-Measures.—These consist of alternating strata of sandstone, shale, coal, and ironstone.

The sandstone beds, of varying thickness, consist of the same materials as the millstone-grit, but are generally softer and more argillaceous. They both indicate an origin from decomposed granites, or similar crystalline rocks. Iron nodules, marine shells, *Goniatites, Unios, Pectens,* and, in some localities, shells of fresh-water molluscs, together with the usual fossil plants of the coal-formation, are common to the true Coal-measures, as well as the accompanying shales, grits, and sandstones.

The chief workable coal-fields of Great Britain consist of the South Wales basin, the Dean Forest, Gloucestershire, the great central and Western coal-field extending through Nottinghamshire, Derbyshire, Yorkshire, Durham, Northumberland, and on the West through Cheshire, Lancashire, Westmoreland, Cumberland, a distance of 200 miles in length, with an average breadth of 60 miles ; the coal-fields of Berwickshire and Dumfriesshire in Scotland, and the great Scottish basin, extending from the mouth of the Firth of Forth on the E., to the mouth of the Clyde on the W. shores.

The Great South Wales Coal-Field.—This extensive deposit occupies the N.W. portion of the Bristol Channel, extending from St Bride's Bay on the W., to Pontypool on the E., a distance of 90 miles, the maximum breadth being about 60 miles. It is divided into two parallel basins by a longitudinal axis of elevation. The depth from the carboniferous limestone to the uppermost coal-series is computed at 12,000 feet,* and the depth of the true Coal-measures 8000 feet. There are 23 beds of workable coal, with an aggregate thickness of 92 feet—12 beds are from 3 to 9 feet thick, 11 from 18 inches to 3 feet, with numerous others from 6 to 18 inches thick.

The nature of the coal varies at different points even in the same beds. On the N.E. side is a coking coal, well suited for the manufacture of iron ; on the N. the coal or culm is an anthracite ; on the S. side, from Pontypool to Caermarthen Bay, it is of a bituminous quality.

There are at least sixteen layers of ironstone and iron nodules in thin beds. No trap-dykes or igneous rocks in any form enter this basin, though syenitic rocks adjoin it in Pembrokeshire.

The South Wales coals are shipped for the supply of the S.W. coast of England, and for Ireland, as also Spain, France, Malta, and Egypt.

Home consumpt and exports in 1841, ... 4,800,000 tons.
Price of anthracite coal from 8s. to 10s. per ton ;—other coals from 7s. to 10s. and 11s. per ton.

The Welsh semi-bituminous coal is similar to that of Pennsylvania, and is in request as steam coal.

Anthracite is employed largely in South Wales in the iron manufactories, which have of late years rapidly multiplied there.

In 1854 the amount of anthracite coal raised in Glamorgan and Pembroke shires was .	1,000,000 tons.
Of bituminous coal from Monmouth and Glamorgan shires, ...	7,500,000 „
There were exported by sea, coastwise, in the same year, of coals, coke, and culm, .	2,065,957† „
Exported to foreign countries, do., ...	829,058 „

North Wales Basin.—This basin lies S. of the estuary of the Dee in Flintshire, and extends from N. to S. upwards of 30 miles. The coal shales rest upon the Silurian slate of Selattyn Mountain, and dip generally E., forming, in the N. part, a trough below the estuary of the Dee ; from thence they rise on the E. side of that estuary, and, sinking below the red sandstone, extend to the river Mersey, and probably join the Lancashire coal-beds. The seams are of various thicknesses, from 2 to 15 feet, and consist of the common bituminous and cannel coals.

Forest of Dean.—This small isolated basin lies on the E. side of the estuary of the Severn in Gloucestershire. It contains twenty-seven seams, with an aggregate thickness of 37 feet of coal, mostly soft-burning, but in the lower seams of a coking quality.

Coalbrookdale.—This small coal-field, about 12 miles in length, is situated in Shropshire, on the E. slopes of the Wrekin. There are various coal-beds, forming an aggregate thickness of from 16 to 55 feet, the whole greatly broken up by the intrusion of trap rocks and dykes. The coal is slaty-bituminous, frequently sulphurous. Cannel coal is rare ; petroleum abounds in the centre and upper part of the field.

Broken patches of coal strata lie on the S. side of the valley of the Severn, along the vale of Shrewsbury.

South Staffordshire Coal-Field.—This field extends 20 miles from N. to S., and about 7 miles in breadth, including Dudley, Bilston, and Cannock Chase. In the centre of the field a saddle-shaped anticlinal ridge of the Wenlock limestone of the Silurian system rises up, upon the summit of which is built Dudley Castle. The Coal-measures lie on each side of this limestone, and are traversed from N.W. to S.E. by a basaltic dyke, which causes numerous faults in the strata. The new red sandstone lies above the Coal-measures ; the millstone-grit is absent below, and the strata are mostly argillaceous, interspersed with ironstone, the only valuable seams of which are near the base of the series.

The coal-seams are numerous, and vary in thickness from 9 inches to upwards of 30 feet. Only the lower seams are workable. The aggregate thickness of coal near Dudley is about 57 feet, and between Bilston and Wolverhampton upwards of 70 feet.‡ The seams crop out, and are lost to the N. of Walsall. The coal-seams are classed into three divisions, the great "Ten-yard Seam" being the chief. This "main seam" lies near Dudley, at a depth of 360 feet. It is composed of thirteen different beds, separated by thin partings, which in some places swell out into considerable extent, the greatest aggregate thickness amounting to 39 feet. Each of these divisions has its particular name, and is characterised by varying qualities of coal. The middle portions are the best, and are used for household purposes ; about one-half is inferior, and is used only in the ironworks. The coal does not cake, but burns freely, leaving a white ash. Cannel coal is found in some of the seams of this coal-field to a limited extent.

From the basaltic masses which traverse the coal-field, wedge-like portions pass off laterally into the seams, and at the points of junction the coal appears to have been altered by the heat of the igneous rocks.

There are seventy coal-pits worked in this district. The deepest workings are 780 feet, the shallowest 120 feet. About 2000 miners are employed. The celebrated Stourbridge fire-bricks are manufactured here ; and large quantities of iron are produced, amounting in 1846 to half a million tons. In 1837 there were conveyed by canals from this district 2,091,596 tons of coal. In 1854, from 531 collieries in Staffordshire and Worcestershire there were raised 7,500,000 tons of coal.

* De la Beche. † *Mining Records.* ‡ JUKE'S *Records of School of Mines.* § *Mining Records.*

North Staffordshire Coal-Field.—This field, broken up by numerous faults, contains a valuable series of coal-seams. About thirty-two beds have been determined, and their numerous workings supply the populous district of the Potteries.

Bristol Coal-Field.—This field occupies a surface of about 50 square miles around the city of Bristol, besides numerous other beds to the W. and the S. detached from the main basin.

The coal strata here have undergone intricate upheavals and depressions, forming anticlinal, synclinal, and variously-waved arrangements; they are, besides, covered by thick beds of new red sandstone and lias, which render them still more difficult of investigation. Below are irregular belts of old red sandstone, mountain limestone, and millstone-grit. The coal strata, according to De la Beche, consist of the following series:—

Upper shales and sandstones,	1800 feet, with	10	beds of coal,	18 feet 3 inches.
Middle sandstones (Pennant grit),	1725	do.	5	do.	10 feet.
Lower shales, . . .	1565	do.	36	do.	72 feet.
Farewell rock, &c., . .	1200				
Forming an aggregate of	6290 feet.				

The thickness assigned to the coal includes partings, and in the lower shales an admixture of under-clay. Ironstone is not common in this district.

Notwithstanding the thinness of the individual seams, and the difficulties and expense of working them, a large amount of coal is now mined. In 1854 there were forty-five collieries in operation, and 1,050,500 tons of coal were raised.*

THE YORKSHIRE AND GREAT CENTRAL COAL-FIELD.

This field extends from N. to S. a distance of about 60 miles, stretching from the middle of Yorkshire to Nottingham, its broadest part being between Halifax and Went Bridge. Here the strata dip regularly and at a moderate angle to the S.E.

This coal-deposit is characterised by three divisions, thus—above, magnesian limestone, unconformable to the Coal-measures:—

UPPER SERIES, ...	Shales and thin seams of inferior coal. Ackworth Sandstones. Two seams of coal worked at Wragby and Sharlston. Coarse red sandstone, as at Wooly Hooton, &c.
MIDDLE SERIES, ...	Furnace coals, Barnsley thick coal. Intermediate coal, Rock of Herbury, middle coal. Ironstone coals, Silkstone and Flockstone beds, Low Moor coals. Flagstone, a fine-grained micaceous slaty sandstone.
LOWER SERIES, OR GANISTER,	Shales and *Ganister*—a hard silicious sandstone. Coal. Shales and *Ganister.* Coal. Shale. Millstone-grit.

The lower series is included between the millstone-grit and flagstone, and has a thickness of from 360 to 450 feet. Near the bottom are two thin seams of coal, from 16 to 30 inches, which are workable, with several other thinner layers scattered through the mass. One of the larger seams, which can be traced through a wide range, is remarkable for its roof, which, instead of having its usual covering of shale, with remains of fresh-water plants, is filled with a number of marine shells belonging to the genera *Pecten*, *Goniatites*, and in one locality *Orthocera;* also nodular concretions, enclosing *Posidonia* and scaly fishes. The Ganister stone, which also prevails in this lower series, is a hard silicious sandstone, similar to the Crow-stone of the mountain limestone series in Swaledale. This stone in some instances forms the floor of the coal-seams, a circumstance never observed in the upper coal-series of the district, which invariably rest on a fine clay, full of Stigmaria roots; † while the *Goniatites*, *Nautili*, *Pectens*, and *Orthocera*, which are found in the cover of the seams, are analogous and in part identical with fossils of the mountain limestone. In these respects this *Ganister* series corresponds to the upper limestone series of the Penine chain, and with the millstone-grit series of Derbyshire; but near Halifax it is also found to contain fresh-water *Unios*, similar to those found in the upper coal-series of Northumberland and Derbyshire. Two layers of these shells occur—one of them about the middle of the series, considerably above the *Pecten* coal; the other near the bottom, and considerably below that coal. It would thus appear that during the formation of the successive beds of this lower series, the locality had been more than once subjected to the dominion of the sea.

The Flagstone, which lies intermediate between the lower and middle series, forms a thick deposit of fine-grained micaceous sandstones, which readily separate into slaty layers, and which are extensively used over the whole district as a building and roofing stone. In many localities this rock exhibits vegetable remains. *Equisetaceous* impressions are abundant in the flagstones of Leeds, accompanied by trihedral fruits; but *Lepidodendra* and *Sigillariæ* occur less frequently.

* HUNT, *Mining Records.*

† PHILLIPS'S *Geology.*

The middle series is the most valuable, and contains ten workable seams of coal of various quality, with several layers of ironstone bands, one of which is full of fresh-water bivalve shells.

The upper series lies on the coarse reddish sandstone and shales of Wooly Edge. These differ from the sandstones and shales of the lower groups in containing no layers of marine shells, no productive beds of ironstone, few vegetable remains, and coal of inferior quality, being earthy and less bituminous. Two workable coal-seams occur near the bottom, and one or two thinner seams are near the top. This seems to exhaust the coal-deposit, and magnesian limestone succeeds by a well-defined and distinct line of separation.

No trap-dykes intersect the Yorkshire coal-district, but there occur many faults, some passing nearly E.N.E. and W.N.W., and others nearly N.N.W. and S.S.E.

In 1854 there were 7,260,500 tons of coal raised in the West Riding of Yorkshire, the greater proportion of which was consumed in the extensive manufacturing towns of the district, and in the iron manufactories.

The Ashby-de-la-Zouch Coal-Field is separated into two bands by an anticlinal flexure of mountain limestone, which, like some of that of Derbyshire, contains a large admixture of magnesia. One coal-band, made up of several others, has a thickness of from 17 to 21 feet. The coal is generally of a hard quality. There is one seam of cannel coal.

In the Derbyshire Coal-Field, about twenty beds, having an aggregate thickness of 60 feet, are workable.* The strata are much disturbed by faults, but generally lie in a regular manner. About 30 feet on the E. side are attainable, and yield largely. The varieties yielded are anthracite, bituminous, and cannel coals.

The Nottingham Coals are similar to those of Derbyshire. The general characters of this central district resemble those of the great Yorkshire coal-field. The same millstone-grit and shales lie beneath both. The lower part of the series contains the most bituminous coals; in the middle is the best ironstone, the shale of which contains fresh-water shells; and above are fast-burning coals. The thickest bed in the district is the same as the Ten-feet Seam in Yorkshire.

Around Halifax, the coal which belongs to the lower series is of inferior quality, and only fit for iron-smelting. At Newton colliery, near Leeds, seven seams are wrought, containing about 18 feet of coal. A shaft near Wakefield has a depth of 290 yards.

The Lancashire and Yorkshire Coal-Field.—This important deposit adjoins on the W. the central coal-field, and is separated from the Carboniferous system of the North of England by the intervention of the Penine chain of mountains. The field is of an irregular form, but, including the millstone-grit, it extends from Macclesfield on the S. to Colme on the N.—a distance of 56 miles; and from Torbock, near Liverpool, to Todmorden on the N.E., about 40 miles. Exclusive of the millstone-grit, it occupies an area of about 250 square miles. This area includes the productive portion of the field, the remainder extending over the millstone-grit, and containing scattered and thin beds of coal. The district includes Manchester, Liverpool, Bolton, Oldham, and other manufacturing towns.

In a section from Manchester to Hollin's Brook, the depth of strata, including the millstone-grit, is 6000 feet, in which are imbedded seventy-five seams of coal, each not less than 1 foot thick, and forming an aggregate thickness of 150 feet. In another section, through Worsley, Bury, and Burnley, to the limestone shales of Pendle Hill, there are thirty-six seams of coal, ten of them not exceeding 1 foot in thickness, and making in all 93 feet of coal. In West Lancashire the thickness of workable coal is about 80 feet, and the total thickness of strata upwards of 6000 feet. Mr Binney divides the coal-field into three groups :—

1. The Upper or Manchester series, containing a bed of limestone, with fossil fishes and marine shells.
2. A middle series, containing the thickest seams, and the cannel coal of Wigan.
3. The lower seams, of no great thickness, corresponding to the Ganister series of Yorkshire, with marine fossils, *Goniatites*, *Posidonia*, and *Pectens*.

The bituminous coals are distinguished into two kinds—the cubical, where the cross cleavage runs at right angles to the main cleavage; and the rhomboidal, where it makes an acute angle. Cannel coal is found in the lower part of the middle series, and along with it fossil fishes and shells, but rarely vegetable remains. The Wigan cannel and Orell coals are highly hydrogenous. Upwards of 6,000,000 tons of coal are annually raised from this district. Price (1840), Orell 14s. 6d., River 11s., Cannel 20s. per ton.

At Patricoft is a seam of coal 6 feet thick, at the depth of 1350 feet. At Pendleton, near Manchester, the shaft is sunk to 1521 feet.

Extensive faults divide the Lancaster coal-field. At Pendleton the "red-rock fault" causes a dislocation of strata to the extent of 3000 feet. Near Wigan a series of faults range nearly N.N.W. and S.S.E., causing upthrows and downthrows of from 500 to 1600 feet.

Coal-Field of Durham and Newcastle.—This field extends from the river Tees to the Coquet, about 55 miles, with a breadth of about 15 miles, and includes an area of 780 square miles. Part of the E. side is covered by the magnesian limestone and red sandstone of the Permian series. If the millstone-grit and shale were included, the above area would be doubled. About three-fourths of the coal-field lie in the county of Durham.

Though these coal-fields are separated at the surface from those of Yorkshire and Derbyshire by about 60 miles,

* PHILLIPS's *Geology*.

yet the strata have such a general correspondence in both as to lead to the conclusion that they are of one formation, and perhaps connected towards their borders, and in the deeper parts of the deposit. Both are superimposed upon a bed of coarse pebbly sandstone or grit, with the mountain limestone below. The coal-seams in both have a corresponding resemblance. The upper seams consist of coals abounding in volatile matter; the lower seams contain bituminous coals of excellent quality. Ironstone is most plentiful in the middle and lower part; and the "*muscle-bands*," composed of marine bivalves, which are so conspicuous in the great central field, are also found to some extent in the N. deposits. Lastly, unconformable beds of magnesian limestone cover portions of the upper strata of both basins.

The total thickness of the strata is upwards of 1600 feet; the aggregate thickness of the coal-beds about 60 feet; but the workable beds do not exceed 30 feet of aggregate thickness. The thickest bed does not exceed 6 feet. Dividing the strata into three sections, we have—

1. *Upper Series*, consisting of eight or nine thin beds of coal of little value, interstratified with a variety of sandstones and shales, with ironstones, and a muscleband forming the base. Total thickness, 900 feet.

2. *Middle Group.*—At the top the *High Main Coal-Seam*, 6 feet thick; then various strata of shales and thin coal, with three seams of coal, each 3 feet in thickness, forming 423 feet, followed by the *Low Main Seam*, 6 feet in thickness.

3. *Lower Series*, consisting of sandstone and shale of the thickness of 700 feet, with two beds of coal, each 3 feet thick.

Numerous trap-dykes traverse this coal-field—two in particular, "the Ninety-Fathom Dyke," which runs along the valley of the Tyne to the sea-cliff N. of Tynemouth; and the "Cockfield Fell Dyke," in the S. part of the county of Durham, which crosses the district from W.N.W. to S.S.E. Many of these dykes, crossing the coal-seams, have charred the coal in the neighbourhood.

A system of natural fissures, called "Cleats," prevails throughout the district in a direction from N.N.W. to S.S.E.

Many of the coal-shafts about Newcastle are from 1000 to 1200 feet deep; that of Monkwearmouth, near Sunderland, is 1674 feet; the S. Helton shaft in Durham County is 1488 feet.

The water from the deep shafts of the Tyne and Wear is impregnated with chloride of soda, lime, and magnesia.

The greater portion of the coals of this district are of the bituminous coking kinds, but there are several varieties. The High Main and Wallsend coals are highly esteemed in the London market. The best coke for engines is made from the Auckland districts of Durham, and Shotley Bridge district of Northumberland. The best steam-coal is got from the N. side of the Tyne and the Blythe district.

The Newcastle coals obtained an early celebrity, and were extensively exported. In 1813 there were no less than four millions of tons raised in this district; and though the other coal districts of England and Wales now largely compete with it, the home consumption for 1843 was 4,711,000 tons, and the export from the various ports of the district, both for home and foreign consumption, amounted in the same year to 6,123,000 tons. It is interesting to observe the rapid increase of the consumption of coal within the period of 140 years. In 1710 the total exports from this district only amounted to 820,000 tons. In 1854 there were raised from the districts of Northumberland and Durham 15,420,615 tons of coal, more than one half of which was exported by sea, or carried by railway to other districts, as in the following summary:—

	Tons.
Coal and coke exported to foreign countries,	2,766,098
Coals and coke sent coastwise (to London 3,252,000 tons),	5,830,439
Coals and coke sent to and exported from Maryport and Port Carlisle,	92,014
Coals sent inland by various railways,	3,032,064
Coals used in ironworks within the districts,	1,200,000
Coals consumed at collieries,	1,100,000
Coals for local consumption and manufactures,	1,400,000
	15,420,615*

Cumberland Coal-Field.—This field forms a narrow crescent, extending from Whitehaven to near Hesket, Newmarket, and below the Irish Sea. The curve is about 40 miles in length, with a mean breadth of 3 miles, forming an area of 120 square miles. Seven productive beds are worked at Howgill, to the W. of Whitehaven, at a depth of 600 and 900 feet, and the workings are carried 3000 feet under the sea. At Preston How, the coal-shaft, after passing several thin beds, comes to a bed 5 feet thick, and a little lower to a bed with 8 feet of coal. This coal burns at first with a clear flame, and ultimately forms a cake. Professor Sedgwick divides this coal-field into two divisons, the upper containing the *Great Main* and *Bannock bands*, the lower containing five beds of inferior quality. A fault on the W. of the field produces a downcast to the S.W. of 1000 feet. To the W. of this the coal-seams dip into the sea; to the S. the dip is reversed.

At Sobergham, near Hesket, a seam of coal nearly 3 feet thick is worked, which partakes of the characters of

* *Mining Records*, 1855.

an anthracite and cannel coal—a semi-anthracite. To the W. of Appleby, in Westmoreland, there are three detached coal-basins, forming together about 26 square miles.

In 1854 there were raised in this district 887,000 tons of coal, of which 580,000 tons were shipped from the neighbouring seaports, and 36,000 tons used at the iron-founderies.

Great deposits of hæmatitic iron-ore are found in the limestones in the vicinity of Whitehaven, and between Ulverstone and Furness.

SCOTCH COAL-FIELDS.

The Carboniferous system of Scotland occupies a trough formed by the great Grampian range of mountains on the N., and the Lammermoors on the S., through which flows on the E. the river Forth, and on the W. the Clyde, with their expanding estuaries. Along the N. and S. edges of this great trough appears the Old Red Sandstone formation, on which the Coal-measures rest.

A series of trap-rocks intersect this hollow trough with an evident range from W. to E., but appearing on the surface irregularly, and causing considerable elevations and undulations of the country; and these igneous rocks have also broken up the original continuity of the coal-field, and separated it into numerous belts.

The general outlines of the great Scottish coal-basin are easily defined. On the S., a line drawn from near the town of Haddington, in East Lothian, extending along the base of the Lammermoors, passing through the upper part of Lanarkshire, and terminating at Turnberry Castle in Ayrshire, will bound this formation; and a line from St Andrews in the E. coast of Fife, extending along the S. banks of the River Eden, and the S. edge of the Ochil Hills, passing through Stirlingshire, Dumbartonshire, and the N. part of Renfrewshire, will limit its Northern extent. It thus embraces an area of about 90 miles in length, with a mean breadth of 30 miles, the workable coal-surface being estimated at about 1500 square miles. It will thus be apparent that at the era of the coal-deposit there existed a hollow trough between the Primary range of the Grampians on the N., and the lower Silurian mountains on the S., the base of which trough was formed of old red sandstone; and that, subsequent to the coal-deposit, the valley was elevated, by the agency intruding the trap-rocks, to the position which it now holds.

The Coal-measures of this district consist generally of the following alternations of strata, beginning with the uppermost:—

1. Sandstone and Shales.
2. Coal and Ironstone.
3. Limestones, various beds.
4. Old Red Sandstone.

The millstone-grit of the English coal-fields is here wanting, the lower limestones and shales resting on the old red sandstone. There are from five to six district bands of limestone, varying in thickness from 3 to 30 and 40 feet. These bands are found in the lower half of the series, and the thickest beds are in the lowest part of this half. The limestone beds generally contain marine shells exclusively, but there are others interspersed which contain *Unios* and land-plants, with an absence of marine fossils, and these are generally considered to be of fresh-water origin. The E. part of this coal district in the Lothians has an aggregate thickness of 6000 feet in the centre, but it thins out towards the edges. In Lanarkshire the thickness is great, but the thickness of individual strata, especially of the sandstones, as well as the aggregate thickness of the whole deposits, varies much in different localities. All the coal-basins of the district are more or less intersected by trap-dykes and faults, and where the trap-rocks have come into contact with the coal-seams, shales, and sandstones, the action of heat is evident from the altered structure of these latter.

The general character of the sandstone is that of a fine-grained mass, interspersed with mica of a white, yellowish, or reddish colour; in some places, as near Glasgow, it is of a reddish-blue tint, and coarse-grained; in others, as at Killaloe in Fifeshire, it is nearly pure white. Beds of conglomerate alternate with the more compact sandstone. The usual coal-fossils, *Stigmariæ*, *Lepidodendra*, *Ulodendrons*, *Sigillariæ*, *Equisetaceæ*, and *ferns*, abound in the strata, and large fossil *Coniferæ* are frequently found from 20 to 40 feet in length, imbedded in and intersecting the shales and sandstones.

From position and other circumstances, it has been conjectured that the Scottish coal-fields are deposits of earlier date than those of England. The coal is generally of the kinds called splint, cubical, bituminous, and cannel coal, of varying degrees of richness. The bituminous coals, with a few exceptions, are not of the caking kind, but burn with a steady heat and flame, generally leaving a considerable quantity of white and reddish ash. Some of the cannels, as the Torbanehill, Methil, and Lesmahago, are highly hydrogenous.

In the coal-mines of Scotland the spontaneous evolution of hydrogen gas or fire-damp is little known. The Lothian coal-field is entirely free from this, though it occurs occasionally in Ayrshire, and still more rarely in Fife. Carbonic acid gas, or "choke damp," is not uncommon, and, accumulating in the lower parts of the mines, sometimes proves fatal.

The coal-formation first appears in the S. of Scotland, in irregular patches along the N. slopes of the Cheviot Mountains, which separate this country from the N. of England.

The carboniferous strata of Berwickshire occupy a triangular space on the N. and S. banks of the Tweed, extending from the town of Berwick to Kelso.

To the N. are Silurian strata in highly-inclined positions; on these rests the Old Red Sandstone. Immediately succeeding this latter are about eight bands of mountain limestone, with intermediate beds of sandstone. The lowermost limestone-bed is of considerable thickness, and forms the bold shores to the N. of Berwick. To this succeed beds of white sandstone resembling that of the Lothians, interstratified with shale, with numerous vegetable impressions, and in some places thin seams of coal. The coal, however, has not been found in sufficient quantity to form profitable workings.

The same carboniferous strata appear to the W. of Roxburghshire, and extend along the valley of the river Liddel.

At Canonbie and Langholm, coal is wrought to some extent, but none of the beds exceed 3 feet in thickness.

The Mid-Lothian Coal-Field.—This coal-field occupies the valley of the Esk River, or E. part of Mid-Lothian, extending E. into Haddingtonshire, and terminating in the S. along the base of the Lammermoor Hills. It forms an area of about 17 miles square, and contains about 225 square miles.

An anticlinal ridge to the S. of Dalkeith separates the basin into two, the one occupying the valley of the Esk River, the other that of the small river Tyne. The series consists of alternating beds of sandstone, shale, coal, ironstone, limestone, and clay, forming an aggregate thickness in the middle part of 6078 feet.

There are from six to seven beds of limestone, the thickness of the beds varying from a few feet to 40 feet, the aggregate thickness being 300 feet. These beds first appear in the lower half of the series, and increase in thickness as they descend. The Burdiehouse limestone, in its absence of all marine fossils, and in the abundance of vegetable remains and minute *Cyperaceæ*, and several species of sauroid and other fishes, indicates a fluviatile and perhaps estuary deposit.

The aggregate thickness of coal amounts to 180 feet. There are between fifty and sixty seams exceeding a foot in thickness, but none more than 13 feet thick; the average thickness is about 3½ feet. The most remarkable seam is the "Great Seam," 13 feet in thickness, accompanied by a mass of coarse-grained reddish sandstone above, and a fine-grained white slaty sandstone below. From 250 to 300 fathoms below this seam is the "North Greens Seam," which yields a cannel coal. The coal-seams almost invariably rest on bands of ironstone and iron nodules, containing a nucleus of organic matter.

The district is traversed by numerous faults, one slip affecting the level of the beds from 400 to 500 feet. Of 109 slips, 94 range between the N. and W., and 7 run due W. The total effect of 78 slips is 35 downthrows to the S. 385 fathoms, and 43 downthrows to the N. 734 fathoms.* The seams are also divided by greenstone dykes of considerable breadth, in the vicinity of which the coal has been carbonised, and the shales and sandstone indurated.

The coal-seams, on an average, thicken towards the N., while the limestone bands, on the contrary, thicken towards the S. Splint, cherry, and cannel coals are raised.

The total amount of available coals in this coal-field has been estimated at 2250 millions of tons.†

Lanarkshire Coal-Field.—This extensive coal-district is a continuation of the great Scottish coal-field to the W., and along the N. slopes of the Pentland Hills, and the more elevated porphyritic mountain-ranges of the Lanarkshire mountains. The workable coal-district extends from Bathgate to Carluke, and hence to Glasgow and Airdrie, occupying the whole central basin of the Clyde.

The old red sandstone forms the base of this carboniferous deposit, and crops out on the S. near Lanark, forming cliffs 400 feet in height, over part of which the river Clyde pours its waters, forming the celebrated water-falls of this district.

Above the old red sandstone, and intermediate between it and the Carboniferous Limestones, are a series of beds of light-grey sandstone, chert, and shales. The true coal-basin consists of alternating beds of limestone, shale, ironstone, sandstone, and coal. Mr Craig ‡ divides this basin into a lower and upper series. The lower series contains three beds of limestone, from 3 to 12 feet in thickness, several bands of valuable ironstone, and fifteen beds of coal. These beds crop out in the S. district of the coal-field, immediately following the old red sandstone, and they again appear to the N. of Glasgow, while the upper beds occupy the centre of the coal-field. These upper beds contain only a few thin bands of limestone, and are composed chiefly of sandstone, with shale, ironstone, and thirty-four seams of coal. About twenty-five of the coal-seams are under 15 inches in thickness, and some seams, with an average thickness of from 3 to 5 feet, are workable. The aggregate thickness of coal is about 37 feet.

The workable seams are :—

1. *The Upper Coal*, only 2 feet thick, and workable at Coatbridge.
2. *The Ell Coal*, 3 or 4 feet thick, forming the Upper Coal of the Glasgow field, wrought at Chapelhall and Airdrie, at Quenter near Hamilton, Dalserf, Motherwell, and Coltness, at which latter place it thickens to from 6 to 14 feet.
3. *The Pyot Shaw Seam*, Monkland, from 3 to 5 feet thick.

* Phillips's *Manual of Geology*.

† Milne's "Account of Mid-Lothian Coal-Fields," *Edinburgh Royal Society Transactions*, vol. xiv.

‡ In Prize Essays of Agricultural Society.

4. *The Main Coal,* sometimes connected with the Pyot Shaw, and forming a thickness of 9 feet.
5. *The Hump Coal,* in the vicinity of Glasgow, with a thickness of 2½ feet, but seldom wrought.
6. *The Splint Coal,* from 2 to 4 feet thick, near Glasgow, affords the best quality of household coal.
7. *Shotts Coal,* from 2½ to 4 feet in thickness.
8. *Killorgan Coal,* from 2 to 4 feet thick—very bituminous.
9. *Drumgray Coal,* 1½ feet thick.

The coals are chiefly of the splint, cherry, and cannel varieties. The Boghead and Torbane cannels are the most celebrated of the hydrogenous coals. The latter is situated near Bathgate, and occurs in a bed of from 2 feet to 4 feet in thickness, having 4 feet of shale above, and a bed of common coal below, separated from the other coal by a thin bed of ironstone.

The fossil remains of the lower beds are all of marine origin, while in the upper are found fresh-water shells of the genus *Unio* in abundance. The thickness of this group is calculated at 1320 feet. It abounds in the usual fossil plants of the coal series, and in the dorsal rays, scales, and teeth of *Ganoid* fishes.

There are, in particular, four valuable deposits of ironstone, called "Blackband," in this coal-field, which are very extensively wrought in the district.

1. The Upper Blackband, Palace Craig, Old Monkland.
2. Mushet's Blackband, 16 fathoms below the splint coal, is from 14 to 18 inches thick, and occupies an area of 9 or 10 square miles in the neighbourhood of Airdrie.
3. Crofthead Band lies below the last workable coal-seams, and is about 18 inches thick. It is found also at Langside and Shotts.
4. Shotts Ironstone. This overlies the Shotts Laigh Coal, and consists of a thin band, with rich nodules, having a nucleus of bivalve shells.

The limestones associated with the upper coal-field are seen at Levenseat, where there is an arenaceo-calcareous deposit of 8 feet in thickness. At Gare is a band 3 feet thick, with clay above and below. At New Monkland is a bed 5 feet thick. The same limestone-bands crop out in the vicinity of Glasgow and Port-Dundas. In the lower basin there are three beds of marine limestone—the lowest, which is the best, is wrought at Wilsontown and Carluke in the S. border of the coal-field.

In this lower basin are altogether fifteen beds of coal. The main seam is from 160 to 200 feet below the lowest of the limestones of the upper basin. This seam corresponds in position with that found at Netherwoodson and Temple, to the N.W. of Glasgow, at Calderside, and at Auchinheath and Nethanfoot. This latter yields a cannel or gas coal.

The shales of this lower basin are rich in ironstone. Some of the bands have a thickness of 4 feet. The bands amount to fifteen; that above the third limestone is the richest. There is also a rich ferruginous deposit in connection with the cannel coal, consisting of several bands. The nodules and bands above the main seam are also of superior quality.

The whole coal-basin is traversed by numerous faults and trap veins. When the latter come in contact with the coal, it is charred and altered, as at Airdrie, Barn, and other localities.

A range of trap rises to the surface on the N.E. of the basin of Shotts, and three trap-dykes traverse the district. One is seen crossing the country between Snobe limeworks and High Drumclog; two others on the N. run nearly parallel in a direction from E. to W. These vary in width from 30 to 40 yards, rarely rising above the surface, except at Cameron, where they form elevated ridges of 40 feet in height.

Renfrewshire Coal-Field.—From Port-Glasgow to Ardrossan, along the borders of the river Clyde, old red sandstone strata prevail, having a general dip to the N., and occasionally to the S. and S.E. Its highest elevation inland does not exceed 600 feet. This formation is succeeded by Coal-measures, which are again overlaid and interrupted by a mass of trap, which stretches along the whole N. part of the country, and extends S. into Ayrshire and Lanarkshire. On the N.E. edge of this trap-rock, coal is found in the valleys of the Black Cart Water and the Garnock. Coal and ironstone are wrought at Maxwellton, near Paisley; at Hurlet, coal has been wrought for 300 years. The seam is 5 feet thick, but the coal is much mixed with iron pyrites and alum shale. At Quarrelton are five seams of coal, separated by thin seams of ironstone, the whole having a thickness of 50 or 60 feet. At one place a vertical fault seems to have displaced the strata, and then a horizontal movement has caused the two seams to overlap each other, forming an aggregate thickness of nearly 100 feet of coal. At another place the overlapping strata were separated by a thick bed of sandstone. Limestone crops out at several localities along the edges of the trap-hills, and a fine-grained compact sandstone is abundant.*

Ayrshire Coal-Field.—The Ayrshire deposits form the S.W. portion of the Scotch coal-field, and are separated from the Clyde basin by the trap-hills already mentioned. In the vicinity of Ayr, three thin seams have been wrought, but are now nearly exhausted. Towards the interior of the district the seams thicken, and there is an aggregate of 23 feet of workable coal. At Kilmarnock there is a bed of anthracite 4 feet thick, resting upon sandstone.

* MONTGOMERY, *Transactions Highland Society,* vol. vi.

Coal is partially found at Sanquhar, in the Nith. At New Cumnock, seams are wrought near the surface; and at an elevation of 1000 feet above the sea-level are three beds of 9, 11, and 12 feet in thickness. Imbedded in the Twelve-feet Seam is a cannel coal, which supplies the Dumfries gasworks.

All these Ayrshire beds are much disturbed by trap-dykes, and the coal in their vicinity is charred.

Fifeshire Coal-Field.—The N. half of the Scotch coal-district lies chiefly on the N. side of the Firth of Forth and its valleys to the W., occupying considerable portions of Fifeshire, Clackmannan, and Stirling, and extending to the Clyde basin in Dumbartonshire.

The Fifeshire beds commence in the S. valley of the river Eden, and extend across the country, with considerable intervention of greenstone rock, to the shores of the Firth of Forth. The mountain limestone, forming the lowest bed of the series, and resting on the old red sandstone, crops out along the N. edge of the coal-fields at the valleys of Ceres and Cults, and makes its appearance in the S.E. corner of the county at Pittenweem. Very interesting sections of the carboniferous sandstone are seen along this E. sea-coast, exhibiting a succession of waved and anticlinal upheavals. The lower band of limestone is of marine origin; an upper band of a less pure quality exhibits no fossiliferous organisms, with the exception of minute shells, probably of the *Cypres* and *Entomostraceæ.** By frequent intrusions the trap-rocks have been thrown up to the surface. The coal-seams are wrought at many points in the county. In the N. division, coal is wrought at Ceres, where are seventeen beds, having an aggregate thickness of 70 feet at Kettle, Skelpie, and Lathocker; and in the E. and S., at Pittenweem, Elie, Wemyss, Dysart, and Kirkcaldy. Near Kirkcaldy are nine seams, with an aggregate thickness of 25 feet. From Dysart to Wemyss occur twenty beds, with a thickness of 94 feet. The Dysart Main Coal, divided by thin seams of shale into six beds, has an aggregate thickness of 21 feet. Another seam at Wemyss is 9 feet in thickness. The coal here dips under the Firth of Forth, and is wrought at a depth of 900 feet below its surface. The aggregate thickness of the coal strata here is 1700 feet.

The faults run generally E. and W., and raise the strata to the N. 130, 200, or 600 feet. The coals are mostly splint and cherry. At Methil is found a rich cannel coal.

Dunfermline Coal-Field.—This coal began to be wrought as early as A.D. 1291, probably the first in Scotland; and nearly contemporary with this are two other notices of coal in England—one A.D. 1234, the other 1284. This field extends for nearly 3 miles in length, and contains from four to seven workable seams, having a thickness of from 17 to 26 feet. In the Elgin hills there are twenty-seven seams of coal, with an aggregate thickness of 56 feet. Ironstone is found in this field, and limestone is wrought, especially at Charleston, on the coast, to a great extent. The coals are bituminous, and of the caking kind, somewhat similar to Newcastle coals. The quality is generally superior.

Clackmannan Coal-Field.—This field is bounded on the N. by the Ochil Hills, in an extensive trap-chain, which in this vicinity have yielded, in former times, silver and copper ores, with irons, cobalt, and lead ores. The coal-field at Woodhill rests on old red sandstone, and extends to the coast, a distance of 6 miles. It is divided by steps into three portions. The general dip is to the N.; to the S. it assumes a saddle shape. In a depth of 200 feet are twenty-four beds of coal, with an aggregate thickness of 59 feet.† The carboniferous strata extend to Stirling, where they crop out to the N., and then strike W. by Dumbarton, and join the Renfrewshire coal-fields on the W. borders of the Clyde basin.

N. of this great coal district there are no traces of the true carboniferous formations throughout Scotland, though two imperfect beds of coal occur in the Oolite of Brora, Sutherlandshire. The upper seam is 3 feet 8 inches in thickness, the lower 1 foot 4 inches. These were at one time partially wrought, but the quantity of iron pyrites which the coal contained rendered it useless.

This formation, in its mineral beds and organic remains, bears a close resemblance to the Yorkshire Oolite.

Another exception occurs in the Isle of Mull, where a thin seam of coal appears on the shores of Loch Scridden. It is conjectured by the Duke of Argyle to be a prolongation of the Tertiary leaf-beds of Ardtun. ‡

IRISH COAL-FIELDS.

The carboniferous system occupies two-thirds of the whole area of Ireland.§ Succeeding the Silurian and Devonian formations which skirt the outer margins of the island, the centre is almost wholly composed of the mountain limestone and lower series of the Coal-measures.

This formation on the W. extends to the coast, composing Donegal, Sligo, and Killalo bays. It then skirts the E. base of the Connemara Mountains, and appears again in Galway, and partially in Dingle Bay. It overlies the old red sandstone in the S. of Cork County, appears at Dungarvan in Waterford County. It is interrupted by the Wicklow range of mountains, but reappears on the coast of Dublin and Drogheda. N. of the trap mountains of Antrim it is again found on the coast.

There appears to exist an intimate relation between the carboniferous beds of Ireland and the corresponding formations of England and Wales. The sections in Cork County exhibit an identity with those of the W. extremity of South Wales, and the beds of the North of Ireland resemble the coeval beds of the North of England.

* LANDALE, *Essays of Highland Society of Agriculture*, vol. v. † BALD, *Wernerian Transactions*, vol. iii.

‡ DUKE OF ARGYLE "On the Tertiary Leaf-beds in the Isle of Mull;" *Quar. Jour. Geol. Soc. Lond.*, vol. vii. § Griffith.

The Carboniferous system of Ireland forms an area of 150 miles square, and, according to Griffith, presents the following general section in descending order :—

E.—The Coal Series, but slightly represented.

D.—Millstone Grit.—Occupies a large space around the source of the Shannon, forming the elevated crags of Kulkeagh ; it contains coal, ironstone, and furnace-grits. Thickness, 500 feet.

C.—Great Shale Series of Kulkeagh, containing *Goniatites*, *Posidoniæ*, *Orthoceratites*, *Bellerophons*, &c. Thickness, 600 feet.

B. { *Upper Limestone*, cavernous, with coral bands.
The Calp Series.—Grey and dark limestone, with shale and sandstone ; in some districts only.
Lower Limestone.

A. { *Carboniferous Shale*, locally rich in *Spirifer*, *Strophomena*, Fossil fishes, &c.
Yellow sandstone, with shale, and occasionally limestone.

Each of these lower and upper groups, *A*, *B*, and *C*, *D*, *E*, has an aggregate thickness of 3000 feet. The upper series (*E*, *D*,) are most conspicuous in the N. about Lough Erne and the sources of the Shannon, about Kilkenny and Castle-Conner, and in the elevated country on each side of the estuary of the Shannon. The true mountain-limestone (*B*) exists to an immense extent in the central districts, while the lower series (*A*) appears in the S. tracts about Cork and Kinsale. At Knock, Upper Kilkenny, the limestone rests in dark shale and yellow and brown sandstone, 150 feet thick : below these are red slates, and red and green argillaceous sandstone, with impressions of *Sphenopteris*.

Near Carrick-on-Suir, Tipperary County, the limestone rests in a thin-bedded yellow sandstone, and green and yellow shales, 150 feet thick, followed by alternations of yellow sandstone and hard red shale, 350 feet thick. Below this succeeds old red sandstone to a depth of 1800 feet. Farther to the W., in the same county, the red shale has a thickness of 900 feet, and the whole series, including the old red sandstone, an aggregate thickness of 4500 feet. To the S. of Cork the dark-grey and green shales alone, with red and green slates and purple sandstones, form an aggregate thickness of 4250 feet. Mr Jukes refers them to the Devonian system, and in their characters they bear a close resemblance to the corresponding strata in the W. of Pembrokeshire, Wales.

The upper Carboniferous series, or true Coal-measures, are but sparingly developed in Ireland ; and there appears to be but little chance of any such rich beds being discovered as those of England. In so far as they prevail, however, they appear similar to the English coal-formation. Thus anthracites, similar to those of South Wales, are found in Leinster and Munster, and bituminous coals in Connaught and Ulster.

Ballycastle Coal-Field.—This field is situated in the N. extremity of Antrim County, and is surrounded and penetrated by trap-rocks—a columnar basalt overlying the coal, and also the chalk, at Fair Head Point. One seam is about 3 feet in thickness, and the quality of the coal is a bituminous splint, but very slaty. Near Gab Cliff colliery the seam is intersected by a trap dyke at right angles, which has charred the coal on each side of it. These collieries were wrought at an earlier period than any others in Ireland, and used to yield annually from 10,000 to 15,000 tons ; but now they are disused.

Tyrone Coal District.—Near Coal Island is a partial deposit of coal, but the beds are now nearly wrought out. At Dungannon nine workable seams, from 3 to 9 feet thick, were worked with moderate success, but are now given up.

In Leitrim, Cavan, and Roscommon counties, surrounding Lochallen, the source of the river Shannon, there are several detached basins of coal, which, however, contain only one bed not exceeding 2 feet in thickness. The shale is rich in ironstone, and the Arigna ironworks here formerly attracted considerable attention, but have been ultimately abandoned.

Kilkenny Coal District.—This district, lying to the W. of the main branch of the Barrow River, is divided by intervening ridges of mountain limestones into four basins. The coal is anthracitic, very much mixed with sulphur. There are several seams, two of which are 3 feet in thickness, two less than 3 feet, and one 4 feet. The upper beds are wrought out ; the lower still remain, but the quality of the coal is so impure as to be unfit for any other purpose than for burning limestone.

The Munster Coal District occupies a considerable portion of the counties of Clare, Limerick, Cork, and Kerry. It contains three beds of anthracite, but none of great thickness. The most valuable portion is found on the N. of the river Blackwater, where several excellent beds of anthracite occur.

Antrim Lignites, or Brown Coal.—This Tertiary deposit occurs abundantly in the N. of Ireland, as well as in some other localities. It underlies the basaltic trap of Antrim, and the beds exhibit a variation in thickness of from 3 to 30 feet in the space of 100 yards. At Lough Neagh these beds attain a thickness of 294 feet, composed of alternations of wood, coal, clay, and sand. It is difficult to ignite, and forms a dull fire, but is, on the whole, superior to peat.

In the year 1854 there were of collieries in operation in Ireland :—

In Leinster field,	5
Tipperary,	5
Munster,	2
Connaught,	5
Tyrone,	2
	19

These produced a total of 148,750 tons of coal.

GENERAL SUMMARY.

On a review of the leading details of the British coal-fields, the following conclusions may be drawn:—

The Coal-measures of England, Scotland, and Ireland are, as regards local position, contiguous to each other, occupying the greater part of the W. and central portion of the British Islands.

The Irish Sea separates Ireland from the West of England; but the characteristics of the Carboniferous limestone and lower Coal-measures of Ireland bear such a striking conformity to the similar strata of Wales, as to lead to the presumption that they may have been originally continuous. The distance from Whitehaven in Cumberland, where the coal-seams dip into the Irish Sea, is so little, and that little so far connected by traces of the Carboniferous system in the Isle of Man, as to afford additional proofs of the supposed connection of the two opposite shores of Ireland and England. The Scottish coal-fields are only disjoined from those of the North of England by the intrusion, by igneous elevation, of the underlying Silurian and Devonian rocks; and the same line of basaltic trap appears to be traceable from the coal of Antrim through the Isle of Arran, and North-eastward through the basins of the Clyde and Forth.

From South Wales to the North of Yorkshire, the continuity of the various coal-basins suffers such interruptions only as may be supposed due, in the first instance perhaps, to the original inequalities of the surface previous to the coal deposition; and in the second place, to the breaks necessarily caused by the upheaval of the surface posterior to the close of the coal era, and to the effects of denudation consequent upon such upheavals.

The mineral and fossiliferous contents of the various basins bear a striking similarity throughout the whole. There exist the same underlying strata of the older Palæozoic series; the same mountain limestone, with marine organisms, forms the basis of the Coal-measures, the deposits of this limestone varying in thickness according to their localities,—in some places existing in one or two thick beds, in other localities dividing into two, three, or more thinner beds; some of those upper beds exhibiting fossils indicative of a fresh-water formation.

Above this, the millstone-grit is generally prevalent, or, if absent, it is replaced by beds of red sandstone shales and conglomerates.

In the alternating beds of shales, sandstone, and coal forming the true Coal-measures, certain well-marked strata and seams of coal can be traced as prevailing to a wide extent through several districts in England; while the same is the case with some of the well-marked Scotch coal-seams.

The fossil vegetable remains are of identical character throughout the whole of the English, Scotch, and Irish basins; and similar species prevail from the highest to the lowest beds of strata, having a thickness of 6000 feet. *Stigmariæ* and *Lepidodendrons* abound in the sandstones, and large trunks of Coniferous trees are not unfrequent, especially in Scotland; while impressions of ferns and equisetaceous plants are found in the shales above the coal-seams.

TABLE OF COAL PRODUCE OF GREAT BRITAIN AND IRELAND, 1854 AND 1855.

DISTRICTS.	Tons raised in 1855.	Number of Collieries in 1855.	Persons Employed in 1854.	Price per ton at the Mines in 1854.	Price in London, &c., in 1854.
ENGLAND.					
Northumberland and Durham,	15,431,400	273	38,801	8s. to 11s. 6d.	18s. 9d. to 23s. 10d.
Cumberland,	809,549	23	3,636	8s. 5d.	...
Yorkshire,	7,747,470	333	21,030	5s., 10s., 16s.	20s. in Hull.
Derbyshire,	2,256,000	171	5,434	...	20s.
Nottinghamshire,	809,400	20	3,671	...	...
Warwickshire,	262,000	17	1,414	...	...
Leicestershire,	425,000	11	1,646	...	...
Staffordshire (N. and S.) and Worcestershire,	7,323,000	500	27,869	...	...
Lancashire,	8,950,000	357	28,834	...	...
Cheshire,	755,500	32	2,618	...	...
Shropshire,	1,105,250	56	4,580	...	...
Gloucester, Somerset, Devon,	1,430,620	88	7,501	...	...
NORTH WALES.					
Anglesea, Flintshire, Denbigh,	1,125,000	65	...	...	...
SOUTH WALES.					
Monmouth, Glamorgan, Pembroke, Caermarthen,	8,550,270*	245	...	...	...
SCOTLAND.					
Total of all the coal-producing districts,	7,325,000	403	32,969	...	...
IRELAND.					
Total of all the coal districts,	145,620	19	...	...	...
Grand total,	64,351,079	2613		...	...

* Of which 997,500 were Anthracite.

The three leading divisions of coal—the Anthracitic, the Bituminous, and the Hydrogenous—have their representatives in the various coal-fields,—even the same seams sometimes exhibiting in different places different kinds of coal, and there appearing no fixed order of position of any one particular kind.

The South Wales coal-field abounds in anthracite. The most common kinds of coal are the bituminous, consisting of the splint and cuboidal subdivisions. The *caking* kinds are much more common in England than in Scotland, while the latter district contains the richest hydrogenous or cannel coals.

The Scotch coal-field has been supposed lower in position than the English. Some of the lowest seams alternate with bands of mountain limestone, and the Berwick coal is altogether in this position.

Bands of limestone and shale, with fresh-water bivalves and impressions of plants, exist in the lowest carboniferous beds of Scotland, and are found alternating with marine limestones in the English coal-districts, affording evidence of the alternate elevation and depression of the surface during the formation of the strata.

COAL—ITS COMPOSITION, AND A CLASSIFICATION AND DESCRIPTION OF ITS VARIETIES.

This black hard carbonaceous substance, produced by the vegetation of former geological periods, and regularly imbedded in the stratified crust of the globe, is at once the most interesting to science, and the most valuable to the wants of civilised man, of all the materials imbedded within the earth: it deserves, therefore, a careful investigation of its composition, origin, and uses. Being a very complex substance, or rather a genus of substances of kindred composition, whose ingredients vary much in their proportions, its several varieties must be classified and separately examined or analysed.

Subdividing the whole class of substances we call coal in accordance with their most natural characters, we find them to arrange themselves into the following four principal groups in the order of diminishing carbon and augmenting hydrogen:—*Anthracites, Semi-anthracites; Semi-bituminous coals, and Bituminous coals.*

All the varieties of coal agree in containing, though in very different relative proportions, the following contituents.

Carbon, invariably the most abundant ingredient, and the gases hydrogen, oxygen, and nitrogen, the relative proportions of which are very influential in imparting to certain coals their special qualities. To these (the organic products of vegetation) we must add a variable amount of earthy matter (the ashes of the coal when it is burned), consisting generally of silica, alumina, oxide of iron, and sometimes a little lime, magnesia, potash, &c., and likewise frequently a small amount of sulphur.

It has been pretty clearly ascertained by careful chemical researches, that all coal, even the hardest and driest anthracite, contains more or less of these various substances, and that in the different kinds they not only differ in their relative proportions, but in their condition of chemical union with each other.

In the so-called bituminous varieties of coal, the three principal constituents—carbon, hydrogen, and oxygen—are in chief part at least chemically united into the form of one or more oily inflammable liquids, erroneously called bitumens, recognisable by the microscope in the cells of the coal; and it is clear from certain phenomena, such as the constant evolution of the gases in the free state from the pores of the coal, that another portion of these is locked within the coal in an uncombined but greatly compressed and possibly liquid condition.

Thus it may be stated as a general analysis of all the bituminous coals, that they contain, besides their earthy ingredients—1, Solid carbon; 2, Carbon, hydrogen, oxygen, and nitrogen, chemically combined, but not, as is generally supposed, in the state of bitumen; 3, A residual portion of the hydrogen, oxygen, and nitrogen in the form of free gases, easily disengaged; 4, A small proportion, seldom more than 1 or 2 per cent, of free water mechanically present in the pores and fissures.

The essential difference between the bituminous coals and the anthracites is, not that the latter contain no gases or volatile matter (for they sometimes possess as much as 9 or 10 per cent), but that they are destitute of a perceptible amount of those chemical compounds of the gases and the carbon known as bitumens. In the driest or most thoroughly de-bituminised anthracites, the hydrogen element amounts to about 2 or 3 per cent, and the oxygen and nitrogen together to about as much; and many facts make it highly probable, that while a part of the hydrogen and oxygen are in combination in the form of water, and that some of the hydrogen and nitrogen is in the condition of ammonia, a residual portion of all these three elements is in an insulated state, condensed in the pores of the solid parts of the coal.

In such anthracites, the carbon varies, according to the purity of the coal, from 84 to 93 per cent, while the earthy matter usually ranges from 2 to 12 per cent.

The composition of a coal may be viewed in either of two aspects, and determined by either of two corresponding methods of analysis. In the one we may regard only the proportions of the several ultimate elements, the carbon, hydrogen, oxygen, nitrogen, and earthy substances which enter into it; in the other we may consider it as a union of certain specific combinations of these—namely, of solid carbon or coke, with bitumen, the gases hydrogen, oxygen, and nitrogen, in a free and condensed state, and some of these in the state of water and ammonia, together with the earthy matters. The mere combustion of a bituminous coal effects the successive disengagement of these last-named proximate constituents. Thus, in the first stage of kindling, the greater part of the free gases and of the water is exhaled at a relatively low heat; next, a portion of the bitumen is converted into vapour, with disengagement of a part of its solid carbon, while the temperature is not yet high enough for actual ignition; still later, the rest of the gaseous matter, and a part of the solid carbon, burn off in flame and smoke; and, finally, the residual coke is consumed, leaving only the earthy matter, the ashes.

The distinctive properties of the different kinds of coal are determined mainly, though not altogether, by the relative proportions of solid carbon and volatile matter which they severally contain. Coals are therefore styled bituminous, semi-bituminous, or anthracitic—that is, purely carbonaceous—as they possess respectively a full supply, half a share, or no trace at all of bitumen. When they contain as much as 18 or 20 per cent of volatile combustible matter, they are usually entitled bituminous coals; when less than 18 per cent, and more than 11 or 12 per cent, they claim the name of semi-bituminous; and when a less proportion than 11 or 12 per cent, they are ordinarily designated anthracites.

Of those having more than 18 per cent of bitumen there are two general varieties, the *open-burning* and the *caking* coals. Both of these burn with much flame and smoke, and both swell into a vesicular coke in burning; but the open-burning kind coheres loosely, and permits the air to pass freely between its lumps, while the caking variety agglutinates more closely into a mass, and partially arrests the draught. This property of naturally caking or not caking does not appear to depend, as very many persons suppose, merely on a greater or less abundance of volatile matter; for both the non-caking *splint coal* of England, and the *cannel coal* of that and our own country, rather exceed the Liverpool and other caking coals in their amount of bituminous or more strictly volatile matter. The splint coals average as much as 36 per cent, the cannel coal seldom less than 35, and frequently as much as 45 per cent, while the caking coals rarely exceed 32 or 34 per cent of total volatile ingredients.

The semi-bituminous coals also soften and swell into compact coke, but do not agglutinate at all, or only slightly; they are therefore equally eligible with the non-caking bituminous varieties for certain purposes of combustion; while, as we shall presently see, they are preferable to them in heating power, in proportion to the greater weight of solid carbon they contain.

The anthracites neither soften and swell or vesiculate while burning, nor do they emit any smoke, strictly so called. Those varieties, however, which contain from about 7 to 10 per cent of volatile matter, evolve in the early stages of combustion a visible amount of yellow carbonaceous flame, the product of the easily-ignitible carburetted hydrogen gas, which is most probably present in the free state in the cells and crevices of the coal, and not derived by decomposition from any bituminous matters. These are the free-burning easily-kindled anthracites. They are, for the most part, fissured by numerous fine clefts or joints, by virtue of which, and of the expansible gases these enclose, the lumps spontaneously subdivide on the fire, in a greater or less degree, into small cuboidal fragments. These coals constitute, I conceive, a distinct variety, being, when of equal purity in regard to earthy matters, intermediate in colour, lustre, and specific gravity, between the semi-bituminous kinds on the one side, and the dry hard anthracites on the other; and as they derive, from their peculiar mechanical structure and special chemical composition, definite and valuable qualities for several of the leading uses to which fuel is applied, I deem it convenient and proper to give them a separate designation: I shall, therefore, always allude to these as the *semi-anthracites*.

The true or hard anthracites constituting the first division of this class of coals contain, when free from mechanically-imbibed water, from 2 to 5 or 6 per cent of volatile matter, consisting of minute quantities of the atmospheric gases, and hydrogen, carburetted hydrogen, and also 1 or 2 per cent of water very tenaciously retained.

These anthracites, when pure, and not dislocated from the excessive pressure which attended the uptilting of the strata, have their fine intersecting joints or clefts far asunder, and nearly perpendicular to the grain of the coal, and they break with a semi-conchoidal fracture. They are harder and denser than any of the other coals, and by their firmer cohesion, their resistance to subdivision on the fire, and their destitution of inflammable gaseous matter, are the most difficult of all coals to kindle, and require the highest temperature for the maintenance of their combustion. The very hardest kinds yield an almost semi-metallic sound when struck, and in their slightly-bluish tint and their faintly plumbaginous lustre, they suggest plainly their affinity in composition to true graphite or black-lead. In these and all their other characteristics the genuine anthracites give evidence of their having been exposed since their deposition to a far greater intensity of terrestrial heat than any of the other kinds of coal. Anthracite is unquestionably the metamorphic form of ordinary bituminous coal, and has derived its peculiar composition of a nearly pure carbon, and its other important qualities, from the slow expulsion, under great pressure, of the volatile parts of the coal, through the action of a high distilling temperature pervading the strata enclosing it.

To a somewhat less elevated or prolonged heat in the earth's crust, we are equally well entitled, by all geological testimony, to ascribe the more imperfect removal of the gaseous elements in the instance of the semi-anthracites; and to various yet feebler degrees of heating, we are manifestly compelled to assign all the corresponding grades of the bituminous character met with in the semi-bituminous and the drier bituminous coals.

These general introductory views of the composition and structure of the several leading species of coals, will be seen to possess much practical importance in suggesting the proper uses and adaptations of the respective varieties, and the conditions under which each species should be burned to insure the highest economy of their heating power. Each of the four dominant kinds of coal described has been found by experiment to subserve, better than the rest, some appropriate end or ends in the multifarious operations of the arts; but the practical man is continually deceived in his calculation of the economy of his fuel through inattention to the chemical laws of combustion, and through incorrect conceptions of the true nature of the special variety of fuel he is using. Without such knowledge, the whole economic problem of his coal and his furnaces is but guess-work the moment he essays a new variety, or introduces any material alteration in his mode of burning even a familiar species.

Directed by these preliminary views of the composition and qualities of the several species of coal, I propose to classify and describe them somewhat more technically, upon a combined basis of their chemical and structural characters, or in accordance with their composition and manner of burning.

Retaining the above convenient classification of coals, into the four varieties of Anthracites, Semi-anthracites, Semi-bituminous, and Bituminous Coals, which has already crept extensively into use since first presented by me, and is constantly employed in this work, I propose to introduce here a more extensive one, simply modifying this grouping, and recognising certain varieties or sub-varieties not yet designated.

Looking at the essential differences in the several kinds of coal depending on their gradations in composition, it will appear, I think, that the soundest general classification is into three great varieties and groups—*the Anthracites, Bituminous Coals*, and *Hydrogenous Coals*, arranged in the order of diminishing carbon and augmenting hydrogen. At the one end of this scale we have the anthracites; natural cokes, yielding almost no flame and no smoke; coals with the maximum of solid carbon, and a minimum of the gaseous elements. At the other end of the scale, the very hydrogenous coals, almost destitute of true coke, and convertible almost wholly into flame with smoke; coals with the least proportion of fixed carbon, and the greatest amount of hydrogen gas; while, intermediate between these extremes, are the common bituminous coals, containing a medium share both of solid carbon and of the gaseous elements—capable of producing a fair amount of coke, and a moderate per-centage of the inflammable or hydrogenous gases. This grouping will be found, I think, at once scientifically correct and expressive, and practically applicable and useful.

But these three classes of coals demand, as we have already partly seen, a subdivision into special varieties—the *Anthracites* being properly separable into *Hard Anthracites* and *Semi-anthracites;* the *Bituminous Coals* into dry or *Semi-bituminous*, and *fat or true Bituminous Coals;* and the *Hydrogenous* into *Cannel* and the richest *Gas Coals*.

To this point the classification mainly recognises the relative proportions of fixed carbon to gaseous matter, especially hydrogen; but a yet further sub-grouping of some at least of these varieties is called for, to express not so much the lesser differences of composition, as the conditions of *constitution* or *chemical structure*, resulting in peculiarities of their modes of decomposing under heat and burning. This gives us a partial classification of certain coals, which is *transverse*, so to speak, to the main linear one of a simple gradation in the quantities of carbon and hydrogen. Guided to these differences among the bituminous coals by this second clue, we shall find the true or fat bituminous group to include three well-marked sub-varieties, already recognised by their distinctive properties, and known under familiar names. These are the *caking coals*, the *cherry coals*, and the *splint coals* of the English miners, and of commerce. In the same manner, looking to the behaviour of the leading kinds of the very hydrogenous coals, as well as to the differences in the proportions of hydrogen in them, we shall find these to include at least three very unlike varieties of the rich gas-making sorts, severally represented by the ordinary or typical cannel coals, by the Torbanehill gas-coal, and by Albert coal of New Brunswick. It is not easy to find suitable familiar designations for the two last named of these three hydrogenous coals; but I think the term hydrogenous shale or clay-coal is a fit enough name for the Torbanehill variety; while the lustrous, fusible, and exceedingly pure Albert coal, may claim appropriately the title which has been sometimes applied to it, of the *Asphaltic* coal, without signifying that it contains or consists of either real asphaltum or solid bitumen.

Applying to the group of semi-bituminous coals a similar discrimination, we may discern even among them the two sub-varieties of cherry and splint coals, each, however, having a less share of volatile matter than in the corresponding true cherry and splint coals of the fully-bituminous group.

Indeed, we might properly enough extend the distinctions of splendent, cubical, and dull splintery or slaty coals to the two leading qualities of anthracite, only that it would mislead to apply to any variety of this the restricted name of Cherry coal.

That peculiar species of coal which is so distinctive in the cannel coals,—that dull greyish-black variety, which evidently owes its want of lustre and of fusibility, not to the presence of earthy matter, but to some essential circumstance in its composition—possibly an abundance of free carbon, some special condition attending its origin, possibly a prolonged masceration of the vegetable matters before their final entombment—certainly mingles with the other, or glance variety, in greater or less proportion, in all the great classes of coals, from the most hydrogenous to the anthracites. Both kinds have been subjected together to various degrees of distillation of their more volatile constituents, perhaps to dissimilar extents in the different groups, anthracites, bituminous, and hydrogenous; and therefore it is that we see the dull and the bright varieties so intimately alternating in all of these classes, even where we cannot impute the dull laminæ to any excess of earthy matter.

Adopting the above distinctions, we may accordingly arrange all the best-known descriptions of coal upon the following scheme or classification:—

ANTHRACITES, ...	Hard Anthracites.	
	Semi or Gaseous Anthracites.	
COMMON BITUMINOUS COALS,	Semi-bituminous Coals,	Semi-bituminous Cherry Coal, and
		Semi-bituminous Splint Coal.
	Bituminous Coals,	Caking Coal.
		Cherry Coal.
		Splint Coal.
HYDROGENOUS OR GAS COALS,	Cannel Coals.	
	Hydrogenous Shaly Coal (Torbanehill, &c.)	
	Asphaltic Coal (Albert Mine).	

Having taken this brief general survey of the whole class of coals, and developed the classification adopted in this work, we may now look more closely at the physical and chemical characteristics of the several species or kinds. In doing this we will follow the order in which they are presented in the foregoing Table, beginning with the most carbonaceous coals, and ending with the most hydrogenous.

THE ANTHRACITE COALS.

The term *Anthracite* may be strictly applied to all those dry or non-bituminous coals, which, possessing from 2 to about 10 per cent of gaseous matter, do not swell or intumesce when burned; or which, in other words, give off the small amount of volatile constituents they contain without coking. All of these coals enclose, as already said, a minute quantity of the atmospheric gases and hydrogen, with a little water firmly retained; and some of them contain, besides, a notable amount of the combustible gases, probably in a free condition.

The *carbon*, their chief and most important constituent, prevails in all proportions, from 94 per cent in the very purest and least gaseous anthracites, to any lower ratio, until, from excess of earthy matter, the substance can no longer be called nor used as coal, but deserves the name of carbonaceous slate. The earthy matter is seldom less than 3 per cent in the purest varieties, and more than 10 per cent is incompatible with excellence as a fuel.

THE TRUE OR DRY ANTHRACITE.

This the first species in the Table, is characterised by its semi-conchoidal fracture, the fewness and squareness of its joints or clefts, great relative hardness and density, its high specific gravity, ranging from 1.40 to 1.80, iron black or plumbaginous colour, and its semi-metallic and splendent lustre. It burns without any smoke or yellow flame, but with a weak blue flame—that of carbonic oxide when newly kindled—and with a thin transparent pinkish and intensely-hot flame when in full combustion. True anthracite, when pure, is slow to ignite, conducts heat very badly, burns at a very high temperature, radiates an intense warmth, and is difficult to quench. Generating almost no water during its combustion, it powerfully desiccates the atmosphere of an apartment in which it is burning. Like the diamond, it is a perfect conductor of electricity, but acquires negative electricity when insulated, and subjected to friction. It is sometimes described as a mineral, but is more truly a rock, or mechanical solid aggregate of earthy and organic matter stratified, and therefore neither amorphous nor crystalline.

It consists, when pure, of—

Carbon, . . .	from 94 to 90 per cent.	Water, . . .	from 1 to 2 per cent.
Hydrogen, ...	1 „ 3 „	Ashes, ...	3 „ 4 „
Oxygen and Nitrogen, . .	1 „ 3 „	... ...	...

The constituents which vary most are of course the carbon and earthy matter; and in the impure sorts, the first of these is frequently as low in amount as 75 per cent, the ash being then as much as 20 per cent. In Pennsylvania, such earthy or slaty coal is technically called by the miners *bone coal*. One variety of impure anthracite is where all the laminæ are earthy, and dull in lustre; another is where the dull or slaty leaves alternate intimately with the splendent or pure anthracite, but in such excess as to render the mixed mass impure.

One of the synonyms of anthracite is glance-coal, from its brilliant lustre; another is blind-coal, from its burning without bright flame; while that of Wales and Devonshire is locally called *culm*. It is familiarly called hard coal, in contradistinction to the softer bituminous coals in New England and other parts of the United States, where it comes into contact with the fuels of the other class.

Hard anthracite, from its great richness in carbon and its density, stands at the head of all coal for its heat-generating power, if adequately supplied with air. It is therefore particularly valuable for producing steam, where power only, and not speed, is wanted; and it is the most economic of all fuels—weight for weight—for smelting and melting iron and the other metals. For domestic uses, it is best employed, where the climate is cold, as an auxiliary for warming air; but it is difficult to control, and it emits too scorching and intense and dry a heat to make it a pleasant or wholesome fuel, burned in the open grate. Skilfully employed, it is admirably adapted for cooking, but it requires special appliances and more skill than other fuel for an economical application to this purpose. It is extensively applied to all the purposes here mentioned in the Middle Atlantic and Eastern States, where it is abundant and cheap.

The superior density of hard anthracite over every other kind of coal, by lessening the room demanded for stowage, gives it a decided preference in this respect as a fuel for ocean steamers, where the trips are very long or the tonnage precious; and in these cases even the fracture of the coal, by influencing the closeness of its stowing, is a consideration.

The *conchoidal fracture* in dry or hard anthracite seems to depend as much on its homogeneity or evenness of composition and structure, as on its purity or freedom from slaty matter; for some rather earthy varieties, in which the ashy constituents are diffused throughout the coal, exhibit this in a higher degree than other more carbonaceous kinds, in which the pure coal and the slaty are distinctly laminated. Hence this fracture is not so true a test as is generally supposed of the purity of the fuel. Every bed of tolerably pure hard anthracite displays at its outcrop, and to a small depth below, a prevalence of the ovoidal and globular shapes in its loose and weathered lumps. This is a consequence of a tendency to the conchoidal fracture, and of that exfoliation or peeling off at the corners and edges which results from alternate wetting and drying, and which belongs to nearly all homogeneous earthy aggregates when similarly exposed to the weather. Where the coal is finely laminated and uniform in texture, the form resulting from long weathering is ovoidal, or that of an egg more or less flattened; but where the mass is very homogeneous, and cubical in its joints, the shape approaches near to the globular.

We may distinguish two kinds of joints or planes of separation in almost every bed of hard anthracite—viz. structural joints, or clefts symmetrically disposed, and generally pretty nearly at right angles to the planes of bedding or lamination of the coal, and also at right angles to each other; and mechanical joints, or planes of fracture, resulting from compression during unequal tension of the strata. The second of these classes, the mechanical joints, numerous in all strata which have been much moved or uptilted, abound more in the highly-inclined and faulty beds than in the more horizontal ones, and more in very hard and highly-metamorphic anthracites than in the softer semi-anthracites and bituminous coals; while, on the other hand, the true structural joints, or those arising from evenly-diffused shrinkage and from the molecular forces excited by the heat which dislodged the bituminous matter, are most numerous and closely disposed in the softer or semi-anthracites. An interval of from half an inch to several inches usually separates these *cleats*, as they are called by miners, which cross the lamination of the coal at right angles, and are coincident approximately with the line of the dip. These are the smoothest and best-marked of the two sets of joints. The others, which are also perpendicular to the stratification, but are approximately at right angles to the dip, or parallel with the strike of the beds, are generally farther asunder, and not so clean and smooth. Both systems of cracks, but especially the cross-cleats, are very frequently filled with a white substance—a nearly pure form of silica—which, we may conceive, has been either segregated from out the substance of the coal itself, where some original silica no doubt exists as a secretion from the reed-like vegetation, or introduced mechanically into the clefts of the shrinking coal in a vaporous state, sublimated very probably by the hot steam and volcanic gases which everything indicates to have been the main agents in the de-bituminisation or metamorphosis of the coal-beds. One form of these cleats, both with and without this white coating, is where the clefts are excessively slender, or not wider than the thickness of fine paper, and of proportionately small areas, losing themselves in the coal. When these minute fissures are numerous, the fresh fracture of the coal is marked with small roundish or oval eyes, whence I have proposed for this variety the title of *Bird's-eye coal*. Frequently these small disc-like figures, which exhibit a curling or flattened conchoidal fracture, such as we frequently see in badly-annealed glass, and which suggests that they have been caused by contraction or shrinkage of the coal, are filled with the white flaky silica, each fissure, when small and undulated, enclosing a delicate round or oval scale of it like a white spangle. An anthracite in which this feature much abounds, however pure it may be in other respects, or rich in carbon, is called technically by our miners *rough coal*. For certain uses, especially for domestic consumption, its value is sensibly impaired by even the small amount of incombustible mineral matter it contains in its clefts; for this, though minute in quantity, has a tendency to exclude the air from contact with the coal when burning, which it therefore causes to kindle, and consume too slowly. Some of the rough Bird's-eye coal does not crumble down or fall asunder by its fissures, as much cleaty coal is apt to do; and therefore, where lumpy coal is preferred, as it is by some of the smelters of iron, its toughness is a recommendation. The most highly metamorphosed coal of the United States—that of Rhode Island—exhibits this mineral matter in its clefts in great abundance; and partly from this cause, and partly, perhaps, from its great density, it is the most difficult of all the anthracite coals to ignite, or to maintain in active combustion when employed alone, or without a strong current of air.

Occasionally in the anthracite coal-beds of Pennsylvania we meet with minutely-diffused silicious sand in coal otherwise pure; indeed, this so-called *sandy coal*, the best instances of which are to be seen in the Dauphin Basin, is usually not a slaty or argillaceous variety.

Sulphuret of Iron.—All coals, and all carbonaceous slates and shales, contain, it is well known, more or less sulphuret of iron, generally minutely diffused in scarcely-discernible crystals, but sometimes in visible and even large crystalline aggregates, or in flakes lining the cracks and joints of the stratum. Anthracite, on the whole, would seem to contain a rather larger proportion of sulphur in this combination than those coals which retain their volatile constituents, but the cleaty varieties are not necessarily the most charged with it. The sulphuret of iron would seem to abound most in the slaty laminæ of the anthracite—though small specks of it may be often detected in the coal itself, with help especially of a magnifier. Even when it is not more abundant in dry anthracite than in the bituminous coals, it causes the air from this species to be more deleterious than from those gaseous fuels, in consequence of the conversion of nearly all of it into corrosive sulphurous acid gas, while in the bituminous coals the hydrogen and other gases serve as a partial counteraction, by forming with it other less injurious compounds. Ventilation of apartments in which anthracite is burned is therefore even more indispensable than where the fuel is an *equally* sulphurous soft coal.

Mineral Charcoal, as it is sometimes called, but which is a true vegetable production, as its structure discloses, but preserved in the fossil state, is equally a constituent of the anthracite as of the bituminous coal. It occurs in little layers, parting the solid seams which make up the thicker beds of the anthracite, in all thicknesses from that of a shilling to several inches, though it is seldom met with more than half an inch thick. Its presence in the non-metamorphic coals as abundantly as in the anthracites, is one of several circumstances connected with it, going to prove conclusively that it is an original product formed at the time of the deposition or first conversion of the vegetable elements of the coal, and not an after-result of any partial heating or combustion of the coal by subterranean fires, as many persons imperfectly instructed in the chemistry of geology have imagined. This charcoal, produced possibly in contact with the atmosphere, and not under water, on the surface of the ancient coal-forming bogs, and not within them, has escaped the masceration which converted the rest of the vegetation to a soft pulpy disorganised mass, already freed from the gases associated with it in the tissues of the plants, and reduced to the elemental and unalterable condition of pure carbon, but by a change so gradual and soft as to have retained its original organic structure, has undergone no after-alteration whatever, when the more complex soft coaly matter enclosing it was heated and decomposed, and had its volatile and bituminous constituents distilled and driven away.

SEMI-ANTHRACITE, OR SOFT GASEOUS ANTHRACITE.

This variety of the anthracite class of coals is distinguished from dry or hard anthracite by possessing a black or less plumbaginous hue, less hardness, less density, and a less metallic lustre and sound, and by containing a perceptibly greater amount of gaseous ingredients. The conchoidal or "glass-bottle fracture," as it is sometimes familiarly named, is not so predominant, while the fine transverse clefts or cleats are closer and more numerous, their average distance not exceeding a third or a half of an inch. Adopting 1.50 as the mean specific gravity of the hard anthracites of Pennsylvania, that of the semi-anthracites of the same region is expressed by 1.40, which is the density of the pure Welsh anthracites. The semi-anthracitic qualities are restricted, with few exceptions, to those coals which possess from 6 to 10 or 11 per cent of total volatile constituents, or on an average from 7 to 8 per cent of volatile combustible matter. In consequence of this element, part of which at least resides probably in a free or gaseous state in the cells and clefts of the coal, this variety kindles more promptly, and, when sufficiently supplied with air, burns more rapidly, than the hard anthracite. When first ignited, it emits a small amount of yellow flame, distinctive of the burning of the carburetted hydrogen gases; after which it gives off only the lambent, thin, but very hot flame of true anthracite. The semi-anthracites crumble up or divide into small angular fragments more readily on the fire than less-jointed hard anthracites; and this quality, inconvenient in some cases where the draught is feeble, by causing too dull a fire, is a real excellence wherever the draught can be regulated, and a sufficiently energetic one secured; for if only the additional influx of air is sufficient to overcome the increased friction consequent upon the increase of surface and multiplication of edges arising from the smallness of the lumps, these coals are found to engender almost as high a heat as the anthracites, while they can be made to burn both faster and more steadily. Their absolute efficiency for equal weights is perhaps a little less, proportioned to their smaller total quantity of carbon; but their actual efficiency in equal times is as great, or even greater, than that of the hard anthracites, by virtue of their superior quickness of consumption.

Good semi-anthracites of the Western portions of the Southern and middle anthracite coal-fields of Pennsylvania, display an average composition as follows:—

Fixed carbon, ...	84.00 per cent	Water dispelled at 312°, . .	2.50 per cent.
Inflammable gases, . . .	7.50 „	Earthy matter, ...	6.00 „

Precisely the same inequalities in purity, or in the proportion of carbon to earthy matter, exist in this class as in the hard anthracites, both kinds having about the same minimum of sedimentary foreign matter.

The especial excellence of the semi-bituminous coals consists in the readiness with which they burn after being kindled, combined with an absolute heating power almost as great as that of the dry anthracites. When once the proper appliances are used for giving them their fullest efficacy, these coals will probably take the very highest rank among the fuels best adapted for the economical generation of steam. Their successful application to the smelting of iron in high furnaces—a result not yet achieved—must depend altogether on the adequacy of the weight of blast employed. They evidently present more friction to the blast than the large-lump anthracites, for a reason already assigned; but this need be no hindrance to their economic application, since in all well-constructed anthracite iron-furnaces there is a larger surplus of heat engendered—a far larger—than is equivalent to any additional amount of power demanded to overcome increased assistance from a partially-friable fuel.

Under every mode of burning coal for ordinary domestic purposes, excepting perhaps that of the common open grate, having a languid chimney-draught, the semi-anthracite proves to be an admirably convenient and profitable fuel. It is more easily checked and regulated than hard anthracite, while it yields, when required, as hot a fire.

It is interesting to observe the several manifestations of a lower degree of metamorphism in the semi-anthracite, compared with the true anthracites. Thus, while the latter resemble jaspery slates in the extent to which a semi-crystalline cohesive force, causing conchoidal fracture, predominates over the force of mere sedimentary aggregation, the former are more nearly equivalent to that stage of alteration in clay-slate which presents an abundance of jointage, with a moderate but not excessive induration. Again, the semi-anthracites are less dense and compact, and even in some instances are minutely and partially *vesicular*—in the condition, that is to say, of a true *coke*, in which the cells have not been altogether obliterated from excess of heating and dissipation of the volatile matter, as they have been in the anthracites; more acted on by subterranean heat than the bituminous coals, which seem not to have had their temperature raised to the point of chemical decomposition, and extrication of their gaseous matter, or to the point of *coking*; and less excessively baked than the dry anthracites, in which this decomposition was total. These and the semi-bituminous coals, the two varieties of semi-metamorphic coal, display just those intermediate grades of organic change in which we can best discern the proofs and the modes of the metamorphism.

THE BITUMINOUS COALS.

Next in the order of classification are the Common Bituminous Coals, divided into the semi-bituminous and full-bituminous varieties, which are again subdivided, as shown in the Table, into Caking, Cherry, and Splint coals. This class of coals is separated from the anthracites on the one side, and from the hydrogenous coals on the other, by containing or yielding both coke and the combustible gases, while the anthracites consist almost exclusively of fixed carbon or coke, and the hydrogenous produce scarcely any coke, but only the inflammable hydro-carbons. Perhaps, in the generic sense, all coals, except the anthracites, should come under the denomination of bituminous coals, using this term in its ordinary loose acceptation; but it is not precise enough for the purposes of definition, unless restricted as here proposed. In strict chemical language, it is doubtful if any coals are truly bituminous, or contain the substance bitumen (unless perhaps occasionally in minute quantity), in the free or ready-formed condition; they only abound in the elementary principles of bitumen, and yield products very analogous to those which it furnishes when similarly distilled and burned. Perhaps the most generally intelligible designation for this special group of coals is that I have chosen of "*Common Bituminous Coal.*" A not inappropriate familiar name would be *coke coal*, distinguishing it from the gasless anthracites and the cokeless gas coals.

In external properties, the common bituminous coals range in colour from a pitch black to a dark brown; their lustre is vitreous, resinous, or, in the more fibrous varieties, silky; their structure is compact or cuboidal, slaty, columnar, and even fibrous; and their fracture, irrespective of structural joints and cleavage, is conchoidal, and often flat and rectangular, and sometimes fibrous. It is distinctive of these coals to burn with more or less of yellow bituminous flame and smoke, and to emit, when burning, a bituminous odour. In *proximate composition*—namely in fixed carbon or coke, volatile matter or combustible gases, and earthy sedimentary residue or ashes—they may be regarded as ranging between the following general limits:—

Fixed carbon, .	. from 52 to 84 per cent.	Earthy matter, .	. from 2 to 20 per cent.
Volatile matter,	. „ 12 „ 48 „	Sulphur, . .	. „ 1 „ 3 „

Dried at a temperature of 212° F., they yield of water from 1 to 3 or 4 per cent.

The proportion of earthy matter is of course too variable to have a maximum limit affixed to it, as all the kinds of coal may by impurities graduate into carbonaceous shales.

In *ultimate composition*, the coals of this class may be recorded as ranging approximately nearly thus:—

Carbon, . . .	75 to 80 per cent.	Oxygen, ...	4 to 10 per cent.
Hydrogen, . . .	5 „ 6 „	Sulphur,. . . .	0.4 „ 3 „
Nitrogen, . . .	1 „ 2 „	Ash, ...	3 „ 10 „

BITUMINOUS COALS.

Caking Coal.—This very common variety of bituminous coal, when put in the fire, breaks into a number of fragments; as it becomes more heated, these fragments melt, and run into a mass or *cake*, which, as the heat increases, emits from its interior jets of inflammable gas, leaving a very porous coke or cinder.

The colour of this coal is a velvet black, streaked with greyish black; the lustre shining and resinous. The longitudinal fracture is straight and slaty; the cross-fracture partly small-grained and uneven when the lustre is dull and glistening, and small conchoidal when the lustre is brighter. It is soft and easily broken, the fragments assuming a cubical shape. It readily soils the fingers, and makes a distinct streak on paper. Specific gravity, 1.269.

This is one of the most commonly used English coals. It readily ignites, and burns with a lively yellow flame. It is lasting, and gives out a steady heat; but from its property of fusing into cakes or masses, it requires to be frequently stirred, so as to admit the air into the interior of the masses. The best qualities contain 76 per cent carbon, 5 hydrogen, and leave 1½ ash.

Cherry Coal.—This coal in appearance nearly resembles caking coal. The colour is a velvet black, with an admixture of grey; the lustre is resinous, sometimes dull, in other cases shining. The longitudinal fracture is slaty, the plates having a varying lustre; its cross-fracture is usually flat conchoidal. It readily splits into rectangular fragments, approaching a cubical form, and is so frangible as to break down into a great amount of waste. When exposed to heat, it does not run into cakes, but readily ignites, and burns with a clear yellow flame, giving out much heat, but consumes faster than either caking or splint coal. It in general contains more carbon and hydrogen than the caking coal, and leaves about 10 per cent of ash. It is a very abundant coal, and is extensively used as an article of fuel. It is called *cherry* by the miners, from its lustre and beauty. Specific gravity, 1.265.

Splint Coal—Slate Coal.—The colour is black, with a shade of brown; lustre resinous, dull, glistening. The longitudinal fracture is imperfect, curved, slaty; the cross-fracture fine-grained, uneven, and splintery. In mass it is not easily broken. Between the splint coal, thin layers of cherry coal frequently intervene, which are distinguished by their superior lustre. Splint coal requires more heat to ignite it than either caking or cherry coal; but it then burns with a durable, steady heat. The best qualities leave about 9 per cent of ash, but inferior kinds a much greater amount. Splint coal is of various qualities, and is extensively used for economical purposes. Specific gravity, 1.290.

HYDROGENOUS COAL.

The varieties grouped under this head, from the amount of combustible matter which they contain, and the readiness with which this is given off in combustion, have by the miners obtained the name of *cannel* or candle coal, pieces of the coal, when ignited, giving out a flame like that of a candle. When a large piece of this coal is put in the fire, it splits up into fragments with a crackling noise, somewhat like the chattering of a parrot; hence also the provincial name of *parrot* coals.

The general aspect of the hydrogenous coals is that of a dark compact mass of a black, brown, or greyish colour; a resinous lustre, sometimes dull, sometimes glistening. The fracture is sometimes slaty, or flat conchoidal. The surface is softish, may be easily marked with a sharp-edged instrument, and in many of the varieties (especially in *jet*) takes a good polish. They break up into fragments of various forms,—sometimes approaching the cuboidal, sometimes flat wedge-shaped, and in others quite irregular. Specific gravity, 1.272.

These coals are distinguished by the amount of volatile combustible matter, which varies in the different qualities from 30 to 70 per cent. In a common fire they burn away quickly, with much flame and smoke, but impart little heat. The richest hydrogenous coals are those of Lesmahago, Capeldrac, Methil, and Torbanehill in Scotland.

The Torbanehill coal, when treated in a particular mode of distillation, yields also a peculiar oil, called paraffine.

The Torbanehill coal-seam is from 2 to 4 feet in thickness, and lies above a seam of common splint-coal, with a bed of ironstone intervening.

Most of the varieties of cannel coals are more or less employed for the manufacture of gas, those in which hydrogen bears a high proportion to oxygen being the best. Those also which are free from sulphur or iron-pyrites are also preferred.

From the Torbanehill coal 14,000 cubic feet is obtained per ton, occasionally 16,000 to 18,000 feet; the Wigan yields 11,500 cubic feet.

The best Wigan cannel yields 10 per cent of the heavy carburetted hydrogen, a highly-illuminating gas; the Torbanehill yields 20 per cent of the same gas, and occasionally even more.

The best gas-yielding coals yield the best coke.

The minimum yield of gas from cannel coals is 9000 cubic feet per ton.

CAUSES OF THE GRADATIONS IN COAL.

Corresponding with the progressive augmentation N.W. of bituminous matter in the coals of the whole Appalachian chain, is a gradual but perceptible increase of volatile constituents in the anthracites of Pennsylvania, within the more restricted limits which they occupy. In this part of the chain, however, the direction of the maximum rate of softening of the coal, and introduction of volatile and bituminous matters, would seem to be nearly due W., or perhaps more exactly towards the W.N.W. The gradation will be found to be not absolutely regular, but to fluctuate within quite narrow extremes, as might be anticipated from the very obvious relation of the degree of de-bituminisation, to the varying degrees of heat and disturbance which have locally affected the strata. Even in the same locality, the closely-adjacent beds will differ by 2 or 3 per cent in their quantity of volatile matter.

Surveying the whole anthracite coal-field, and comparing the coals in their average composition, we find that from the Lehigh and the Lackawanna streams, W. to Black Spring Gap in Dauphin, and to Shamokin, their usual proportion of total volatile matter is about 5 per cent. Of this, generally one and a half per cent is moisture, and the other 3 or 4 per cent hydrogen, oxygen, nitrogen, and other gases. The coal between these limits may be all classed under the one denomination of genuine or hard anthracite. But for a few miles from the meridian mentioned, extending in the Southern Basin from Black Spring Gap to near Rausch Gap of Stony Creek, and in the Wiconisco Basin from Klinger's Gap W., and in the Shamokin Basin from a little W. of Shamokin Gap to the extreme W. end of that basin, the coals show a gradual but decided increase in their quantity of volatile matter, with a progressive departure from the characteristic hardness, lustre, and colour of the true anthracites. These are the limits of what I have termed the *semi-anthracites*, which are nowhere so well characterised, so well developed, and so accessible, as in the Shamokin Basin, for 2 or 3 miles both E. and W. of Zerbe's Gap, near Trevorton. Between the meridians now defined, the average amount of volatile matter in the coal is about 9 per cent, some 6 or 7 per cent of which is combustible gaseous matter, and the rest is moisture and non-combustible gases. As already mentioned, these gaseous anthracites are traversed by more numerous fissures than the harder kinds farther E., and, as a consequence, their mode of burning is essentially different. A very regular gradation in the increasing frequency of the little joints alluded to, is perceptible in tracing these coals from where they merge into the compact anthracites on the one side, to where they pass into the semi-bituminous coals on the other. From a third to a half of an inch is the prevailing distance which separates the cracks in the genuine semi-anthracites of Zerbe's Gap, those of the W. end of the Wiconisco Basin, and those of the E. part of the Dauphin Basin; and it is an interesting fact, that they are almost absolutely parallel with each other, and constitute but one set or system of joints, whereas the softer semi-bituminous coals are traversed perpendicularly to the lamination of the coal by *two* or more sets of still more closely adjacent fissures, by which their laminæ are throughout extensive districts rendered minutely *columnar*. The economic considerations connected with the respective effects of these modes of fissuring, will be discussed in another section of this paper.

From about 2 miles E. of Yellow Spring Gap of Stony Creek, W. along the Dauphin Basin to its termination within 10 miles of the Susquehanna, the proportion of bitumen in the coal increases from an average of 10 per cent to an average of 14 or 15 per cent, fluctuating in the different beds from 8 to 12 per cent at the Eastern end of this belt, and from 13 to 14 at the Western; this range includes, then, the drier class of semi-bituminous coals, and towards its E. limit some true semi-anthracites. And the same seams which at Yellow Spring Gap are dry semi-bituminous coals, are all of them semi-anthracites at Rausch Gap, only 4½ miles farther E. Into the question of the sources of this difference in the amount of volatile matter remaining in different closely-contiguous coals of any group, either semi-bituminous or bituminous, I shall not here enter, as this is not a point of any obvious practical moment.

By the foregoing description of the progress of the gradation in bituminous matter, it appears that in the Dauphin Basin the transition to semi-anthracite commences somewhat earlier in this Southern coal-field, and in the Shamokin Basin, than it does in the Wiconisco coal-valley, where this variety is confined almost to the W. end of the trough. It is also shown that the semi-bituminous coals are found only in the Southern Basin, and that the transition from the semi-anthracites to these there takes place, considerably East of the Westernmost meridian of the semi-anthracites of the two other basins. Had the Zerbe's Run Coal Valley been prolonged but a very few miles farther W., the present rapid increase in that direction of the volatile matter in this coal shows that it too would have included the semi-bituminous class.

The causes not only of the general gradation in composition, but of the local differences in the progress of this curious transition in the bitumen above described, are plainly indicated in the particular geological structure of the respective coal-fields. Applying the theory of the cause of the de-bituminisation of our coals to the inequalities of composition, it is important to observe, that the phenomena are truly those of a baking and metamorphism of all the strata by an intense and pervading heat; that this heat has obviously been in greater excess in the E. than in the W. tracts of the anthracite country, and has been even differently operative, upon the different beds of coal, in proportion as these were encased in more or less conducting strata, or in strata more or less pervious to the escaping volatilising gases and bitumen. Independently of the satisfactory evidence presented by the transition of the coal itself, we have proofs, in the altered character of the other members of the formation—the shales and sandstones—and in the conditions of the rocks external to the coal-basins, that the igneous action was most intense towards the E. In that quarter the shales or mud-rocks of the Kittatinny Valley have been so thoroughly baked as to have been converted into roofing-slate; and not only this formation, but all the other strata from the Schuylkill and the Lehigh to the Delaware rivers, are traversed by a system of close-set, parallel, uniformly-dipping cleavage-planes, in token, not to be overlooked, that the drying and polarising agency of internal heat was here exerted in its fullest energy. Westward from the sources of the Schuylkill, both within and outside of the coal-fields, the parallel South-east-dipping cleavage pervades the argillaceous masses in a constantly-declining degree, so that the same rocks which near the Lehigh are almost indefinitely divisible into thin parallel slates, have had, in the country between the Schuylkill and the Susquehanna, this polarity less intensely imparted to them, and break, by two or three intersecting sets of planes, either into rhombs or elongated horizontal pencils. This declension in the metamorphism of the shales or mud-rocks is in parallelism with the similar change in the cleavage of the coal itself, which, in the anthracites and semi-anthracites, occurs only in one direction, and is parallel, and in the softer semi-bituminous variety in two or more intersecting directions, resulting in a columnar fracture.

But we have still more positive proof of the truth of the view here taken, that the E. portions of these anthracite fields were more invaded than the W. by volcanic heat, in the fact that it is only adjacent to the former that any igneous mineral dykes or veins of molten matter, injected during the elevation of the coal strata, burst through the crust to the surface. Along the chain of the South Mountains or Highlands, from the Delaware to the Schuylkill, occur numerous intrusive dykes of magnetic iron-ore, greenstone, and other igneous rocks; while in the humbler range of hills scattered between the Schuylkill and the Susquehanna, these injections are much more rare. In the E. quarter, therefore, the earth was far more violently rent than in the W., and we are conducted to the almost necessary inference, that the districts respectively opposite these differently disturbed and heated belts were themselves in a somewhat corresponding degree differently heated; for although not a single intrusive vein or dyke is to be met with in all the anthracite country, there evidently issued through the coal strata a copious efflux of hot volcanic gases and steam by the dissimilar heating and distilling power of which, in the different districts, the coal itself was variously de-bituminised and metamorphosed.

CONDITIONS IN THE COMPOSITION AND STRUCTURE OF COAL AFFECTING ITS ECONOMIC VALUE.

It will assist us to estimate more correctly the relative practical values of different coals, if we consider the various qualities which good coals should possess, and the extent to which certain conditions in their constitution influence their efficiency as fuels.

The chief useful applications of coal, at the present day, are—to the warming of houses, the generating of steam, the smelting of iron and some other substances, the burning of bricks and lime, and the manufacture of illuminating gas.

For all these and sundry other uses, excepting the making of gas, the semi-anthracites, it is conceived, will be found quite as well suited as the hard, dry anthracites, while they are undoubtedly even better adapted to some particular applications.

A good anthracite, for domestic purposes, should be as free as possible from *sulphur* and from *ashes*, and it should ignite readily, and maintain its own combustion until entirely consumed, and not under too intense a temperature. A most essential requisite to the health and comfort of all communities, living in cool and especially in variable climates, is the maintenance of a tolerably uniform in-door temperature; but it must be acknowledged that the harder anthracites, burned in the crude and unscientific modes almost universally in practice, absolutely resist control in this respect. When fully kindled, in quantity enough to make a lasting fire, either in an open grate or a stove, almost any compact anthracite will heat the space around it to excess, and moreover, cause a dryness in the air, which is extremely unwholesome. These coals can only burn at a very elevated temperature, and with an abundant admission of atmospheric air, and they therefore oppose much difficulty to all attempts, unless made with very exact adjustments, at restraining their combustion to the satisfactory point of a low mild heat.

The semi-anthracites are susceptible in this respect of much more easy management. Under a strong draught, which they require for full activity of combustion, these coals (as our Table of comparative results will show) burn quite as fast, and create as extreme a heat, as do the hardest anthracites; but with the ordinary supplies of air, they consume slowly, and give off only a moderate and comfortable temperature.

The chief reason of this difference is, in their readily breaking into small fragments on the fire, and damping thereby the draught by the increased friction which the air encounters. When the current of air, on the contrary, is strong, the effect of the greatly-extended surface resulting from this subdivision overrules the influence of the friction, and these coals then burn with a rapidity and an intensity of heat which give to them an efficiency for other purposes, decidedly superior to that of any but the very purest and quickest-burning among the true anthracites. The greater amenability to control of the softer coal, compared with that of hard refractory anthracites, renders it especially well suited for domestic consumption in stoves and cellar furnaces, as already amply demonstrated by numerous and protracted trials. In these arrangements it is altogether more easy with it than with common hard coal to maintain a steady and sufficient temperature in an apartment or throughout a house for many hours together, or even a whole day and night, without a renewal of the fuel. Its important property of burning at a relatively lower temperature keeps it enkindled to the last; and, as a consequence, it leaves behind it after combustion almost no unburned residuum. Not so with the densest dry anthracites. These rage for a while under a moderate strength of draught, and then, at a point much short of entire consumption, they die out from decline of temperature, leaving a serious amount of fuel wasted, and causing in household economy no trivial inconvenience. To obviate this form of waste and extra labour, the fires are replenished with fresh fuel when it is not required, and then an almost insupportable heat is created, while a still larger waste, with much increased discomfort, are the consequences.

Another material point of difference in the fitness of the two classes of anthracites for domestic use, when burned in open fires, is in their sensibly dissimilar influence on the dryness of the surrounding air. The atmospheric moisture exists as an independent gas, inter-diffused with the other less variable elements of the air. Any local source of aqueous evaporation, or of chemical production of water, as in the combustion of wood or of bituminous coal, suffices to spread a more or less diffused humidity throughout the rest of the space, by virtue merely of the power inherent in every vapour and gas to diffuse itself among the others, uninfluenced by mechanical currents. Thus an actively-blazing wood fire, by producing a copious supply of watery vapour in its smoke, serves slightly to moisten the atmosphere around, because, notwithstanding that the flow of air is towards the fireplace, the humid particles percolate through the current by a more active force in the opposite direction. But such is not the case where a fuel, like a hard dry anthracite, is burning in presence of the atmosphere of the room. Being almost destitute of hydrogen, it develops by its combustion little or no water, while at the same time it creates a great avidity for moisture in its own smoke, and in the air around it, by the high temperature to which it heats these. It therefore occasions a filtration or diffused movement of the watery particles of the atmosphere of the room towards the fireplace, and not from it. A mass of such fuel ignited is, in other words, an *absorbing vacuum* for moisture, while a blazing wood or bituminous fire is a *dispersing plenum*. In this opposite action of the two kinds of fuel, we find the explanation of the obvious and acknowledged difference, in the agreeableness and wholesomeness of their respective open fires.

Now it is deserving of remark, that this detrimental drying action of the anthracites is possessed in a decidedly smaller share by the soft, free-burning, and gaseous semi-anthracites, several of the characteristics of which depend on their containing a sensible proportion, often one half as much as belongs to bituminous coals, of the important moisture-producing element, hydrogen. All the non-bituminous coals desiccate the air too much; but these do this least, and will be found, upon this account, decidedly the most wholesome class, if open fires are used.

Another very important application of fuel is the development of steam, either for warming buildings or propelling machinery. In this latter function, as the foremost of all the agents employed by civilised man for his industrial ends, and as incomparably the most condensed form of mechanical power which he can hope to wield, coal is rapidly becoming the chief material minister to human progress. Whatever, therefore, relates to a correct theory and practice in applying it to steam, must be regarded as of paramount interest. Any careful experimental inquiry into the properties and relative value of the semi-anthracites—a variety hitherto but little investigated—is therefore, upon general considerations, no less than local ones, deserving of attention.

The principal requisites of a good fuel for steam purposes are easily enumerated.

1. It should possess a high absolute evaporative power.

2. It should at the same time, as far as is compatible with the foregoing property, kindle readily, and burn with great celerity, generating a large body of steam in a short time.

3. It should be easily managed, and steady in its combustion, and to this end its ashes or earthy matter should tend as little as possible, to choke the draught of the grate by fusing, even at an extreme heat, into an adhesive clinker.

4. The fuel should be free from any excess of incombustible matter, as this, all other things being the same, will materially impair its efficiency; and its ashes should produce but little clinker.

5. It should be exempt from any considerable amount of sulphur, for this tends to corrode the flues, and is otherwise detrimental.

6. Whatever volatile matters it possesses should not be bituminous, but should be in the condition of the free gases, susceptible of ignition or disengagement without smoke; and these volatile matters should not exist in any greater amount than will suffice to give rapidity of combustion to the fuel; any larger proportion is at the expense of its heating power.

7. A fuel should not be too cohesive and refractory on the fire, nor yet too tender and divisible. In the one case its combustion will be slow and irregular, and in the other it will be still slower for want of the requisite draught. A certain degree of spontaneous frangibility, such as is shared by some of the less-resisting anthracites, and by many of the firmer semi-anthracites, appears from practice and experiment to be the structure best suited to extreme vigour and steadiness of combustion.

8. For certain purposes of domestic consumption, coals should be capable of sustaining a mild and steady combustion, and of remaining ignited at a low temperature with a comparatively feeble draught.

9. For certain uses, it is important that a coal should unite with a high evaporative power such a degree of density and structure combined, as will enable it to contain a relatively large amount of carbon in a given space. This capa-

bility of being economically stowed or packed away, is a point of daily-increasing consideration. The difference between the least and the most stowable anthracites, is as much as 16 per cent, and between the closer-packing anthracites and the lighter and more open bituminous coals, it even exceeds 20 per cent.

10. It is likewise desirable that a coal should possess sufficient tenacity in the lump, to bear the abrasion incident to its transportation, without serious waste by reduction to fine coal.

These are the principal qualities in coals which materially influence their economical value. No one variety will ever be found to unite them all, for some of them can hardly coexist in a high degree in the same specimen. The relative worth to be assigned to these several desiderata, is itself variable with the uses to which the fuel is to be applied. But having a specific application in view, it is easy to ascertain what union of compatible qualities will insure to a coal the highest possible efficiency. This once determined on, the records of judiciously-conducted practical experiments will then prove the proper guide in selecting the kinds required.

If I now present a condensed synoptic view of the composition and comparative efficiency of a number of well-known and characteristic American and British coals, derived from the able experiments of De la Beche and Playfair, and the full and careful researches of Johnson, and from our own trials, the reader will have before him all the data necessary for determining the general relative excellence of the several species, and the rank which each particular coal can claim, when measured by either of the practical standards established.

In offering this tabular statement, it is expedient to remark, that in all such comparative estimates of the values of different fuels, strict impartiality and accuracy require that the conditions under which the different varieties are tested, should be modified, as far as possible, to meet their individual peculiarities. A just comparative view will embrace not merely a faithful account of the chemical and physical characters of the several coals, but the results of sundry trials of their efficiency in numerous modes of their application, as in warming, generating steam, and smelting, and with the circumstances variously adapted to bring out the fullest economy and power of each kind of fuel. Our own investigation of the semi-anthracites* embraced, together with a chemical analysis of several average specimens, a determination of their usual specific gravity and power of being economically stowed, and in addition, many comparative trials of the combustible efficiency of the coal in open fires and stoves, and under a set of four well-arranged steam-boilers. No actual experience has yet been had touching the suitableness of the semi-anthracites to the various processes of iron-making, but several important inferences may be deduced from what has been ascertained of their composition and structure, and their fitness for other uses, involving the same combination of qualities essential to a good smelting-coal.

In the experiments made upon the evaporating power of the coals, due care was observed to insure comparable results, so far as was practicable, upon good boilers, without any special adjustments for adaptation to differences in the fuels and working for a copious production of steam. As the furnaces and flues connected with these boilers were planned especially to meet the requirements of the harder kinds of anthracite—the grate bars being three-fourths of an inch apart—the conditions have been rather adverse than otherwise to the impartial claims of the semi-anthracites.

It will be seen that in planning and conducting these researches, we have not aimed at any extreme scientific precision, or even at procuring results by perfection in the apparatus or otherwise, beyond such as are easily obtainable in the way of good daily working practice. The two kinds of coal were deemed sufficiently alike, after all, to yield approximately comparable values, and it is very doubtful whether the most refined apparatus, unless variously adapted to the peculiarities of each fuel, where the coals are more diversely organised, as in comparative trials between the bituminous and anthracitic varieties, can ever exhibit more closely than ours has here done the respective merits of the different species.

While, therefore, we do not pretend to rank our experiments with the above-mentioned skilfully-conducted observations of De la Beche and Playfair and their assistants, or the elaborate researches of Professor Johnson, and while we are aware that the very active blast we used was incompatible with as economical a combustion as those experimenters produced; we are content, for the sake of affording an insight into the relative efficiency of the semi-anthracites, to tabulate our results with those of the esteemed authorities we have named.

The design of the General Table which here follows, is to present in one condensed comparative view the more practically important physical and chemical characters, manner, and rate of burning, and evaporative power and activity, of the chief American and foreign coals hitherto subjected to experiment; and to show, moreover, by a series of impartial averages, the relations to each other, in these respects, of the four great classes into which the coals naturally rank themselves.

Let us now review concisely, by aid of the following Table, the relative values of each leading class of coals. In this inquiry it will be proper to judge of the rank of each kind of coal by the extent to which it possesses the several qualities already mentioned as the chief requisites of every good fuel. But it must be carefully borne in mind, that, though the numerical results here exhibited offer a fair approximate measure of such relative rank, they are not to be adopted in certain cases without allowance for the modifying influence of differences in the modes of measuring and burning the coals.

* See *Reports on the Combustible Qualities of the Semi-Anthracites of the Shamokin Coal-fields.* By Augustus A. Hayes, M.D., and Prof. H. D. Rogers. Boston: 1851.

[TABLE.

TABLE

(SHOWING THE RELATIVE PROPERTIES AND ECONOMIC RANK OF THE DIFFERENT CLASSES OF COAL).

		DENSITY.			COMPOSITION.			CONDITIONS OF THE COMBUSTION.						EVAPORATION.			RANK.
	NAMES OF COALS.	Specific gravity.	Weight of 1 cubic foot broken in lb.	Stowage of 1 ton in cubic feet.	Volume comb. matter in 100 parts.	Fixed carbon in 100 parts.	Earthy matter in 100 parts.		Weight of Coals burned.	Clinker alone from 100 lb. Coal.	Total Waste in Clinker & Ashes.	Pounds burned on sq. ft. of grate per hour.	Hours required to get up full action.	Pounds of Water evaporated.	Pounds of Water evapd. from 212° to 1 lb. Coal.	Rate of evaporation, or lb. evpd. per hour to sq. ft. gt.	In the order of combined evaporative speed and power for equal bulks.
Hard Anthracites.	Rhode Island (Hayes),	1.79	...	...	3.00	77.00	16.00	...	10560.	10.00	10.90	9.44	...	63525.6	7.40	69.85	...
	Beaver meadow—mean of 3 kinds (Johnson),	1.55	55.06	40.03	2.52	90.20	6.13	...	4009.5	1.00	9.35	6.48	3.15	...	9.54	61.82	3403.80
	Lehigh (Johnson), . .	1.59	55.32	40.50	5.28	89.15	5.56	...	3838.2	1.08	7.22	6.95	3.27	...	8.93	61.16	3383.31
	Forest Improvement (J.)	1.47	53.66	41.75	3.07	90.70	4.41	...	3810.	0.81	6.97	6.52	3.32	...	10.06	65.69	3519.55
	Lackawanna (Johnson),	1.42	48.89	45.82	3.91	87.74	6.35	...	4112.5	1.24	8.93	6.45	2.67	...	9.79	63.15	3067.40
	Mount Laffy (Hayes and Rogers), ...	1.54	53.50	41.87	...	...	...	...	8100. largest expt. 34118.	12.80	19.00	9.23 highest, 10.00	...	63525. largest expt. 251513.	9.32 highest, 10.19	85.68 highest 92.32 9.08 X 10.19	4594.6 highest, 4949.8
	Welsh Anthracite (De la Beche & Playfair),	1.37	58.25	37.23	5.50	91.44	1.52	...	...	...	9.58	8.65	...	...	9.46	81.83	...
	Averages of the 4 first Penn. Anthracites, with Johnson's apparatus, ...	1.50	53.23	42.02	3.69	89.45	5.61	.044	3964.5	1.03	8.12	6.60	3.10	...	9.58	62.93	3349.8
Semi-Anthracites.	Zerbe's Run—mean of 5 trials (Hay. & Rog.),	1.40	53.73	41.69	7.31	84.25	6.11	.000	8000. largest expt. 26406.	3.45	11.70	9.26 highest, 10.20	...	64960. largest expt. 237427	9.58 highest, 10.60	88.92 highest, 108.10	4777.4 highest, 5648 2
	Lykens Valley (John.),	1.39	48.56	46.13	6.88	83.84	9.25	.091	2471.	4.40	12.24	6.92	2.63	...	9.46	65.46	3973.66
Semi-Bituminous Coals.	Dauphin, Yellow Spring (Rogers), ...	...	...	...	11.00	76.00	12.10	...	...	...	...	...	...	...	...	...	...
	Dauphin, Rattling Run Gap (Johnson), . .	1.44	50.54	44.32	13.57	74.24	11.49	.269	...	3.50	16.36	68.6	0.83	...	9.34 highest, 9.66	64.07	3238.09
	Cumberland, Md.--mean of 6 samples (John.),	1.35	53.13	42.17	14.20	73.95	10.41	.714	...	3.12	10.70	7.10	1.45	...	9.98	70.85	3764.26
	Welsh Semi-Bituminous—average of 5 varieties * (De la B. & Pl.),	1.33	58.60	...	13.4	81.88	4.72	.610	...	...	...	...	...	...	8.94	84.5	...
	Averages of the above Penn. and Md. S. B. Coals (Johnson), .	1.39	51.83	43.24	12.92	74.73	11.33	.531	...	3.31	13.53	6.98	1.14	...	9.66	67.46	3496.4
Bituminous Coals.	Richmond Va. Cls., of the Oolitic Epoch—mean of 11 Collieries (Johnson), . . .	1.34	49.25	45.71	29.43	58.10	10.90	1.232	3606.4	4.89	11.78	7.41	1.33	...	8.07	59.80	2945.15
	Foreign Coals—mean of 6 kinds † (Johnson),	1.34	50.00	44.86	31.81	57.66	8.44	0.433	3247.7	4.20	8.71	8.89	0.93	...	8.05	71.56	3578.00
	West of Alleghany Mts.—mean of 2 kinds ‡ (Johnson)	1.26	47.23	47.43	30.28	56.68	6.02	0.160	2465. Cannelton.	1.28	6.68	11.09 Canneltn.	0.50 Canneltn.	...	7.77 Canneltn, 7.34	81.40 Cannelton.	3844.50
	Averages of the above Bituminous Coals, .	1.31	48.82	46.00	30.50	57.38	8.45	0.608	3106.3	3.45	9.05	9.13	0.92	...	7.96	70.92	3456.0
		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P

* The Coals are, Graigola, Ward's Fiery Vein, Binea, Pentrefelin, and Duffryn.

† Pictou, Sidney, Cunard's Pictou, Liverpool, Newcastle, Scotch. ‡ Pittsburg, Cannelton.

The *first* of the qualities to be compared is that of divisibility during combustion. This property, due chiefly to the degree in which the respective coals are intersected by joints, but due also in part to a condition of the cohesive force, and to a low power of conducting heat, as in unannealed glass, is possessed in the least share by the more compact of the anthracites, and reaches its maximum in the softer semi-anthracites. In the semi-bituminous coals of some districts, that of the Alleghany Mountain, for example, the mere mechanical subdivision by innumerable intersecting cracks is in its highest excess, and leads to much waste under severe handling and rough transportation; but upon the fire the minute cubical and columnar fragments cohere together as they coke, and the benefits of that degree of dissolution, seen in the free-burning semi-anthracites, are to a great degree lost.

It has been already stated that the semi-anthracites of the W. end of the Shamokin Basin show the advantages in a sensible degree of this fissured structure. While the actual heating power of the coal, when aided by a proper draught, is not at all impaired by it, the rate of the combustion and evaporation is materially hastened. The strong cohesion of the true anthracites, and the agglutination of the fragmentary semi-bituminous coals, cause these in different ways to retain more of the lump form upon the fire, but the semi-anthracite opens to the current of oxygen a prodigious increase of surface for combustion. When we reflect that a lump of fuel burns only at its surface, that the activity of the combustion is in proportion—other things the same—to the amount of oxygen which can reach an equivalent amount of fuel surface in a given time, and that this amount augments progressively by the subdivision of the fuel, until it is checked again at a certain point by the retardation of the draught from the increased friction—we shall comprehend at once why a particular degree of divisibility may be the most favourable of all for producing high rapidity of combustion. The burning of carbon in atmospheric air, is in part analogous to the dissolving of any other solid in any other fluid. Chemically regarded, it is a case of solution, with formation of new compounds. But such solution is notoriously promoted and hastened by subdivision of the solid body, as we witness in the everyday practice of reducing sugar, salt, and especially the substances which most resist dissolving, to small fragments, or even to fine powder.

The *second* element of practical value in the coals, the first introduced into the Table, is their capacity for *economical stowage*, deduced, not from the specific gravity of solid pieces, but from the ascertained weight of a cubic foot measure of the coal in broken fragments of a standard size. The degree of compactness into which a coal in the state of lumps will stow itself, by no means depends altogether on its specific gravity. It is largely influenced by the shapes into which the coal naturally breaks; those varieties, as it has been well remarked, packing with least waste or intersticial space, which split by parallel joints, and form cubes and other rectangular figures with flat surfaces. And again, the total quantity of efficient fuel which can be stowed in the lump form in a given bulk, will be in proportion, not simply to its weight in fragments per cubic foot, but to this element, and that of its purity from earthy or incombustible matters combined. The present condition and future prospects of ocean steam-navigation, where the fuel-room necessarily encroaches so largely on the freight-room of the steamers, make this quality of stowing closely, an element of great importance. Indeed, the time seems fast approaching, when no other coals will be chosen for the great and growing purpose of replacing the use of the wind upon the seas, but such as unite in the highest compatible degree the three primary qualities of *dense stowage of efficient combustible matter, high evaporative power, and great activity of combustion.*

It will be seen, upon consulting the Table, that though the average specific gravity of the hard anthracites of Pennsylvania exceeds that of the semi-anthracites in the ratio of 1.50 to 1.40, their weight per cubic foot, in the broken state, is very nearly the same, their capacity for stowage being in the near proportion of 41.69 to 42.

Compared with the semi-bituminous coals, the semi-anthracites show an almost exactly equal power of packing, bearing in this respect to the average of the Dauphin and the Cumberland semi-bituminous coals the ratio of 43.07 to 43.24 cubic feet per ton. Here, however, it requires to be noticed, that difference of specific gravity enters as a fallacious element, increasing from the fact of the superior weight of slate over true coal, the apparent quantity of real fuel in the cubic foot of the semi-bituminous coal beyond its actual amount. These semi-bituminous coals exhibit an average of 11.33 per cent of earthy matter, to 6.11 per cent in the semi-anthracite, showing a decided disparity in the proportion of effective combustible matter which the ton weight of each will stow. Where the two classes are of equal purity, the semi-anthracites will, in the larger majority of specimens, be found to be the heaviest, and to occupy, therefore, either solid or when broken, the least bulk.

Comparing again the nearly equal powers of stowage of the three already-mentioned classes of coals with that of the bituminous coals, both domestic and foreign, we find a materially greater difference; these latter requiring on an average as many as 46 cubic feet to hold 1 ton of the fuel. Between the densest Beaver Meadow anthracites, measuring 40 cubic feet to the ton, and the least compact Cannelton bituminous coal, taking rather more than 47.5 cubic feet, the excess of bulk is nearly 19 per cent above the first.

It will be seen from the Table that the Lackawanna coal, which, when pure, approximates sensibly towards the semi-anthracite in its physical structure, is not only light in the solid mass, but relatively bulky when broken.

The figures in the Table indicating the weight per cubic foot of the Welsh coals, both anthracite and semi-bituminous, so far exceed those for the American coals of the same classes, and differ, moreover, so widely in their ratios to the corresponding specific gravities of the coals themselves, when compared to the ratios of the cubic-foot weights of the American coals to their specific gravities, that we are compelled to infer that the mode of estimating the cubic foot of lump coal by the British experimenters was essentially different from that adopted in this country by Professor Johnson and ourselves. In no other way can we account for the large disparity exhibited. This is so serious, considering the lightness, by specific gravity, of the Welsh specimens, that it will be safest not to attempt any comparison here between either the stowage of the corresponding coals of the two countries, or between the rank they respectively hold in the order of their evaporative power for equal bulks, which includes the former as one of its elements.

The *third* important relationship of the coals to each other, exhibited by the numbers in the Table, is that of their *composition*, as determined by proximate analysis, defining the proportions respectively of the volatile combustible matter, the fixed carbon, and the earthy or incombustible residue. In this aspect, it will be seen that the four several classes of coals display a regular augmentation in the average per-centage of the volatile combustible matter, this being about 3 1-2, 7 1-3, 13, and 30, in anthracites, semi-anthracites, semi-bituminous, and bituminous varieties respectively. The corresponding declension in the amount of the fixed carbon is represented by the numbers 89 1-2, 84 1-4, 74 3-4, and 57 1-3; while the incombustible or earthy matter is in no established proportion or gradation, but varies with the individual coal-seams, and even, in fact, with their different subdivisions. Nevertheless it will be noticed as a general feature, that the anthracites and semi-anthracites of the Table are decidedly purer than the two bituminous classes.

An analysis of a coal into its *ultimate* elements shows that its combustible matter, consisting of carbon, hydrogen, oxygen, and nitrogen, embraces, except in the dryest anthracites, invariably a larger amount of carbon than is ever left in the form of coke when the volatilisable portions are distilled or burned away. The cause of this is, that a part of the gases are in chemical combination with a portion of the carbon, while another part, especially the hydrogen and oxygen, though probably in a free state in the pores of the coal, are ready at a low heat to seize upon another equivalent amount of the carbon, so that from both the sources a greater or less proportion of the total carbon, depending on that of the gases, is burned in the gaseous form in the flame and smoke of the fire.

A *proximate analysis* of a coal by heat merely, separates first the free or uncombined water, varying from less than 1 to 3 or more per cent; next, the whole of the combustible volatile matters, including the portion alluded to of the total carbon; then the fixed carbon of the coke, and, as the final residue, the earthy ashes.

As the useful values of coals are variously influenced by the presence and nature of their volatile combustible part, it is expedient that I here notice the chief results of observation and experiments in relation to this ingredient.

One effect of a large excess of volatile matter in a coal, is to impair seriously its heating power. All the researches recorded in the Table concur to prove this point. Comparing the average volatile combustible matter with the average weight of water evaporated from the temperature of 212 degrees by 1 lb. of coal of each of the four classes, the full bituminous kinds display an evaporating power of less than 8 lb. to more than 9.5 lb. for the other three varieties. Numerous elaborate researches go to show, that with very many samples of bituminous coals the heating effect of the whole volatile portion of the fuel is almost "absolutely negative;" and it has even come to be a prevailing opinion, that the total evaporative efficacy of a bituminous coal is no greater than that of the coke or fixed carbon which it contains. Certain it is, that in the ordinary way of practice with the boiler-furnaces in use, the absolute equivalent of heat belonging to the coke (all of which is not procurable, however) exceeds considerably, with rare exceptions, that which is actually produced by experiment on the original coal. Some authorities, among them Professor W. R. Johnson, have evolved results which seem to indicate that the heating efficacy of a coal is measured by that of the whole of its carbon, rather than by that of its coke, which is but a portion, and general experience would appear to sustain this relationship. We must keep carefully in view, however, that such a proportion is liable to be constantly departed from, through imperfections in the furnaces constructed for bituminous coals, and that, moreover, the deviation from this or any other fixed ratio, will vary with the variable nature of the bituminous compounds which different coals contain.

The special qualities of the different bituminous and semi-bituminous coals are not caused solely by the proportions of the volatile matter they contain, but are as intimately connected with their chemical constitution. A most important practical distinction in coals, is that between the caking and the open-burning varieties; and upon these characters, even more than upon their mere amount of bituminous matter, depend their adaptations to many economical uses. For the manufacture of coke, and the production of a hollow forge-fire—where this is needed—the melting coals are valuable; but where a very active combustion is demanded, the open-burning kinds are preferable, since, by not fusing, but only partially swelling, they afford a freer passage to the oxygen, and give out a higher heat. A comparison of the analyses of coals, with the observations upon their manner of burning, shows clearly that, except within certain limits, the proportion simply of bituminous matter has little to do with their free-burning or their caking qualities. As a general rule, the small amount of combustible volatile matter in the semi-bituminous coals, is associated with the absence of any marked tendency to cake into a close or hollow fire; but among the true bituminous class this tendency appears to bear no relation to the degree of bituminisation, some of the driest of these having not more than 25 per cent of volatile matter in all, being decidedly fusible and close-burning; while there are others with not less than 45 per cent, which burn with a free open fire.

It would appear "that the property of caking generally increases with the quantity of hydrogen and oxygen in the coal, and especially with that of the hydrogen," yet to this rule there are found some striking exceptions; and we are compelled, in considering all the phenomena, to refer the different tendencies in various coals to soften and cake, to the existence of different kinds of bitumen, or at least to differences in the constitution of the coals as respects the mode in which the gases are combined with the carbon. This is a subject of much practical and scientific interest, and one which calls for further investigation at the hands of chemists.

A review of all that has been done in relation to this question of the effect of the volatile matter, seems to justify this general statement, that the evaporative power of a coal never exceeds in practice that due to its whole amount of carbon, and is oftentimes as low as that procurable from its coke alone; while the extent to which it falls short by imperfect combustion, of that fullest attainable measure of efficiency, is greater in proportion as the coal is more bituminous. The cause of the waste of so much power in the combustion of bituminous coals, notwithstanding the intense temperature developed by the gaseous products while burning, is clearly to be ascribed to the amount of heat absorbed in raising the cold fuel to the point of ignition, and the yet larger portion made latent by the change of the volatile portions from the solid to the gaseous condition, while only a part of the heat of their combustion is returned. Unless burned with a very intense heat, and with a large excess of atmospheric air, a part of the carbon of the coal passes to the chimney in the form of carbonic oxide gas, having but half undergone combustion, or having given out but half of its possible full product of heat. At the higher temperature evolved by the drier coals, a more total combustion takes place with the immediate production of carbonic acid, and the entire amount of heat produced by oxygen and carbon is developed.

It must not be inferred from what has now been said, that every amount of volatile matter in a coal, whether much or little, must necessarily impair its heating power. The whole tenor of the researches made would seem to contradict this, and to show that the possession of a certain proportion, within restricted limits, exalts not merely the activity or speed of the combustion, but the total heating power, as measured by the evaporative effect. Thus it appears that both the semi-anthracites and the drier semi-bituminous coals, when they are properly burned, rather surpass, in calorific energy, the class of the hard anthracites. A small share of the easily-combustible volatile gaseous matter seems very useful, by promptly kindling the solid carbon with which it is in contact, and thus enabling the fuel to dispense with so vast a current of cooling air, as it is demanded for the full ignition of a dry refractory anthracite. But to confer on a coal the highest heating efficacy, experience and practice would suggest that the proportion of gaseous matter in it should be no more than just enough to facilitate the kindling of the freshly-supplied portions, by quickly transmitting its own combustion to the other parts, but not so large as to occasion any sensible waste of power. It is therefore, as adding to their activity without impairing their strength, that we regard as so important the presence of the trivial quantity of free-burning gases in the semi-anthracites.

Another class of ingredients in coal, the proportions and qualities of which are equally influential with those of the gaseous products, are the earthy matters. These, like the volatile constituents, are somewhat variable in their nature, and by the forms they take under different intensities of combustion, much affect the efficiency of the coals to which they belong. Being differently fusible themselves, and affecting differently the fusion of each other, no two of the earths, alkalies, or metallic oxides, of the ashes, but differ in their agency when subjected to an elevated heat, and their mutual reactions are moreover changed, as the temperatures are changed to which they are exposed. It hence arises that the residue from many coals melts to a large extent, under no very intense combustion, into various descriptions of hard semi-vitreous slags; others yield a less stony clinker; and some again, at a far more elevated heat, result only in a partially agglutinated spongy open cinder, or even in a pulverulent or flaky ash. There are perhaps no coals, whose ashes, when exposed to the extremest heats procurable by artificial blasts, will not soften to a cohering cinder, or even melt in part into a stony clinker; but as the tendencies to these several degrees of fusion are very various, it proves to be a distinction affecting the practical value of coals, which is of the utmost importance. In domestic consumption, where the heat of combustion is comparatively moderate, the quantity rather than the quality or fusibility of the ashes is the point of greatest consideration; but where an excessive and melting heat is required, as in many modes of generating steam, the practicability of employing a coal at all will oftentimes be determined by this one quality of the clinkering of the ashes. In all such circumstances, those coals are best, the ashes of which are of a nearly pure white, and which, with large amounts of silica and alumina in their composition, contain little or no alkali, nor any lime, nor oxide of iron. Of this character are the earthy residua of the best white-ash anthracites of Pennsylvania, and, in an eminent degree, the ashes of some of the semi-anthracites.

The columns G and J in the Table, the one relating to the per-centage of clinker alone, the other to the per-centage of the total waste, including clinker ashes and fine particles of intermingled unburned coal, are instructive in this connection in several points of view, in disclosing, first, the different proportions of residue from different coals; secondly, the varying ratios for the different classes of coals, of the clinker formed, to the total waste, and of both of these to the actual amount of earthy matter; and again, the marked influence of an increased intensity of combustion by strong mechanical blast, in increasing where the coals are of the same class, and of equal purity, both the quantity of clinker and of total waste.

It will be noticed that the hard white-ash anthracites of Pennsylvania, all the samples of which, experimented on by Professor Johnson, appear to have been of at least full average purity, exhibit not more than 50 per cent of additional waste beyond the total quantity of earthy matter detected in them by chemical analysis, and not more than one-eighth of the total waste, in the form of clinker; while the Mount Laffy coal, investigated by ourselves, displays a waste very nearly double the actual amount of earthy matter, and a proportion of clinker to the entire waste of fully two-thirds. The reason for this important difference is obviously to be found in the dissimilar conditions of the combustion. The apparatus employed by Professor Johnson had only that activity of draught which could be supplied by a chimney 45 feet high, while the furnaces beneath our boilers, besides connecting with a tall chimney-stack, were artificially supplied with air by a powerful fan, 30 inches in diameter, driven at a speed of 480 revolutions per minute. In the one case, the heat was barely enough to fuse a small part of the ashes; in the other, it was so energetic as to melt two-thirds of the total quantity, and to augment the weight of the clinker formed, by enclosing unburned fragments of coal to the amount of several per cent.

The effect of the same extreme degree of heat was witnessed on the ashes of the semi-anthracite from Zerbe's Run, but to a less extent, from its greater infusibility. The total waste from this coal was on an average almost twice the absolute amount of earthy matter, but the clinker was between a third and a fourth part only of this total waste. In the case of the Rhode Island coal, a higher fusibility in the ashes, due to the presence of lime and other fluxing ingredients, resulted in the conversion of almost the whole of the waste matter into clinker.

Directing our attention for a moment to the clinker and waste from the semi-bituminous and bituminous coals, we perceive that while the ratio of the total waste to the earthy matter in the coal is very nearly what it appears in the anthracites, the proportion of clinker or fused matter to the whole residuum is, notwithstanding the far milder heat employed, nearly or fully as great as that from the semi-anthracite of Zerbe's Run burned under the strongest blast.

The explanation of this greater tendency in all these bituminous coals, compared with the anthracitic, to form clinker when exposed to the same heat, is to be detected in the different constitution of their ashes—the Pennsylvania anthracitic basins containing remarkably little lime, or other fluxing earths or alkalies, either in the substance of their coals, or in the strata which imbed them; whereas it so occurs that an influential quantity of one or more of those fusion-promoting ingredients appears in the ashes of almost all the fuels of the bituminous groups, as well those of the Dauphin and the Cumberland basins as those of the Richmond, the Trans-Alleghany, and the British coal-fields. In the ashes of the anthracites, the proportion of lime rarely surpasses 2 per cent, while in those of many of the bituminous coals it exceeds 5 or 6 per cent.

A *fourth* property of fuels, upon which their value for certain leading and rapidly-extending applications in a large degree depends, is that of kindling rapidly, and burning with great celerity when required. This quality in coal now enters as a large element in the conditions which control, through the agency of steam, the speed of commerce and the facilities of human intercourse, and which are enriching all the resources of civilised life by daily-increasing conquests over time and space. To it, therefore, even more earnestly than to the mere absolute heating energy of different fuels, must the researches of practical science henceforth be directed. An enormous amount of yet unawakened speed, as well as strength, still slumbers in certain forms of coal—the most condensed and the most tractable material shape in which a gigantic mechanical power is stored away. Only a portion of either of these has hitherto been evoked by art, and it is of the utmost importance that every point connected with our fuels, or with the conditions under which they are burned, which promises to procure from them either increased activity or additional total heat, should be closely investigated.

The peculiarities of mechanical structure and of chemical constitution, which are mainly influential in conferring on coals a high degree of combustible or evaporative activity, have been already stated, and it will suffice here merely to recount them. They are chiefly the absence of too extreme a density or cohesion; a certain medium amount of divisibility on the fire; a moderate proportion of combustible volatile matter, to quicken ignition and propagate the heat; the quality of keeping an open fire, and purity from much earthy matter, especially clinkering ashes.

The experimental results embodied in the Table, under the appropriate columns, express the relations of the various coals to each other in these respects. These, and the numbers in the columns K and O, giving the pounds of coal severally consumed per hour to each square foot of furnace grate, and the pounds of water evaporated per hour to the same amount of surface, embrace in one view both of the elements which modify the rate of activity of the different fuels, and the rates themselves, as ascertained by experiment.

Keeping in view what has been already carefully stated of the superior energy of the draught used in the experiments made by ourselves upon the Mount Laffy and Zerbe's Run coals, over that employed upon all the other results, and making our comparisons only between those results which were procured under similar or comparable conditions, we are guided by the Table to some instructive conclusions.

Looking first at the combustible activity of the several classes of coals, as determined by the apparatus used by Professor Johnson, we discern the fact, that the rapidity with which they burn is greater as they are more bituminous, or contain more combustible volatile matter. Thus, the anthracites burn at the rate of 6.60 pounds per hour on each square foot of the grate, the semi-bituminous coals at the rate of nearly 7 pounds, and the full bituminous coals at the rate of more than 9 pounds. The Lykens Valley semi-anthracite shows a rate of 6.92 pounds; the semi-bituminous coals of the Dauphin basin a rate of 6.86 pounds, and those of the Cumberland, 7.10 pounds; while the middle secondary bituminous coals of the James River basin, in Virginia, display the greater rate of 7.41 pounds to the same surface.

Turning to the figures indicating the respective *times* required for getting the boiler into full action, we perceive that the differences in the rapidity of kindling are much more marked than those of the rates of sustained combustion; the periods being for the four classes of coals, 3.10, 2.63, 1.14, and 0.92 hours respectively.

Giving our attention, in the next place, to our own experiments upon the hard anthracite and the Zerbe's Run semi-anthracite, with an artificial blast, we notice two points for comparison; first, a strikingly greater activity in the combustion of the same kind of coal under a strong current than under the gentle draught used by Johnson, in the ratio, for the anthracites, of 9.23 to 6.60; and, secondly, a trivial superiority in this particular on the part of the semi-anthracites of Zerbe's Run over the hard dry anthracite burned under like conditions. Under both rates of combustion the semi-anthracites display a rather higher activity than the true anthracites—with the ordinary chimney draught, a ratio of 6.92 to 6.60; and with the blower, one of 9.26 to 9.23; or by the longest and most complete trial with strongest blast, a ratio of 10.20 pounds burned to precisely 10 pounds.

It here is especially worthy of remark, that a moderate force of draught through the fuel seems to be the condition which is best suited to the fullest economical performance, speed and power both considered, of the semi-bituminous and bituminous coals, while to the anthracites a strong current is best adapted for the same ends.

The maximum heating effect from any coal is procured when the air passes it fast enough to burn entirely all the combustible matter it can surrender to it by its own heat; but when the current exceeds this rate, its influence is *counteractive*, cooling and quenching a portion of the burning matter, and driving it wastefully forward with the combustion not completed. The different ignitibility of the various classes of fuel sets of course different limits to this point of economical rapidity of blast and of combustion—limits which are sooner passed with the bituminous than with the anthracite coals.

Bearing upon this topic, it should be noticed that, since we inevitably lose a portion of the whole heat procurable from a coal, when, in our desire for speed or copiousness of combustion in a given time, we urge the fire too eagerly, we may perceive under what disadvantages the hard Mount Laffy anthracite and Zerbe's Run semi-anthracite were burned in our experiments, so far as mere evaporative economy is considered. Nothing speaks so strongly to the merits of both these coals as pure and efficient fuels than the fact under consideration, that the very high evaporative power indicated in column N of the Table co-existed with a rate of combustion so manifestly wasteful of heat as that shown in the preceding column K.

Another, and, as already intimated, a very essential quality in coals, affecting more perhaps than any other element their commercial value, is a *high absolute heating power*. This *fifth* principal relationship of the coals under comparison will be seen numerically expressed in the General Table, in column N, which shows the experimental effects of their combustion in pounds of water, evaporated from the standard temperature of 212° by 1 pound of each kind of coal. After what has been already pointed out on a previous page respecting the unfavourable rapid rate of the combustion in our own experiments with the hard Mount Laffy anthracite and the coal of Zerbe's Run, little farther need here be said in calling attention to the true relative evaporative power of the different classes and varieties of coals, than to suggest to the reader to make due allowance for that circumstance. Between the anthracites and the semi-bituminous coals burned under the same conditions of draught, there is a trivial difference of effect in favour of the latter, attributable mainly to the superiority of one or two of the Cumberland samples; but comparing either class with the true bituminous coals, we perceive that those which take the lead in rate of burning are far behind both the others in point of real efficiency. The pounds of water respectively evaporated were 9.58, 9.66, and 7.96, for the anthracites, semi-bituminous, and full bituminous coals.

In the next place, regarding the results of our own experiments, we observe that the average performance of the excellent hard anthracite we tried was sensibly lower than the average work of the similar anthracites burned by Professor Johnson with a gentler current; corroborating what we have alleged of the loss of evaporative economy from an over-active supply of air; but we perceive that notwithstanding the same important drawback on the full efficiency of the Zerbe's Run coal, the experiments demonstrated a decidedly superior evaporative power in the Zerbe's coal over the other in the ratio of 9.58 pounds to 9.32 pounds of water to the one pound of coal. When the conditions were less unfavourable for economical results, the product in steam was respectively 10.60 and 10.19 to each pound of fuel. During this best experiment the rate of combustion on the grate was, with the Zerbe's Run coal, as high as 10.20 pounds to the square foot per hour, while with the hard Mount Laffy anthracite it was 9.08 pounds.

This brings us to a review of the results shown in the next column (O) of the Table. This series of numbers, denoting the relations of the coals in their two important qualities of rate of burning and evaporating effect from equal weights—or, in other words, their *activity* and their *strength*—expresses more justly than any other portion of the Table the relative practical values of the several coals. It will here be seen that the anthracites, semi-bituminous, and bituminous coals, burned in the same apparatus, and under conditions best adapted to the two latter classes, display evaporative rates in the ratios of 62.93, 67.46, and 70.92 pounds of steam per hour to each square foot of grate.

Reducing our own results to the same units of time and surface, we notice that the hard anthracite produced as much as 85.96 pounds, while the semi-anthracite of Zerbe's Run went even beyond it in the proportion of 88.71 pounds, both of which are certainly very enormous products. But these, which are only averages, were much exceeded in the best states of working, when, after the middle of the week, the flues being all fully heated, the very copious blast employed was attended by a rather less than usual waste of fuel. At those times the highest activity and heating power united, yielded in steam the enormous product of 91.52 pounds from the hard anthracite, and 108.10 pounds from the semi-anthracite of Zerbe's Run.

In approaching the conclusion of this portion of our subject—the relative efficiency of the various coals in generating steam—we arrive finally at a comparison of the fuels in their three several aspects of evaporative activity, absolute heating power, and capacity of stowage combined: in other words, we have now to ascertain in what order the several varieties and classes range themselves, when each is estimated according to the degree in which it unites the three primary qualities of speed, strength, and compactness. The column P, the last in the Table, derived from multiplying together the three ratios expressing the pounds of coal burned on each square foot of grate per hour, the pounds of steam produced to each pound of coal burned, and the pounds of coal containable in each cubic foot of space, exhibits for the several coals their relative total values compounded of all these elements.

The Table here speaks for it itself. The numerical aggregates denoting the rank of the anthracites, the semi-bituminous coals, and the full bituminous coals, are respectively expressed by 3349.8, 3496.4, and 3462.3 pounds of water evaporated each hour on each square foot of furnace grate by each cubic foot of broken coal. It thus appears that the semi-bituminous coals surpass somewhat the bituminous, and that these exceed the true anthracites.

The relative rank of the hard anthracite of Mount Laffy, compared with the semi-anthracite of Zerbe's Run, is indicated by the ratio of the numbers 4598.8 to 4635.1, which denote the relative efficiency of each for marine navigation.

It will not be correct, of course, to compare these high results last recorded critically with the first series, since, as we have several times stated, the data included in them were procured from experiments differently arranged as to the rates of combustion. Yet, if we will keep in view the fact, that the strong current with which we blew our fires was probably as inimical to a large evaporative result per pound of coal, as it was friendly to an increased speed of combustion, the conclusion becomes very manifest that the numbers in the Table cannot be far astray in denoting the relative values of the coals reviewed in their triple aspect of combined *activity*, *strength*, and *portability*.

Having in the foregoing pages disposed of the various topics connected with the value of the several kinds of coal in their application to the production of steam, and with the merits of the semi-anthracites for that important purpose, it remains for me to add a few concluding remarks on the suitableness of this particular variety to the smelting and working of iron.

It is well known that purity in the fuel is a most important element of economy in the process of iron-smelting. A difference of only 5 or 7 per cent in the quantity of earthy matter in two coals is the source of a serious difference in the final cost which they involve. Not only must an extra amount of coal be introduced into the furnace to supply the deficiency caused by the additional impurities, but a still further portion is needed to melt the excess of ashes in the whole body of the fuel. The increased quantity of earthy matter difficult of fusion thus supplied, calls for a proportionate increase in the limestone or flux, which itself again exacts a certain amount of fuel to melt it with the additional ashes. Thus, from the one cause we require to make a triple augmentation to the fuel. If the ore employed be of a fair degree of purity, the surplus foreign matter, ashes and flux together, thus made to burden the furnace, will materially exceed 5 or 7 per cent of the total amount of earthy matter originally there; and we therefore perceive that a seemingly trivial difference in the coals may cause a really important difference in the results. But besides these sources of extra cost, there are others which flow in their train. Among these are the items of expense for labour entailed by handling the additional fuel and flux, and the increased cinder from the furnace, and the more indirect loss from the lessened product which the furnace yields in a given time.

But the quality or nature of the extraneous matter has even a greater influence than the quantity upon the fitness of a fuel for the purposes of smelting. Of all the substances of a hurtful kind commonly to be found in coals, *sulphur*, usually combined with iron, forming minutely-disseminated sulphuret of iron, is by far the most injurious. The proportions in which it prevails in different coals are very various, many beds revealing scarcely a trace, while others again contain as much as 3 or 4, or even 6 per cent of this deleterious constituent. As a general fact, the anthracites and semi-anthracites are decidedly more free from sulphur than are either the semi-bituminous or the fully bituminous coals.

The better kinds of the two first-named classes exhibit, according to our analyses, but insignificant traces of it—not more in the *average* than 0.05 per cent, or one part in 2000 of the coal. The semi-bituminous coals, on the contrary, display an average proportion of more than ten times as much, or 0.53 per cent, while the mean amount for the three groups of bituminous coal is materially greater still, being as much as 0.61 per cent, or one part in every 164 parts of the coal.

Upon the view which I have advocated, that the anthracite coals are true *solidified cokes*, or the de-bituminised forms of the ordinary gaseous coals, the reason of their comparative exemption from sulphur becomes obvious and natural. The same highly-heated volcanic steam, in issuing through the strata, baking and metamorphosing the soft clays into indurated slates, and distilling out from the bituminous coal-beds their volatile bitumens and gases, would, by a well-known and often-practised chemical reaction, carry off the sulphur. By a process more refined and admirable than any which man can hope to imitate, these matchless varieties of coal have been ages ago de-sulphuretted, coked, and compactly pressed. They are the fuel of the world in its most elaborated, purified, and perfected form; fine enough for any of the most delicate behests of chemistry, yet strong enough to achieve, with the aid of mechanism, the wildest and most daring dreams of speed and of physical power which the genius of invention can conceive.

METHODS OF SEARCHING FOR, OPENING, AND MINING COAL, PURSUED IN PENNSYLVANIA.

SEARCHING FOR COAL.

WHEN the soil of a district is already known to be underlaid by the coal-formation, the first process adopted for the discovery of the seams of coal is searching the beds of the brooks and the hill-side ravines for fragments and particles of the coal itself, and of the black carbonaceous slate which is one of the commonest associates of productive coal-seams. This examination, which requires close attention and a quick and critical eye, is best pursued when the streams are shrunken in summer, or when the ravines are entirely dry, as the debris from the outcrops of all the strata swept into the channels by the freshets of the winter and spring, may be then readily turned over by the pick, and handled. A sagacious use of geological knowledge becomes of great assistance in this species of search. Guided by it, the explorer will select those ravines and other places, where, from his previous examination of the outcrops of the strata and the directions of the wash, he infers that the fragmentary matter of a certain relative lightness must have accumulated. Having once detected the debris of a coal-seam, it is usually a simple matter to trace it to the parent bed; for unless this rises very high in the adjacent hills, a studious tracing of the loose fragments up the channels or ravines will presently, by the sudden cessation of any signs of coal, show him that he has passed their source. He will then make assiduous use of a light pick, turning the soil and inspecting it very closely for indications of the "smut" of the seam—that is to say, for any stain imparted to the earth by very finely divided coaly matter.

Another mode of searching for coal is to commence at the stage just indicated: it dispenses, that is to say, with any preliminary inspection of the wash accumulated in the water-courses, and aims at detecting the smut of the coal-seam immediately by systematic digging in the supposed vicinity of the coal-bed. This method implies a knowledge of the topographical indications of coal, and nice judgment in availing one's-self of the conditions of the ground to test the presence of the looked-for bed with the least expenditure of time and labour.

The topographical features which indicate the presence of beds of coal in a group of Coal-measures are obvious enough to an eye once familiarised to them. They are merely indentations or benches in the sides of the hills, more or less conspicuous in obedience to certain geological conditions easily understood.

As every mass of Coal-measures embraces necessarily an alternation of stratified deposits, more or less unequal in their power of resisting the wearing or grooving action of water, and as water under great pressure has passed over the outcrops of all our coal-fields, the several strata betray in a remarkable manner their relative degrees of softness by the extent of the depression left upon their outcrops. The harder beds stand forth in steeper slopes, and under a less depth of wash or of debris; the softer occupy the indentations in the surface, and are generally the most deeply covered with soil. Seen in profile, the edges of a series of alternating hard and soft deposits will be distinctly undulated, and the undulation will be conspicuous in proportion to the inequality in the degree of softness, combined with two or three other conditions, such as the more or less prominent manner in which their outcrops have been exposed to erosive action, and the width or narrowness of the more easily trenched softer beds. For a full exemplification of this subject, the reader is referred to a former chapter on the effects of erosion on horizontal and variously-inclined strata. Now of all groups of sedimentary rocks, the coal-formation, especially where it has been partially metamorphosed, is that which exhibits the greatest known inequality in the hardness of its constituent beds, possessing, on the one hand, closely cemented, thoroughly compacted, massive strata of silicious sandstones, and even conglomerates; and, on the other, layers of soft shale almost as impressible as mud, and beds of tender coal, which, like the shale, are incohering and brittle from the presence of countless cleavage-joints and closely-set fissures. A mass of Coal-measures will therefore almost invariably betray the positions of its contained beds of coal—its thicker ones at least—by the indentations of the surface. It is the business of the coal-seeker then to study and interpret these. If the strata dip at a moderate angle, and the difference of resisting power in the strata is great, each thicker seam of coal will form, with its accompanying soft shales or slates, a wide, nearly level terrace on the hill-side. Lengthwise, this terrace or bench will undulate in height and advance and retreat on the flank of the hill or ridge to which it belongs, in conformity with the modelling of the ground, in a manner which has been explained in the chapter on Erosion, descending into the ravines with a forward or backward sweep obedient to the direction of the dip, and ascending high on the hill-side where the denudation has been least. These hill-side benches are discernible in almost every portion of the anthracite coal-basins of the State, being particularly conspicuous where they mark the outcrops of the very thick coal-beds of the lower or white-ash series, on the slopes of the main ridges bounding those valleys. They are beautifully distinct and regular on the flank of the Broad Mountain in the Mine Hill Valley, and are hardly less conspicuous on the N. side of the Pottsville Basin fronting the valley of Panther Creek, and near the Little Schuylkill. They are unusually distinct also throughout the Shamokin Basin, owing to the thickness of the lower coal-beds and the conglomeritic and firm character of the coarse sandstones which separate these, and which outcrop in alternation with them on the inner slope of the encircling mountains. Though a dense forest may conceal these terraces of the coal-beds, they are not wholly obscured by a clothing of tall bushes or a copse of young timber. When faint, they are best detected under a slant sun shining in a direction nearly coincident with the slope containing them. The accompanying Plate presents a view of a series of conspicuous benches on the N. side of the Panther Creek Valley, nearly opposite the Summit Mines of the Lehigh Company.

Surface-Shafting.—Having discovered by external signs the probable presence of a seam of coal which it is desirable to open or prove, the next process is to reach it by digging, and establish its thickness and the direction of its dip with the least amount of excavation practicable. Towards these ends we are greatly assisted by an interesting circumstance attending the outcrops of the strata. The softer beds of the Coal-measures have their edges turned down-hill in a remarkable manner. This feature, illustrated in various parts of the present work, is exhibited in Fig. 770. All the more pliable rocks, and those most susceptible of erosion, are either so bent at their outcrops as to conform to the slope of the hill-side, or if friable, their materials are dislodged and strewn down-hill in a tapering sheet, dwindling in thickness, and growing more and more comminuted, until they are lost in the debris of the adjoining strata. The coal, from its indestructible nature, its susceptibility to comminution, and its superior lightness, having been carried farther by the waters from the outcrops of the beds than the materials of the other deposits, the coal-hunter avails himself of this circumstance to test the presence of a bed of coal indicated by a hill-side bench, and to trace it to its true position. He commences by digging a narrow pit on the lower side of the terrace of the coal, extending 6 or 8 feet up and down the hill; and if at the depth of a few feet he encounters the smut or wash of the coal-seam, he infers from its degree of purity, and the average size of the lumps of coal, his distance approximately from the bed in place, and then plants his next pit where he supposes the top layer of the coal to outcrop. After two or three trials—and if he is experienced, sometimes upon his very first essay—he sinks directly through the outcrop of top slate into the soft disintegrated coal itself, the lamination of which he presently discovers. Persevering, he soon cuts the entire thickness of the coal, and reaches its floor or bottom-rock, and is then for the first time able to discover the true inclination of the bedding and the actual thickness of the coal-seam.

FIG. 770.—Overturned Outcrops of Coal-Seams.

Not unfrequently an intermediate trial-pit encounters the outcrop of the coal-bed just at the spot where it is folded abruptly down-hill. If the strata are themselves dipping in the direction of the hill-side slope, this folding is often very abrupt, and can then seldom lead to deception as to the true direction of dip; but in some instances, especially where the coal-bed is thick, and its capping rocks are not very pliable, the overturn at the outcrop is only partial, and the miner, after digging through the crumbled coal, reaches the bottom of its top slate dipping *towards* the outcrop. Unless he is very apt and persevering, he is liable in such cases to conceive that he has reached the genuine bottom rock of the coal-seam, and to suppose that this is dipping in just the contrary direction to that towards which it is declining.—(See the middle shaft *a*.) Not a few serious mistakes, and some flagrant frauds, in developing virgin coal-fields, have arisen from this substitution of a partially-overturned roof-rock for the genuine floor of a coal-bed.

An uninitiated explorer sinking his experimental pit just within or above the turn of the cap rock or top slate of the coal, will be very apt, where the strata have a steep dip, to exaggerate grossly the real thickness of a coal-bed; for he may make a deep excavation before he reaches the bottom-slate, and if this should bulge forward into a flattish slope from a local irregularity, or turn into a gentle dip, self-deception is almost unavoidable. His true check to a blunder from this source is to mark narrowly as he proceeds the grain or lamination of the coal itself, which will betray in its direction and curvature the true dipping of the strata. Whenever it suggests a doubt, he should proceed, before sinking farther, to cut across the coal until he reaches one or both of the rocks which confine it, aiming by preference for the bottom shale.

Another source of fallacy, susceptible of being employed for fraudulently exaggerating the thickness of a coal-seam, is where the top slate of a steeply-dipping coal-bed, being tough and flexible, is turned or folded sharply back upon itself down the hill-side under the soil, as shown at *b*. If a large quantity of the outcrop coal lies over the inverted top-slate, the coal-digger may by chance or by adroitness so cut the coal at the bend as just to graze the knuckle of the folded slate, and make it appear as a layer or parting-band in the middle of the seam, especially as the grain of the coal

Dalson

COAL BENCHES. LOCUST M^{T} OPPOSITE LEHIGH SUMMIT MINES.

Dalston.

W. & A. K. Johnston, Edinburgh.

OVERTURNED OUTCROP NEAR NEWKIRK PENN^A

both above it and below it will, by the inversion, dip towards the same quarter, and approximately at the same angle. The check for this is a very little excavation in the slate itself.

Where the strata dip into a hill, or towards an opposite point from that to which the ground itself is sloping, the outcrops of the softer beds are bent, as in the previous instances, to conform to the hill-side, but in this case they are not folded upon themselves, but only bent back into a flatter inclination, or into a gentle anticlinal curve. The wash of the coal-seam dips in an opposite direction from the coal-seam itself, and the friable shale or fire-clay floor is for the most part mingled with the fragmentary coal. Under this condition of things it rarely happens that either the coal or its top or bottom rocks are in a sufficiently regular or sound state to mislead us as to the direction of the dip; the only error to which we are liable being that of assuming too flat an inclination in the strata. The correction for this is to dig well into the coal, following the bottom-slate until it appears to assume its permanent inclination.

The two opposite conditions are represented in the cut at *b* and *c*, fig. 770.

Boring.—Another method of searching for coal is by boring. This is usually resorted to either where coal is suspected to underlie the soil at easily-accessible depths, or where it is desirable to ascertain the precise depth of a bed or beds already known to be present. In the one case a hand-augur with a shank 6 or 12 feet long is not unfrequently employed, and it is an extremely useful instrument in ground where the outcrop of the coal is not indicated by indentations of the surface, and is covered up by a shallow and easily-penetrated wash. In the other instance, where a known coal lies deep, and where it is important to ascertain its depth, and perhaps its thickness, prior to sinking a permanent pit or mine-shaft to it, boring is performed in a more elaborate manner, very much upon the plan of perforating an artesian well. A chisel of the requisite size is fastened to a stiff iron rod, and this is lifted and allowed to fall in repeated blows by some appropriate mechanism—either a lever worked by hand, or a trip arrangement driven by a steam-engine. As the boring deepens, the rod is lengthened by screwing upon it fresh sections several feet in length.

Great caution is to be observed in judging of the materials penetrated by this process. The materials chipped off by the chisel must be submitted to the closest scrutiny, carefully magnified by a lens, and moistened by an acid to ascertain the presence of any carbonate of lime or limestone. Care is especially necessary where the chisel indicates coal, for it not unfrequently happens that the crumbed coal already cut falls into the bore-hole by the friction of the rod, and mingling with the triturated particles of an underlying coal slate or shale, gives the appearance of an extension of the coal bed to a depth which it does not reach—a fertile source of unconscious error and of frauds. Nevertheless this plan of sounding for coal is a valuable auxiliary in the development of a new coal-field, as a guide to the sinking of deep and costly mine-shafts.

Opening or proving Coal-Seams preliminary to Mining.—The outcrop of a coal-seam having been discovered, the first step, preliminary to the erection of a colliery, is the determination of its thickness, quality, and the direction and condition of its dip within the strata.

When the coal-seam and its attendant rocks have a considerable inclination, the first steps towards proving are those hinted at under the previous head of "Surface Shafting." But prudence requires that the seam should be mined to some distance beyond that which is necessary merely to determine its presence and approximate thickness. It should be cut into far enough to let the miner see its permanent rate of dip; the absence or presence of any slips or faults, the quantity and distribution of its internal layers of slate, and of those soft laminæ which he calls "undermining," the lucky disposition of which affects not a little the economy of hewing the coal. If the coal-bed is somewhat unsound, or is "slippy" near its outcrop, but is yet of sufficient importance and promise to encourage the adventure, the miner will often enter it for many yards, either by horizontal gangway or by a sloping pit, withdrawing the water when necessary by a windlass or otherwise, in the hope that it may grow sounder.

Where the strata are horizontal, or nearly so, the difficulty of proving a newly-opened coal-seam almost vanishes, if the shape of the surface is such as to permit him to enter it at a relatively low level, and mine in the direction of its rise, for the mine gallery or drift will then drain itself; but if no ravine or hill-side exists to offer such approach, he must plan the course of his drift not directly down the dip, but as obliquely to it as practicable, with a view to the least possible amount of descent; and he must remove any water which collects, by digging a trench or drain in the floor of the drift, deepening the level of this from the mouth as he advances, until the task becomes too serious, when he must resort, as in the case of steeply-dipping coal-seams, to lifting or pumping the water out.

A case sometimes arises in which it is impossible to open a mine in horizontal strata which will drain itself, even though the outcrop of the coal-seam is surrounded by ravines or valleys on all sides. This condition prevails where, with a stratification almost absolutely horizontal, on a broad scale, the country is intersected by deep ravines, and the hills insulated by these are lofty and steep. In such ground it sometimes happens that the coal-seams basin inwards from all points with a very gentle descent under the summit of the conical hills, as if the increased pressure there exercised by the superior column of the strata had caused a general dishing of all the more compressible and pliable members of the series. In such cases there is no mode of draining the mine but by a trench under the floor of the gangway, or by a regular mine-shaft sunk into the middle of the basin, from somewhere near the summit of the hill or centre of the plateau.

METHODS OF MINING COAL.

In the coal-fields characterised by an approximately horizontal stratification, the plan of mining the coal in Pennsylvania, and indeed throughout the United States, is that which is pursued under similar circumstances in Europe. The coal-seam is entered by a main gangway or nearly horizontal gallery, so placed and laid out as to drain as large a tract of the contemplated mine as possible.—(See Fig. 771.) If the coal-seam is situated above the beds of the adjacent valleys, it is penetrated, of course, from a point or points in the sides of the hills, and a thick wall or pillar of the coal is left between the gangway and the actual outcrop, to sustain the pressure of the superincumbent strata. After the main entry has been carried in a convenient length, other side-galleries or gangways are excavated, branching from it, either at right angles, or in directions best adapted to command an easy drainage and internal transportation of the hewn coal. From these lateral alleys short rooms or stalls are excavated, leaving massive columns of the coal standing to support the roof.

FIG. 771.—Mouth of Drift in Horizontal Strata.

In the anthracite basins of the State, where the strata are much undulated, and where, for the most part, they are inclined at considerable angles, the plan of entering and mining the coal is somewhat different, being modified to suit the circumstances.

Open Cut.—The simplest of the conditions under which coal is excavated in the State is where it lies accessible to open quarrying. This method is resorted to only where the coal-bed is of such thickness, or has been so effectually protected from deterioration by a covering of easily-removable rock, as to possess a marketable value. Of course it is seldom worth while to strip and quarry a thinnish seam of coal, since the coal itself will be found rotted by the elements throughout too great a portion of its thickness, and even where sufficiently sound, will not yield enough to a given area to repay the cost of uncovering it. Perhaps the most remarkable example of a coal-working in the manner of an open quarry, to be anywhere met with, is that of the Lehigh Summit Mine, already described.—(See the plates illustrating this mine.) Another form of open working is, where a thick seam of coal has been caught, and preserved from denudation from a sharp synclinal fold in the strata. An instance of this sort occurs at Montelius's Open Cut, at the E. end of the Mine Hill Valley, opposite the mouth of Wolf Creek, where the great coal-seam, folded into a V-shaped mass, is entered endwise, and quarried out from between the steeply-dipping sides of the trough, composed of its bottom-slate. The excavation is about 50 feet deep, and nearly as broad at the top. The annexed cut (Fig. 772), represents this quarry of coal as it appeared in 1853.

FIG. 772.—Montelius's Open Cut, Mill Creek, Mine Hill Valley.

Another extemporaneous process of mining is resorted to where the coal-seam is approximately horizontal, and outcrops on both sides of a comparatively narrow hill. The field of coal is then entered from some ravine near the most depressed part of the outcrop, and the coal is mined out in the direction of the rise of the strata, by leaving huge columns of the solid coal to sustain the weight of the hill above. Where the seam is thick, the subterranean quarrying proceeds by benching, or cutting the coal in steps. An extensive excavation of this sort is to be seen at the old mines of the Baltimore Coal Company, about one mile S.E. of Wilkesbarre. The frontispiece to this volume presents one view of the exterior of this mine. An interior view, looking outward, showing the massive columns of coal, and the twilight between the pillars, is shown in another sketch (see Plate, p. 382 of this volume).

By Drift.—A common method of mining hitherto practised in the anthracite basins of the State, has been to select

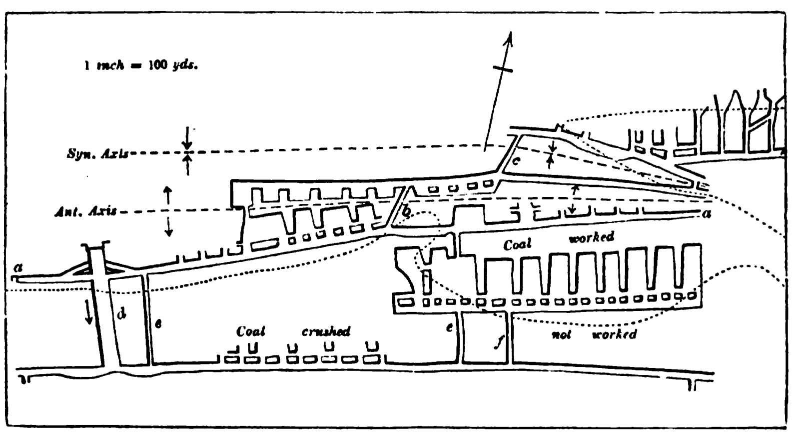
The 14 Ft Seam, NESQUEHONING MINES, *Old drift, Shutes & Screens*

a locality where a coal-seam rises to a remunerative height above some convenient water-level, or the bed of a contiguous valley or ravine intersecting it. The seam is in this case accessible edgewise or endwise from the ravine, and after the surface-matter is removed, it is entered by a *drift* or gangway, which is carried in horizontally, with just a sufficiently gentle rate of ascent to drain out the water to the external valley. After this mine "level," as it is called, has been extended sufficiently far, lateral alleys or schutes are cut at a convenient angle, usually at right angles to it, ascending towards the outcrop, and rooms or small chambers are hewn out of the coal at regular intervals along these alleys, pillars of the firm coal being left between these chambers, and also between them and the schute, except where this communicates with the rooms. Thus each schute is protected by a wall of solid coal, only here and there perforated. Certain of these schutes are extended up to the outcrop as early as practicable, for the purpose of ventilating the workings, the air in which tends to become very foul where the dip is steep, and the "breast" or slant length of the coal-bed is tall. The coal is shovelled by the miners from the lateral chambers into the sloping schutes, and is drawn out of these from an inclined bin by gates or trap-doors, which deliver it into the coal-cars placed opposite them on a railroad which occupies the floor of the main horizontal gangway.

Another mode of carrying on the excavation of the coal in the interior of the mine is, to take it out in broad rooms, still called schutes, extending from the level or gangway up the breast of the coal to within a suitable distance of the next higher level, or of the outcrop, leaving longitudinal pillars or walls of the solid coal strong enough to support the pressure of the superincumbent mass. These pillars are generally from 4 to 8 yards wide, and the long rooms or schutes between them are commonly from 10 to 14 yards broad. Just at the gangway the pillars are generally left as broad as possible, the better to insure resistance to pressure, and for the purpose of more easily closing the outlet of the schute, and providing it with a gate for the delivery of the coal into the cars below. In some cases, especially where the dip is steep, a narrow schute, called a "man-way," is first cut, ascending the breast, and cross-ways are excavated from this to give the miners an opportunity to cut or blast away the coal from the breast above them. These lateral excavations, enlarging and meeting, form the schutes into which all the coal is collected. When the process is completed, the only coal left standing to support the roof is in a series of pillars or columns perforated by the man-way.

The accompanying cut (Fig. 773), exhibits the workings of a colliery in the Pottsville Basin, where the features are somewhat complicated. It is intended to represent the areas from which the coal has been extracted, and those where

a a, *Drift or Gangway at Water Level.*
b, *Tunnel across Anticlinal to Coal on N. dip.*
c, *Tunnel across Synclinal to Coal on S. dip.*



d, *Slope or Inclined Roadway to Lower-Level Gangway.*
e, *Air-ways communicating with Water-Level Gangway.*
f, *Counter-Schute from Counter-Level Gangway.*

FIG. 773.—Part of Underground Workings of the Primrose Coal-Seam at Neill's Colliery on Silver Creek, from a Plan by G. K. Smith, Mining Engineer of Pottsville.

it has been left standing for the support of the mine; or where, being too unsound, it would not repay the cost of mining. It is a ground plan or view of the mine as seen from above, showing in the coarse dotted lines an anticlinal axis, and a synclinal axis in the strata, and in the finely-dotted ones the boundaries of the crushed coal not worked. It also shows the gangways, and the tunnels driven through the strata to connect them, and also the pillars and intervening schutes or rooms.

By Tunnels.—Another and very common mode of reaching the coal, particularly in the steeper-dipping beds of the anthracite basins, is by tunnels cut across the strata, the slates, sandstones, &c. which separate the seams of coal. These tunnels are often resorted to, to get admission to portions of coal-seams which ascend into the hills and outcrop above the levels of the valleys and ravines. In such cases they are designed to give outlet to the coal, and to drain the mines, very much as the gangways do which enter the coal-seams endwise from intersecting ravines. The best level at which the tunnel should be made often requires a nice calculation between the cost involved in lengthening it, by planting it too low, and the sacrifice of losing available coal, by making it shorter and setting it too high. Where the coal-seams occur at comparatively short intervals in the strata, and where their dip is steep, a tunnel of the length of a few hundred yards, made at a moderate outlay of capital, will intersect and develop for mining several valuable coal-seams. These are mined in the usual mode, by gangways cut right and left from the tunnel, which thus becomes the common outlet for all the coal of the several seams which it intersects. It is therefore not unfrequently constructed broad enough to admit two railway-tracks, to facilitate the passing of the coal-cars in and out of the mines.

Such are the tunnels which penetrate the hills of the coal region from the surface; but these transverse excavations are much resorted to for getting access to portions of the coal-seams which lie below the beds of the valleys, and which are not directly reachable by the slopes already sunk. Not unfrequently it is an object for the collier to extract the coal from a seam, the position and value of which he is aware of, without constructing a new slope upon its outcrop, and replanting his machinery. In such a case his course is a very simple one: he selects some wide and suitable place in one of the gangways already communicating with the slope, and cuts a horizontal tunnel directly across the strata to the otherwise inaccessible coal. Reaching this seam, he develops it by a new gangway, and proceeds to mine it like the other. Sometimes these subterranean tunnels start forward or backward at the foot of the slope to intersect the overlying or underlying coal-seams, but frequently they extend from the gangways of the mine. As the mining deepens in the bed containing the slope, it may be deepened in the adjacent auxiliary seams by the construction of these short underground tunnels.

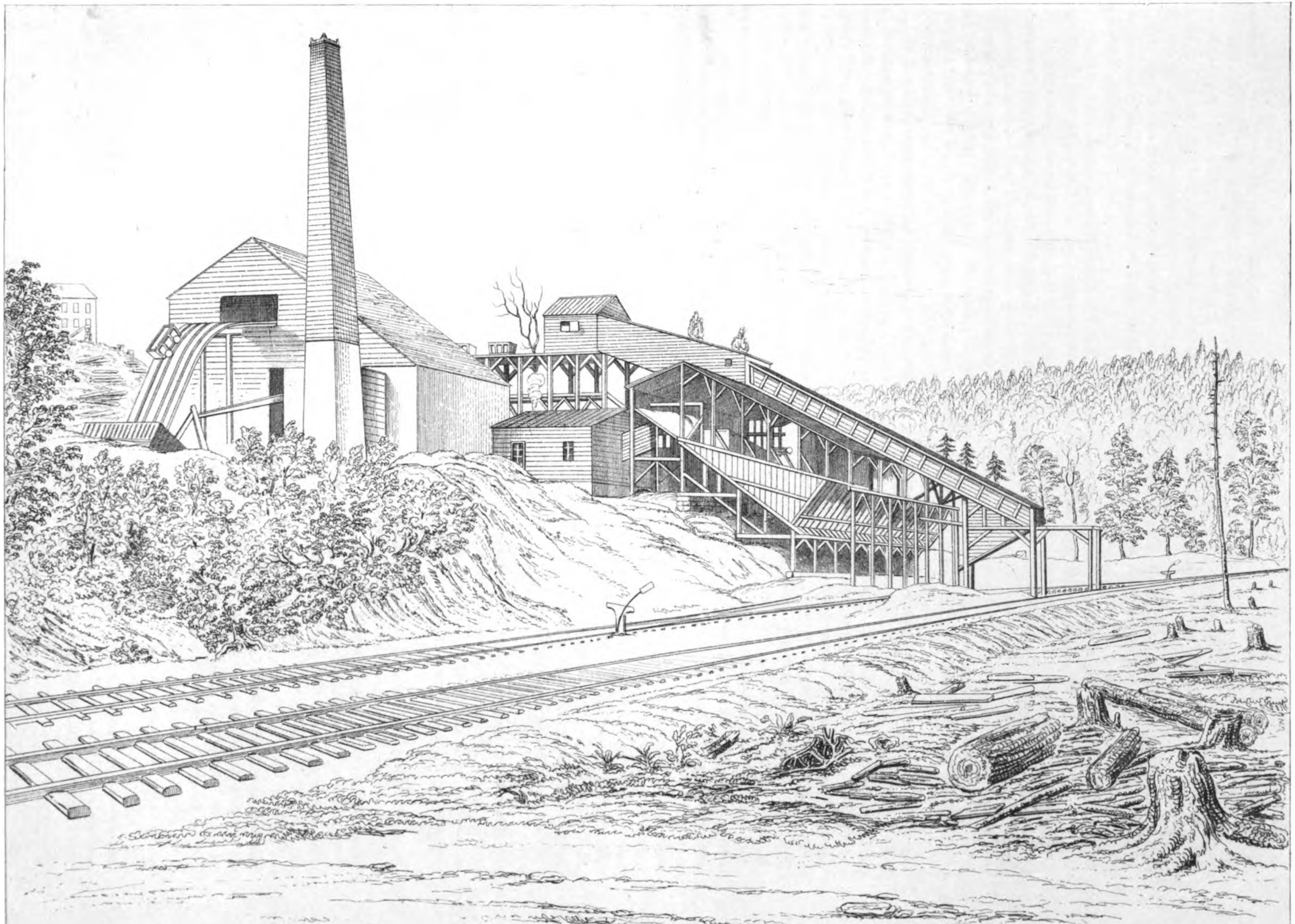
By Slope.—Other modes of entering the coal are necessary where it lies below the water-levels of the country, or where the portion above the valleys and ravines is insufficient to justify the erection of a colliery. The mode commonly resorted to in the anthracite region, is to enter the coal-seam by what is called a *slope*, or a broad gallery hewn in the coal in the direction of its dip; this gallery is usually wide enough to contain two railroad tracks, one for the down-going, the other for the up-coming coal-cars of the mine. The machinery, a steam-engine of competent strength, is planted a little back from the mouth of this slanting tunnel, and the cars are drawn up or let down by a chain wound upon a large drum. In mining the coal, a level or horizontal gangway, such as that already described, is cut at right angles, leading off in one or both directions from the bottom of the slope, with such a departure from absolute horizontality as to allow the water to collect at the intersection. A well, called a "sump" of the mine, is sunk at this spot, the foot of the slope, and a pump usually formed of segments of iron pipe of large calibre extends from this sump to the mouth of the slope, or to some previously-opened water-level or adit-tunnel passing the pump-water to the outside of the mine. From each level or horizontal gangway schutes are extended upwards through the coal, and the coal is mined from them in the ways above described; and when it is all withdrawn from the field thus opened, the slope is prolonged a convenient distance downwards, usually from 60 to 100 yards, dependent upon circumstances; a new sump is planted, and another gangway or level is cut parallel to the upper one. In mining the second lower breast of coal insulated between the two levels, the schutes extended upward from the lower level open into the upper one, and thus a more effectual ventilation of the interior of the mine is insured; and as the mining advances, and the slope increases in length, new levels are set off, and new breasts are wrought out, until the bottom of the basin is reached, or the lift becomes too great for the machinery. In mining the coal, care is observed to leave untouched a broad column or wall of the coal standing along both sides of the slope, as any crushing-in of this from insufficiency of support would be fatal to the operations of the mine.

INTRODUCTION OF COAL AS A DOMESTIC FUEL.

Notwithstanding the immense accumulation of carbonaceous matter in the earlier strata of the earth's crust, its general use as a domestic fuel, and for the purposes of the arts and manufactures, would appear to have been reserved for very modern times. That fossil coal was known as a casual mineral, and partially used as a combustible matter by the ancients, appears from the writings of Theophrastus, the disciple of Aristotle, for undoubtedly the word λιθανθραξ, used by the Greeks, signified fossil or pit coals, in contradistinction to ανθραξ, charcoal, or wood-coal. Theophrastus, in his *Book on Stones*, says, "Those fossil substances that are called coals, and are broken for use, are *earthy;* they kindle and burn like *wood-coals.* These are found in Liguria, where there is also amber; and in Elis, in the way to Olympias, over the mountains. They are used by the smiths."

A Roman writer, Sicculus Flaccus, mentions that coals, among other substances, were made use of as landmarks; and St Augustine mentions the same, remarking that this substance was so used on account of its imperishable nature—the carbon of hard coals no doubt resisting moisture and decay better than wood or soft stony materials. It seems evident, however, that the ancients made no extensive use of fossil coal, much less mined for it, but only casually employed such fragments as were found on the surface of the soil. The comparative rarity of this material in Greece, Italy, and in ancient Egypt, was perhaps the chief reason of its escaping the inquisitive eyes of those early civilised nations.

In the earlier stages of the civilisation of tribes and nations, and in countries but yet partially cultivated, and still abounding in natural woods, the most accessible and easily-procured fuel, as wood, peat, and superficial lignites, would be resorted to; and these, we find, constituted the chief articles employed as fuel in the early periods of the history of Western Europe. It is probable that the aborigines of Britain knew something of coal, and used it partially. The term *kul* or *kole* is of Saxon origin, used primarily to signify any substances capable of ignition as fuel; while *kolom* is the Cornish, and *guel* the Irish name for similar substances. It seems evident, too, that the superficial coal strata of Britain did not altogether escape the penetrating eyes of the Romans. From coal-cinders found in various localities



Dalson

W. & A. K. Johnston, Edinburgh

COLLIERY SLOPE, AND BREAKER, AT TUSCANORA.

associated with Roman coins, and other indications of the domestic establishments of this people, there appears no doubt but that fossil fuel was partially used by them while in Britain.

In A.D. 853, the Saxons, then dominant in England, were familiar with the use of pit coal, for in a grant of land made by the Abbey of Peterborough, among other reservations of certain fragments of goods in kind, is mentioned "sixty cart-loads of wood, and *twelve of fossil or pit coal*."

In the *Bolden Book*, a record of the county of Durham, we find, A.D. 1195, that among the allowances to the tenants in villenage at Bishopwearmouth, "the smith has twelve acres for the iron-work of the carts, and finds his own coal" (*carbonum*).

In A.D. 1239, King Henry III. granted the privilege of digging coals to the "good men" of Newcastle, in the vicinity of that place; and this is perhaps the earliest notice we have of the actual working of coals.

In some additions to Matthew Paris's *History*, dated A.D. 1245, we have the term sea-coal (*carbo maris*) mentioned,—evidently showing that about this period coal was not only dug from pits for consumption in the locality, but also exported, or sent by sea, to other parts of the kingdom. There is also here mention made of the winning of coal of pits, and the wages paid to the men who wrought in them. From an account-book of the servants of the Archbishop of Canterbury during the reign of Edward II., we find that thirty cart-loads of coal were transported from Barston to Croydon, probably for the Archbishop's special use, as wood was then abundant and very cheap in the neighbourhood of his residence.

In Scotland, previous to the twelfth century, "wood, turf, and peat," and other articles of fuel, were subjected to legislative arrangements, but no mention is made of coal,—the earliest notice of the use of this substance being A.D. 1291, when the privilege of digging coal in the county of Fife was granted to the Abbey of Dunfermline. Long after this, Æneas Silvius, afterwards Pope Pius II., in his visit to Scotland about the middle of the fifteenth century, relates, as something novel to him, that he saw poor people in rags begging at the churches, and receiving for alms pieces of stone, with which they went away contented. "This species of stone," says he, "whether with sulphur or whatever inflammable substance it may be impregnated, they burn in place of wood, of which their country is destitute."

Towards the close of the thirteenth century, so rapidly had the use of coal extended, that the coal trade of Newcastle, then, as long afterwards, the great centre of the supply, became an object of considerable importance to the burgesses—so much so, that had not that town been granted before by King John at a fee-farm of one hundred pounds per annum, payable to the Crown, that sum would probably at least have been doubled to the then existing burgesses.

The early workings were no doubt of the simplest and rudest kind; nor for a long period had the deeper and best seams of coal been reached; for we find, from the *Household Book* of the fifth Earl of Northumberland, A.D. 1512, that though coals were largely used in his princely establishment, it was only in conjunction with wood, "because," it is observed, "colys will not byrne without wodd." It is here stated that eighty chaldrons of sea-coal, at 4s. 2d. and 5s. the chaldron, were allowed in the year, and also sixty-four loads of great wood, to make the coals burn. During the fourteenth and fifteenth centuries, the use of pit-coal as fuel gradually increased, especially as there had been a wasteful consumption of wood in the country, and a neglect in planting forest trees, so that wood for the purposes of fuel became very scarce and expensive.

The use of coal in the cities, however, was at first met by that popular and ignorant prejudice which assails all innovations of the kind upon ancient use and wont. In the reign of Edward I., the inhabitants of London loudly protested against the growing use of sea-coal; and in a proclamation of that monarch, A.D. 1306, the use of sea-coal is expressly prohibited in London and the suburbs, on account of its sulphurous smoke and smell, and all persons are enjoined to burn wood.

Even in the reign of Elizabeth, the burning of "stone coal" was prohibited in London during the sitting of Parliament, lest the health of the knights of the shires should suffer during their residence in town.

In 1649, Blythe, an agricultural writer, says—"Not many years since, the famous city of London petitioned Parliament against two nuisances or offensive commodities, which were likely to come into great use and esteem; and that was Newcastle coals, in regard to the stench; and hops, in regard they would spoyle the taste of drink, and endanger the health of the people."

Notwithstanding these popular prejudices and royal proclamations, the consumption of pit-coal still increased; and as more convenient modes of burning it in houses were invented, its "smoke and stench" were greatly abated, till by degrees it gradually began to supersede the use of wood. Other obstacles, however, still impeded its progress as a cheap fuel to the people, such as import duties, and monopolies shamefully abused; so that in 1648 fuel of all kinds was so scarce in the metropolis that many poor people were starved to death. Little more than three centuries ago, two ships were sufficient for the whole coal-trade between Newcastle and London. In 1699, Newcastle had two-thirds of the coal-trade, and 300,000 tons were exported to London. The price was 18s. per chaldron, out of which 5s. were paid as king's duty. In 1845, the same city had an annual importation of 3,403,000 tons, and in 1854, 4,386,971 tons.

As the consumption of coal increased, so also did the spirit for mining; and a writer towards the close of the seventeenth century thus describes the state of mining speculations in the northern counties:—"Many thousand people are employed in this trade of coals; many live by working of them in the pits; many live by conveying them in waggons and wains to the river Tyne. Many men are employed in conveying the coals in keels from the stathes aboard the ships. One coal-merchant employed five hundred or a thousand men in his work of coals, yet for all his labour, care, and cost, can scarce live of his trade; nay, many of them hath consumed and spent great estates. Some south-country gentlemen have, upon great hope of benefit, come into this country to hazard their monies in coal-pits. Master Beaumont, a gentleman of great ingenuity and rare parts, adventured into our mines with his thirty thousand pounds, who brought with him many rare engines not known then in these parts—as the art to bore with iron rods, to try the deepness and thickness of the coal; rare engines to draw water out of the pits; waggons with one horse to carry down coals from the pits to the stathes, and to the river. Within few years he consumed all his money, and rode home upon his light horse." *

On the continent of Europe the use of pit-coal is also comparatively of modern date. We have seen that in the middle of the fifteenth century an Italian traveller of rank and intelligence, Æneas Silvius, when he saw pieces of coal distributed to the poor in Scotland, appeared to be wholly unacquainted even with the aspect and general nature of the substance.

Coal strata are by no means abundant on the European continent, and France first obtained its knowledge of this mineral from Britain.

In the year 1520, coals imported from Newcastle were first used in Paris, and the same prejudice against them existed as in London, so that their employment as fuel was very limited.

In Belgium, pieces of coal, obtained from seams that had cropped out to the surface in the vicinity of Liege, were used as fuel by a blacksmith † as early as A.D. 1200, and from this period coal gradually came into use in that country.

About the middle of the sixteenth century, coal-mining began to be practised in France; and in the eighteenth century, coal-mines were commenced in the basins of the Loire, Brassac, and Decize.

The use of coal and coke in the smelting of iron forms another important step in the progress of coal-raising. In the reign of James I., wood charcoal was employed in the very limited smelting-foundries for the production of iron, which then existed in Britain; and in France, down to a much later period, about one-fourth of the wood used for fuel was consumed in metallurgic processes.

It was in 1740 that the celebrated ironworks were established at Colebrookdale in Shropshire, in which coke produced from pit-coal was successfully used. Many previous trials had been made, and many failures and disappointments arisen, chiefly from the imperfect manner in which the coke had been prepared; but after this period the smelting of iron began gradually to extend in Britain; and as from five to six tons of coal are required to produce one ton of iron, the consumption of coal in this process became in the course of time very considerable. By a fortunate arrangement in nature, the same strata which yield coal also produce the kinds of iron ore from which the metal is most readily extracted; and thus the coal districts of Britain, abounding in both materials, now produce more than a half the whole iron of the world.

The introduction of the hot-blast process in the smelting furnaces, the invention of Mr Nelson in 1828, by facilitating the production of the metal, and especially by permitting the use of anthracite coal, has greatly extended the manufacture both in Britain and America.

The manufacture of glass was also greatly facilitated and extended by the use of coal-coke as a fuel for the furnaces. Though this manufacture was introduced into Britain as early as A.D. 674, and a manufacture of the finer kinds was established in London in 1557, yet it was not till 1619 that an extensive manufactory of all kinds of glass was commenced on the banks of the Tyne, and in the centre of the great Newcastle coal-field, which still continues to flourish, while extensive glass and pottery manufactories have since sprung up in Staffordshire and other coal districts of Britain.

But the most wonderful and beautiful, as well as one of the most important uses to which coal was put, was that of the production of carburetted hydrogen gas for the purposes of illumination. At first, perhaps, indicated by natural gaseous exhalations from the earth, in India, Persia, and North America, where the natives were accustomed to apply hollow reeds, and form the gas into jets of flame—it was subsequently investigated by chemists; but the merit of practically applying it for the purpose of domestic illumination appears due first to Mr Murdoch, who in 1798 constructed an apparatus for its production and use in the Soho Foundry, Ayrshire, Scotland; and secondly to Mr Windsor, who in the years 1803 and 1804 publicly exhibited gas illumination in the Lyceum Theatre, London.

If we add to all these the employment of coal in the production of steam-power, now used in almost every manufactory of whatever description, as well as its extensive use in locomotive engines on land and sea, we shall immediately perceive that this mineral, so abundantly stored up in the earth's strata, yet so long left to repose in utter neglect, has now become the most powerful and universal agent of modern civilisation.

* GREY'S *Chronographia.*

† The name of this blacksmith was Hullos de Plennevaux; hence is said to be derived the now common name of *houille* for mineral carbon or coal.

AMERICAN AND EUROPEAN COAL-FIELDS.

ACTUAL AND RELATIVE AREAS—THICKNESS AND AMOUNT OF COAL IN THEM—AND PRESENT ANNUAL PRODUCT OF THEIR MINES.

Forming a summary estimate of the extent of the productive coal-formation of the United States, as presented in pp. 758 and 942-968 of this volume, for the sake of a comparison with the coal resources of other countries, we find that the E. half of the continent exhibits five great coal-fields, extending from Newfoundland to Arkansas. 1. The first, or most Eastern, is that of the British provinces, Newfoundland, Nova Scotia, Cape Breton, Prince Edward's Island, and New Brunswick. This seems to have been originally one wide coal-field, subsequently broken up into patches by upheaval and denudation, and by the submergence which formed the Gulf of St Lawrence. The area of the Coal-measures of the provinces is probably about 7500 square miles, though not more than about one-eighth of this surface appears to be underlaid by productive coal-seams. 2. The second, or great Appalachian coal-field, extends from North-eastern Pennsylvania to near Tuscaloosa, in the interior of Alabama. It is about 875 miles long, and 180 broad, where widest in Pennsylvania and Ohio, and by a careful estimate contains about 56,000 square miles. The narrow basins of anthracite in Eastern Pennsylvania, containing more than 400 square miles of coal, are outlying troughs from this great coal-field. 3. A third smaller coal-field occupies the centre of the State of Michigan, equidistant from Lake Huron and Michigan; it covers an area of about 13,300 square miles, but it is very poor in coal. 4. A fourth great coal-field is that situated between the Ohio and Mississippi anticlinals, in the States of Kentucky, Indiana, and Illinois. It has the form of a wide elliptical basin. It is about 370 miles long and 200 miles wide, and contains by estimation 51,000 square miles of Coal-measures. 5. The fifth, and most Western, is the large and very long coal-field filling the centre of the great basin of carboniferous rocks which spreads from the Mississippi and Ozark anticlinals W. to the limit of the Palæozoic region, where the cretaceous strata begin. The coal-field itself has its N. limit on the Iowa River, and its S. in the Indiana territory, near the Red River, to the W. of Arkansas. It is in length 650 miles, and in greatest breadth 200 miles. The total area of this great irregular basin is probably not less than 74,000 square miles. Three or more small detached tracts of coal strata, encompassed by the cretaceous deposits, stretch at intervals S.W. from the S. limit of the longer field through Texas. They are probably extensions of the great field laid bare by denudation. Their extent is imperfectly known, but my Geological Map, constructed from the best documents, indicates an area of about 3000 square miles. Other localities of coal-bearing strata occur in the high table-lands on both sides of the Rocky Mountains, and also in the Wahsatch chain of Utah, but it is doubtful whether some of them belong to the true Carboniferous series. The aggregate space underlaid by these vast fields of coal amounts to nearly 200,000 square miles, or to more than twenty times the area which includes all the known coal-deposits of Europe, or indeed of the whole Eastern continent.

Comparing the areas of the coal-fields of other countries with those of North America now indicated, Great Britain may be estimated to contain about 5400 square miles, France nearly 1000, and Belgium 510 square miles. Rhenish Prussia—Saarbrook field—has 960 square miles, Westphalia 380, the Bohemian field about 400; that of Saxony only 30; that of the Asturias, in Spain, probably 200; and that of Russia, scarcely 100 square miles. And as these are the principal known coal-fields in Europe, the whole region is thus seen to possess less than 9000 square miles of productive Coal-measures. Comparing the coal areas with the total areas of the respective countries, the United States has one square mile of coal-field to each 15 square miles of its 3,000,000 miles of territory; Great Britain has one square mile to each 22½ of surface; Belgium a like proportion with Great Britain; while France possesses only one square mile of coal-field to every 200 miles of country. Assuming the total area of the productive Coal-measures of the world at 220,000 square miles, and accepting 20 feet as the average thickness of the available coal, the entire quantity, if estimated as one lump, is equivalent to a cube of very nearly 10 miles linear dimensions, or to a square cake or plateau of coal 100 miles broad in its base, and more than 500 feet high.

AREAS OF COAL-FIELDS.

NORTH AMERICA.

United States.

	Square Miles.	Length.	Maximum Breadth.
Appalachian Basin,	55,500	875	180
Illinois, Indiana, and Kentucky basins,	51,100	370	200
Missouri and Arkansas Basins,	73,913	550	200
Michigan,	13,350	160	125
Texas,	3,000		
	196,850		

British Provinces.

	Square Miles.
Newfoundland,	100 (!)
Cape Breton,	200
Pictou,	350
Cumberland,	200
New Brunswick (only a small part productive),	6689
	7530

EUROPE.

Britain,	5400 square miles.	Bohemia,	400 (?) square miles.
France,	984 „	Saxony,	30 „
Belgium,	510 „	Spain,	200 (?) „
Saarbrook field,	960 „	Russia,	100 „
Westphalia,	380 „		
		Total,	8964 „

AREAS OF THE BRITISH COAL-FIELDS.

Ireland,	200 square miles.	Dudley,	30 square miles.
Scotland—about	1500 „	Forest of Dean,	30 „
Durham,	750 „	Bristol and Somerset,	50 „
Cumberland,	100 „	Flintshire,	100 „
Lancashire,	500 „	South Wales,	1000 „
North Stafford,	100 „		
Great Central,	900 „	Total,	5400 „
South Stafford,	140 „		

EXTENT OF COAL-FIELD IN THE SEVERAL STATES POSSESSING THE COAL-FORMATION.

Massachusetts and Rhode Island,	100 (?) square miles.	Michigan,	13,350 square miles.
Pennsylvania,	12,656 „	Iowa,	24,000 „
Ohio,	7100 „	Missouri,	21,329 „
Maryland,	550 „	Nebraska,	3712 „
Virginia,	15,900 „	Kansas,	11,880 „
Kentucky,	13,700 „	Arkansas,	12,597 „
Tennessee,	3700 „	Indian Territory,	10,395 „
Alabama,	6130 „	Texas,	2,970 „
Georgia,	170 „		
Indiana,	6700 „	Total,	196,939 „
Illinois,	40,000 „		

The number of the workable coal-seams in the anthracite basins of Pennsylvania varies from two or three up to twenty-five, according to the depth of the basin; perhaps the *average* number, estimated for the entire surface, may be about ten or twelve.

It is not so easy to calculate the thickness of the coal itself, which varies ceaselessly with the depth of the erosion which the Coal-measures have suffered, from that of the thinnest workable bed to a computed maximum, in the widest and deepest parts of the Pottsville Basin, of 207 feet. I think it probable, taking the carefully-computed aggregate thickness of the workable coal-beds of the best-developed localities as the basis of my estimates, that the S. anthracite field possesses an average thickness, rejecting the thin seams, of 100 feet, the middle field a thickness of somewhere about 60 feet, and the N. field perhaps an approximate thickness of 60 feet also; while the general average for the whole anthracite region is not far from 70 feet.

The great Appalachian coal-field evidently lays claim to a materially less total thickness of coal, for the aggregate depth of all the workable seams in Western Pennsylvania, Western Virginia, and Eastern Ohio, where the basin is deepest, and the number of beds is fifteen or sixteen, scarcely amounts to 40 feet. Keeping in view the wide areas from off which the upper Coal-measures, and even a portion of the lower, have been denuded, we are hardly entitled to assume a higher general average for the entire coal-field than 25 feet.

Advancing W., the next great basin—that of Illinois, Indiana, and Western Kentucky—containing, as already shown, sixteen or seventeen workable beds in the last-named State, possesses a maximum thickness of workable coal of about 50 feet, and an average amount of perhaps 20 or 25 feet.

The third great coal-field—or that of Iowa, Missouri, and Arkansas—with a much thinner body of Coal-measures, appears nowhere to have more than two or three profitable coal-beds, and a total thickness of workable coal not exceeding 10 (?) feet. The average for the whole area is obviously materially less than this.

In estimating the average or mean thickness of the coal, due attention is paid, of course, to the deductions from the maximum amount, made necessary by unproductive areas, caused by denudation near the edges of the coal-fields, by deep erosion in the valleys, and by a crushed condition of the strata.

A comparison of the above estimates with the computed aggregate depths of workable coal in some of the British Coal-measures, will enable the reader better to appreciate the relative average value per acre of the American coal-fields with the best-explored European ones.

It is stated that the great coal-field of South Wales embraces twenty-three workable beds, having an aggregate thickness of 92 feet; but the *average* thickness for the whole basin is materially less than this—probably not exceeding 60 feet.

In the *South Staffordshire Basin* the coal amounts to a thickness of about 57 feet, and in one quarter to 70 feet. We may assume 40 feet as the average for the whole coal-field.

In the *Derbyshire Coal-field* there are about twenty workable beds, with an aggregate thickness of 60 feet, and an average for the whole area of 40 feet.

The *Lancashire and Cheshire Coal-field*, contains in one district 150 feet of coal in seventy-five beds, and in another 93 feet in thirty-six beds, but some of these are too thin to mine, and therefore these aggregates express more than is actually procurable. Probably the average thickness of workable coal for the entire coal-field amounts to 50 or 60 feet.

The *Durham and Newcastle Coal-field* contains a total thickness of 60 feet of coal, but the workable seams amount to only 30 feet, and the mean thickness of available coal for the whole tract does not probably exceed 20 feet.

In the *Lanarkshire Coal-field* there are nine workable seams, embracing an aggregate thickness of 37 feet, but the average for the whole area is of course less—perhaps it does not exceed 25 feet.

From these and other similar data, multiplying the areas of the coal-fields by the thicknesses of their productive coal respectively, adding the products, and dividing by the total area, I am led to infer that the general average thickness of procurable coal in the 5400 square miles of British coal-fields is somewhere about 35 feet.

If we direct our attention for a moment to the coal-fields of France and Belgium, we find it recorded that the *Basin of the Loire* has a total thickness of 257 feet of coal, measuring all its seams, many of which are, however, too thin for mining. One bed, the "Great Moss," contains from 26 to 39 feet; and one group of the Coal-measures, that of Rive-de-Gier, includes five workable beds, the mean aggregate amount of coal in which is 65 feet.

The *Westphalian Basin*, or that of *Ruhr*, a continuation apparently of that of Belgium, embraces in one group of strata, 1700 feet thick, as many as fifty-six beds of coal, having a united thickness of 140 feet. Of course these thicknesses much exceed the average mass of coal for the entire areas.

The relative superficial magnitudes of the coal-fields of the several countries possessing coal, will be more clearly recognised if we compare them by some simple unit of measure. Let this be 100 square miles. In this case,

Russia will be represented by	1	British Islands, ...	54
Spain, ...	2	British provinces of North America, . .	75
Anthracite fields of Pennsylvania, and coal-fields of Westphalia and Bomheia, each by	4	Europe, ...	90
Belgium, ...	5	Pennsylvania, ...	126
France, ...	10	Appalachian Coal-field, ...	555
Rhenish Prussia, ...	10	The United States, . . .	2000

To approximate more correctly to the relative amounts of coal in the several great coal-fields of the world, we must compare the cubic quantities, deduced from the foregoing statements of the areas in square miles, and the respective depths of available coal,—thus calculated:

	Tons.
Belgium (assuming her coal-fields to have an average thickness of 60 feet of coal) contains about .	36,000,000,000
France (with same thickness) about	59,000,000,000
The British Islands (adopting 35 feet as the average thickness) nearly	190,000,000,000
Pennsylvania (computing her average of workable coal at 25 feet) has	316,400,000,000
The Great Appalachian Coal-field (adopting the same proportion), ...	1,387,500,000,000
The Coal-field of Indiana, Illinois, and Western Kentucky (also with an average thickness of 25 feet),	1,277,500,000,000
The Missouri and Arkansas Basin (accepting 10 ft. as the mean thickness of the coal over the whole area),	739,000,000,000
All the Productive Coal-fields of North America (with an assumed thickness of 20 feet of coal, and a productive area of 200,000 square miles), ...	4,000,000,000,000

The ratio of the actual quantities of coal, in the more important of these several coal-fields, is approximately shown in the following series of numbers:—Thus, making the coal of Belgium, or 36,000,000,000 tons, our *unit of measure*,

The amount of coal in Belgium is represented by .	1	In the Illinois, Indiana, and Westn. Kentucky Basin, by	35½
In France, by less than	2	In the Missouri and Arkansas Basin, . . .	20½
In the British Islands, by rather more than . .	5	In all the coal-fields of North America, . .	111
In Pennsylvania, by a little less than . .	9	In all Europe, ...	8¾
In the Appalachian coal-field, by about . .	38½		

COMPARATIVE QUANTITIES OF FUEL IN COAL LANDS AND FOREST LANDS.

France contains, according to M. Burat, about 280,000 hectares of Coal-measures, while its vegetable fuel is the product of 8,500,000 hectares of forests, or of a surface thirty times as great. But the vegetable fuel is four times as much as all the coal; though whether this comparison is in measure or weight is not stated. Therefore an acre of coal-field in France yields seven or eight times as much fuel as an acre of woodland.

Let us now contrast the rich coal-lands of the United States with the rich forests, acre for acre.

Good timber-lands will yield 200 cords of wood (all cut) per acre, equivalent in efficiency as fuel to 100 tons of coal; but an acre of good coal-land contains from 30,000 to 40,000 tons of coal, or three hundred or four hundred times as much fuel (estimated not by bulk or weight, but by heating power) as the best woodland.

DYNAMIC VALUE OF COAL.

It is interesting to compare the dynamic force of coal applied as fuel to the generation of steam in the steam-engine, with the dynamic effect of a man. The human labourer, exerting his strength upon a treadmill, can raise his own weight, say 150 lb., through a height of 10,000 feet per day, equivalent to 1 lb. raised 1,500,000 feet. The mechanical virtue of fuel is best estimated by ascertaining the number of pounds which a given quantity, say 1 bushel, will raise to a given height, say 1 foot, against gravity. In the steam-engine this is called the *duty of the fuel.* Now, the present maximum duty of 1 bushel of good coal, in the improved Cornish steam-engines, is equivalent to 100,000,000 lb. lifted through 1 foot; but 1 bushel has been made to raise 125,000,000 lb. 1 foot high, or 1 lb. 125,000,000 feet; but as there are 84 lb. in one bushel, this divisor gives 1 lb. as equal to 1,500,000 feet; which is just the result of a man's toil for one day upon a treadmill. Thus a pound of coal is really worth a day's wages. If we estimate a lifetime of hard work at twenty years, giving to each year three hundred working days, we have for a man's total dynamic effort six thousand days. In coal this is represented by the amazingly small amount of *three tons.* Another proof of the extraordinary power derivable through the combustion of fuel is presented in the following calculation:—1 cubic inch of water is convertible into steam of one atmosphere of pressure by 15$\frac{1}{3}$ grains of coal, and this expansion of the water into steam is capable of raising a weight of 1 ton the height of a foot. The 1 cubic inch of water becomes very nearly 1 cubic foot of steam, or 1728 cubic inches. When a vacuum is produced by the condensation of this steam, a piston of 1 square inch surface, that may have been lifted 1728 inches, or 144 feet, will fall with a velocity of a heavy body rushing by gravity through one-half of the height of the homogeneous atmosphere, or through 13,500 feet. This gives a terminal velocity of 1300 feet per second—greater than that of the transmission of sound. From this we can form some estimate of the strength of the tempest which alternately blows the piston in its cylinder, when elastic steam of high pressure is employed. Applying the calculations of the dynamic efficiency of coal for estimating the mechanical strength latent in the coal-fields of the earth, or in the large coal product annually furnished by the mines of Great Britain, we get some interesting results. Each acre of a coal-seam, 4 feet in thickness, and yielding 1 yard nett of pure fuel, is equivalent to about 5000 tons, and possesses, therefore, a reserve of mechanical strength in its fuel equal to the life-labour of more than 1600 men. Each square mile of one such single coal-bed contains 3,000,000 of tons of fuel, equivalent to 1,000,000 of men labouring through twenty years of their ripe strength. Assuming, for calculation, that 10,000,000 of tons, out of the present annual product of the British coal-mines, namely 67,000,000, are applied to the production of mechanical power, it follows that England annually summons to her aid an army of 3,500,000 fresh men, pledged to exert their fullest strength through twenty years. Her actual annual expenditure of power, then, is represented by 70,000,000 of able-bodied labourers. The latent strength resident in the whole coal-product of the kingdom may, by the same process, be calculated at more than 400,000,000 of strong men, or more than double the number of the adult males now upon the globe.

AMOUNT OF COAL MINED.

The annual product of the chief coal-fields of the world at the present time, as stated by the best authorities, would appear to be as follows:—

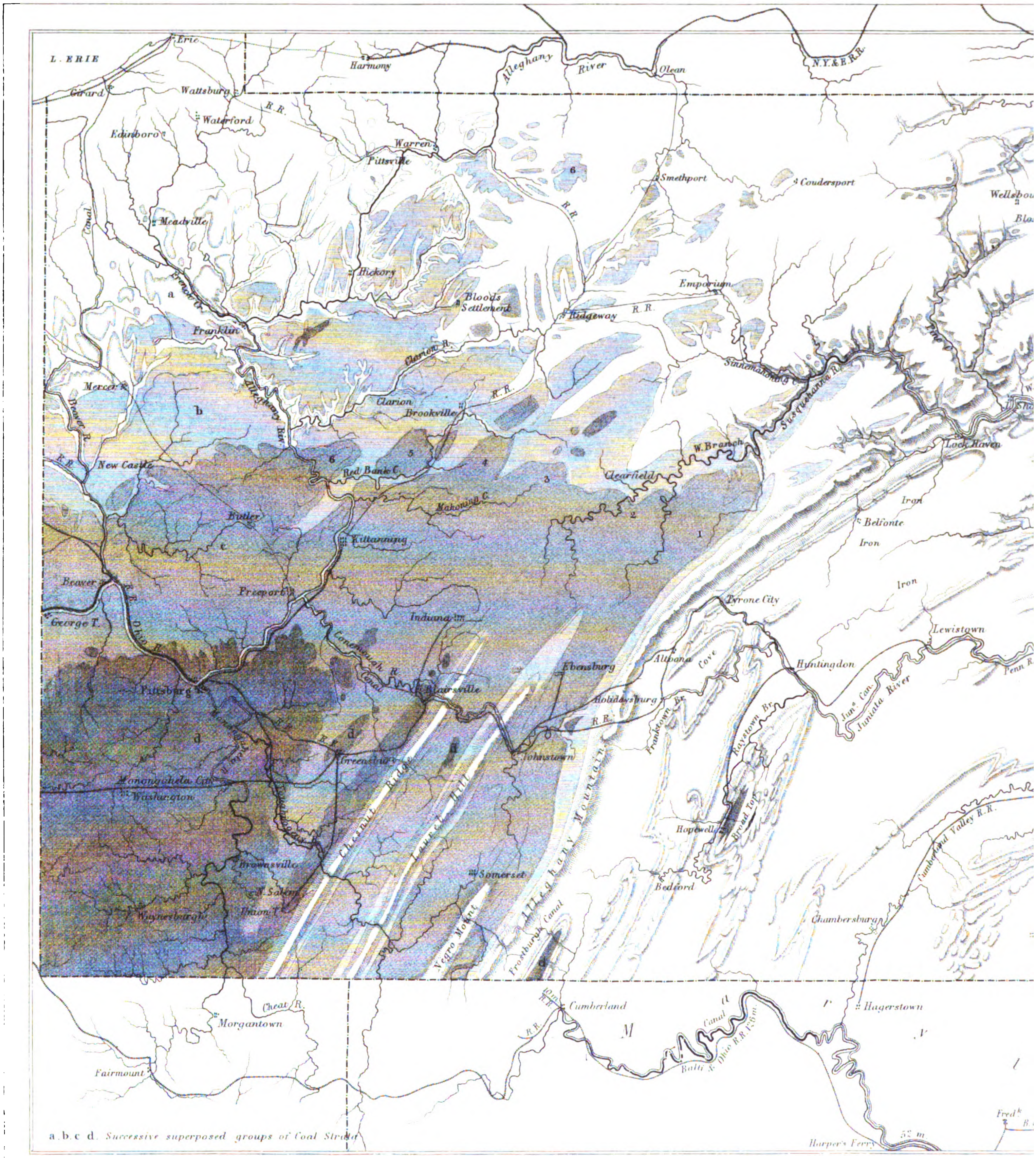
Great Britain extracted from her mines, in 1854, 64,661,401 tons, and is supposed to be producing at present about 67,000,000 tons; the United States, in 1857, about 10,500,000 tons; Belgium, in 1850, 5,820,588 tons; France, in 1850, about 4,500,000 tons; Prussian State, in 1850, 4,000,000 tons.

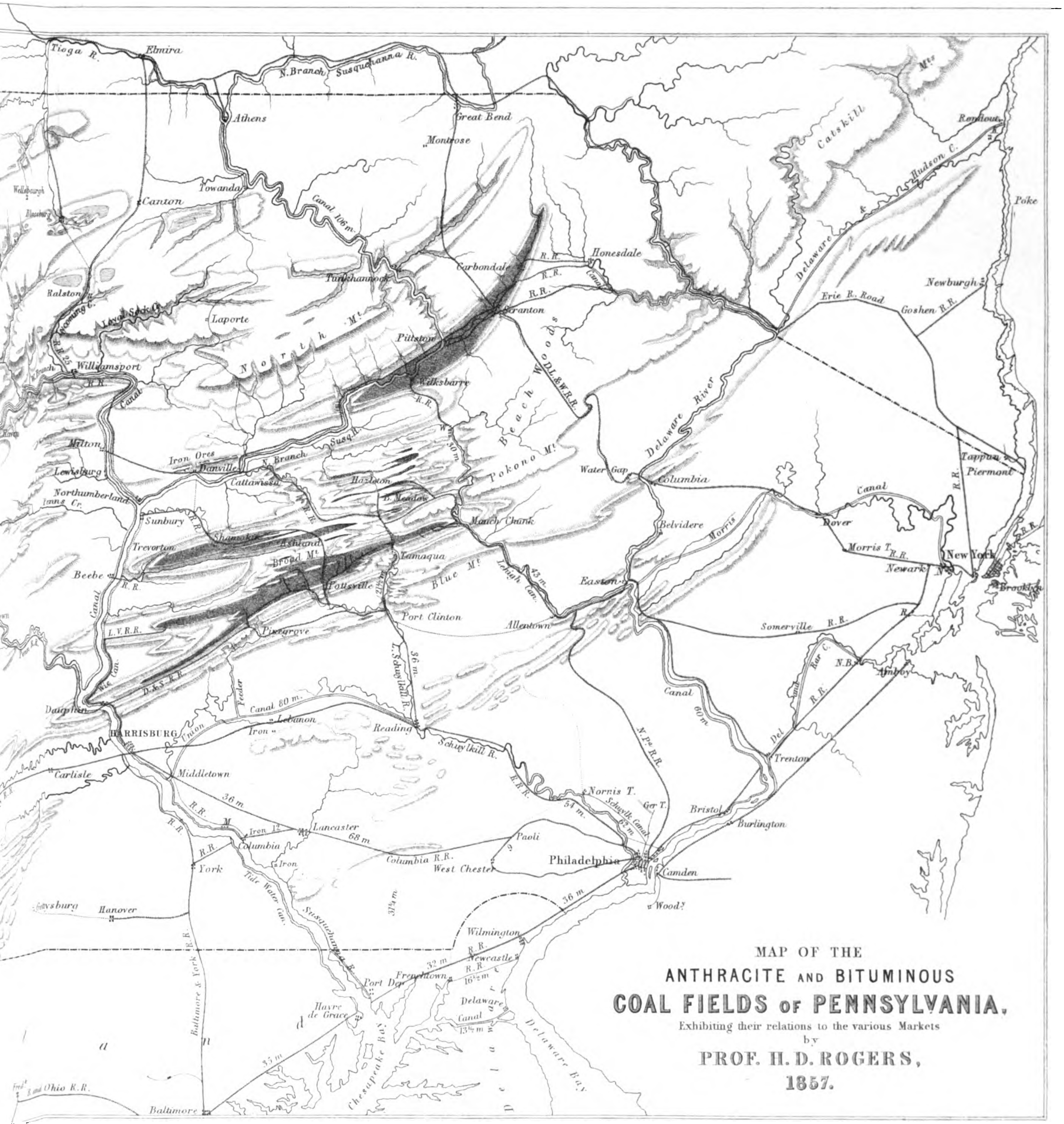
Thus we may fairly assume that the total quantity now annually mined very nearly amounts to 100,000,000 tons. What portion of this large production is applied to the generation of mechanical power we do not know; but it can be calculated that one-fifth of it (20,000,000 tons) is consumed annually in the manufacture of iron alone, where, however, only a part is converted into power. Probably at least 10,000,000 of tons are applied to the propulsion of machinery of all kinds, through the generation of steam.

COAL-TRADE OF PENNSYLVANIA.

The history of the coal-trade of Pennsylvania is interesting. The produce of the anthracite mines, from its commencement in 1820 through all its stages of growth, is fully shown in the Table here affixed, which I take the liberty of copying from the *Miners' Journal* of Pottsville, an admirably-conducted paper, devoted to the coal and iron interests of the State, and abounding in valuable statistical information.

From these statistical details it would appear that, since its origin in 1820, the anthracite trade has grown in thirty-eight years to nearly 7,000,000 tons, or at the rate of about 184,000 tons per annum; and that from 1839 (the date of active development of the mines) to 1849, the product doubled itself each five years, while its subsequent rate of increase has been to double itself to its present point in eight years. The British coal-trade grows more slowly, doubling about every twenty-four years.


L. ERIE
Erie
Girard
Wattsburg
Waterford
Edinboro
Harmony
Alleghany River
Olean
N.Y. & E.R.R.
Warren
Pittsville
Smethport
Coudersport
Wellsboro
Meadville
Hickory
Bloods Settlement
Ridgeway
Emporium
Franklin
Clarion R.
Mercer
Clarion
Brookville
Susquehanna R.
Lock Haven
New Castle
Red Bank C.
Clearfield
W. Branch
Mahoning C.
Butler
Kittanning
Belfonte
Iron
Beaver
Freeport
Tyrone City
George T.
Indiana
Lewistown
Ebensburg
Altoona
Huntingdon
Pittsburg
Blairsville
Holidaysburg
Juniata River
Greensburg
Johnstown
Monongahela
Washington
Chesnut Ridge
Laurel Hill
Alleghany Mountain
Hopewell
Broad Top
Raystown Br.
Cumberland Valley R.R.
Brownsville
Somerset
Bedford
Waynesburgh
Union T.
Chambersburg
Negro Mount
Frostburgh
Cumberland
Cheat R.
Hagerstown
Morgantown
Canal
Balti & Ohio R.R.
Fairmount
Harper's Ferry
a.b.c.d. Successive superposed groups of Coal Strata



MAP OF THE

ANTHRACITE AND BITUMINOUS

COAL FIELDS of PENNSYLVANIA.

Exhibiting their relations to the various Markets

by

PROF. H. D. ROGERS,

1857.

The following Table (I.) exhibits the quantity of Anthracite Coal sent to Market from the different Regions in Pennsylvania, from the Commencement of the Trade in 1820 to 1857, inclusive; to which is appended (Table II.) the Semi-Anthracite Trade, the Cumberland Bituminous Trade, the Importations of Foreign Coal, and the Exportation of Domestic Coal.

TABLE I.

HARD ANTHRACITES.

Years.	Schuylkill.					Sold on Line of Schuylkill.	Lehigh.			Wyoming Region.						Shamokin.	Aggregate.	Annual Increase.
	Canal.	Railroad.	Total.	Pine Grove.	Little Schuylkill.		Canal.	Railroad.	Total.	By Lehigh Railroad.	Delaware and Hudson Coal Company.	Pennsylvania Coal Company.	By Canal.	Great Western Railroad.	Total.			
1820	..	..	..	..	..	..	365	..	365	..	..	..	..	..	..	..	365	..
1821	..	..	..	..	..	..	1,073	..	1,073	..	..	..	..	..	..	..	1,073	..
1822	1,480	..	1,480	..	..	..	2,240	..	2,240	..	..	..	..	..	..	..	3,720	..
1823	1,128	..	1,128	..	..	..	5,823	..	5,823	..	..	..	..	..	..	..	6,951	..
1824	1,567	..	1,567	..	..	..	9,541	..	9,541	..	..	..	..	..	..	..	11,108	..
1825	6,500	..	6,500	..	..	..	28,393	..	28,393	..	..	..	..	..	..	..	34,893	25,352
1826	16,767	..	16,767	..	..	..	31,280	..	31,280	..	..	..	..	..	..	..	48,047	13,154
1827	31,360	..	31,360	..	..	..	32,074	..	32,074	..	..	..	..	..	..	..	63,434	15,837
1828	47,284	..	47,284	..	..	3,154	30,232	..	30,232	..	..	..	..	..	..	..	77,516	14,082
1829	79,973	..	79,973	..	..	3,332	25,110	..	25,110	..	7,000	..	..	..	7,000	..	112,083	34,567
1830	89,984	..	89,984	..	..	5,321	41,750	..	41,750	..	43,000	..	..	..	43,000	..	174,734	62,651
1831	81,854	..	81,854	..	..	6,150	40,966	..	40,966	..	54,000	..	..	..	54,000	..	176,820	2,086
1832	209,271	..	209,271	..	14,000	10,048	70,000	..	70,000	..	84,600	..	..	..	84,000	..	363,871	187,051
1833	252,971	..	252,971	..	40,000	13,429	123,000	..	123,000	..	111,777	..	..	..	111,777	..	487,748	123,877
1834	226,692	..	226,692	..	34,000	19,429	106,244	..	106,244	..	43,700	..	..	..	43,700	..	376,636	*decrease*
1835	339,508	..	339,508	..	41,000	18,571	131,250	..	131,250	..	90,000	..	..	..	90,000	..	560,758	184,122
1836	432,045	..	432,045	..	35,000	17,863	148,211	..	148,211	..	103,861	..	..	..	103,861	..	684,117	123,359
1837	523,152	..	523,152	17,000	31,000	21,749	223,902	..	223,902	..	115,387	..	..	..	115,387	..	879,444	195,327
1838	433,875	..	433,875	13,000	13,000	28,775	213,615	..	213,615	..	78,207	..	..	..	78,207	..	738,697	*decrease*
1839	442,608	..	442,608	20,539	9,000	30,390	221,025	..	221,025	..	122,300	..	..	..	122,300	11,930	818,402	79,805
1840	452,291	..	452,291	23,860	20,000	28,924	225,318	..	225,318	..	148,470	..	..	..	148,470	15,505	864,384	45,982
1841	584,692	850	585,540	17,653	40,000	41,223	143,037	..	143,037	..	192,270	..	..	..	192,270	21,463	959,973	95,589
1842	491,602	49,902	540,892	32,381	37,000	40,584	272,546	..	272,546	..	205,253	..	47,346	..	252,599	10,000	1,108,418	148,445
1843	447,058	230,254	677,295	22,905	31,000	34,619	267,793	..	267,793	..	227,605	..	58,000	..	285,605	10,000	1,263,598	155,170
1844	398,887	441,491	839,934	34,910	57,000	60,000	377,002	..	377,002	..	251,005	..	114,906	..	365,911	13,087	1,630,850	367,252
1845	263,587	820,237	1,083,796	47,928	74,000	90,000	429,453	..	429,453	..	273,435	..	178,401	..	451,836	10,000	2,013,013	382,163
1846	3,440	1,233,142	1,237,002	58,926	91,000	155,460	517,116	..	517,116	5,886	320,000	..	192,503	..	518,389	12,572	2,344,005	330,992
1847	222,693	1,360,681	1,583,374	67,457	106,401	226,610	633,507	..	633,507	10,466	388,203	..	284,398	..	583,067	14,904	2,882,309	538,304
1848	436,602	1,216,233	1,652,835	61,530	162,626	252,837	670,321	..	670,321	10,425	437,500	..	237,271	..	685,196	19,356	3,089,238	206,929
1849	489,208	1,115,918	1,605,126	78,299	174,758	239,290	781,656	..	781,656	19,590	454,240	..	259,080	..	732,910	19,650	3,217,641	128,403
1850	288,030	1,423,977	1,712,007	70,919	211,960	207,863	690,456	..	690,466	32,156	441,403	111,014	243,250	..	827,823	19,921	3,321,136	103,495
1851	579,156	1,650,270	2,184,240	*none*	310,307	312,367	964,224	..	964,224	25,072	479,078	316,017	336,000	..	1,156,167	24,899	4,329,530	1,008,394
1852	800,038	1,650,912	2,450,950	66,543	325,099	322,211	1,072,136	..	1,072,136	41,890	497,105	426,164	319,341	..	1,284,500	25,846	4,899,975	570,445
1853	188,695	1,582,248	2,470,943	80,660	389,295	394,078	1,054,309	..	1,054,309	26,235	494,327	512,659	442,511	..	1,475,732	15,500	5,097,144	197,169
1854	907,354	1,987,854	2,895,208	91,462	444,184	444,160	1,207,186	..	1,207,186	39,232	440,944	496,648	492,689	133,965	1,603,478	63,500	5,831,834	734,690
1855	1,105,263	2,213,292	3,318,555	112,213	426,208	471,861	1,275,050	9,063	1,284,113	50,209	565,460	504,803	464,039	187,000	1,771,511	116,117	6,486,097	654,223
1856	1,169,453	2,088,903	3,258,350	157,152	454,515	520,499	1,186,230	165,740	1,351,979	44,270	499,650	612,500	510,631	305,530	1,972,581	137,406	6,751,542	262,597
1857	1,275,989	1,709,552	2,985,541	145,012	365,349	511,977	900,314	418,235	1,318,541	37,959	480,699	536,008	407,914	490,023	1,952,603	155,806	6,431,378	*dec.* 320,163
..	10,034,585	20,718,471	84,753,059	1,167,451	3,938,702	..	14,153,659	593,038	14,746,689	343,390	7,645,543	3,515,765	4,588,859	1,116,618	17,210,075	717,462	..	..

TABLE II.

Years.	Semi-Anthracite and Bituminous.									Aggregate of all kinds.	Total Increase of all kinds.	Exportation of Domestic Coal.
	Lykens Valley.	Short Mountain.	Dauphin County.	Trevorton.	Broad Top.	Cumberland.	Import of Foreign Coal.	Aggregate.	Increase and Decrease.			
1820	..	..	..	..	..	..	..	..	..	365	..	..
1821	..	..	..	..	..	..	22,122	22,122	..	23,195	..	..
1822	..	..	..	..	..	..	34,523	34,523	12,401	38,243	..	..
1823	..	..	..	..	..	..	30,433	30,433	*decrease*	41,534	..	..
1824	..	..	..	..	..	..	7,228	7,228	*do.*	18,331	..	..
1825	..	..	..	..	..	..	25,645	25,645	18,417	60,538	..	..
1826	..	..	..	..	..	..	35,665	35,665	10,020	83,712	..	..
1827	..	..	..	..	..	..	40,257	40,257	4,592	103,691	..	..
1828	..	..	..	..	..	..	32,302	32,302	*decrease*	109,818	..	..
1829	..	..	..	..	..	..	45,393	45,393	13,091	157,476	..	..
1830	..	..	..	..	..	..	58,136	58,136	12,737	132,820	..	..
1831	..	..	..	..	..	..	36,509	36,509	*decrease*	113,229	..	..
1832	..	..	..	..	..	..	72,978	72,978	36,469	436,849	..	..
1833	..	..	..	..	..	..	92,432	92,432	19,452	580,180	..	..
1834	..	..	..	..	..	..	71,626	71,626	*decrease*	448,262	..	..
1835	..	..	..	..	..	..	49,969	49,969	*do.*	610,727	..	..
1836	..	..	..	..	..	..	108,432	108,432	58,463	792,549	..	..
1837	..	..	..	..	..	..	153,450	153,450	24,377	1,032,894	..	..
1838	..	..	..	..	..	..	129,083	129,083	*decrease*	867,780	..	..
1839	..	..	..	..	..	..	181,551	181,551	52,468	1,000,153	..	..
1840	..	..	..	..	..	..	162,867	162,867	*decrease*	1,027,241	..	..
1841	..	..	..	..	..	..	155,394	155,394	*do.*	1,115,357	..	..
1842	..	..	..	..	..	1,708	141,521	143,227	*do.*	1,251,647	..	..
1843	..	..	..	..	..	10,082	41,163	51,245	*do.*	1,314,833	..	..
1844	..	..	..	..	..	14,890	87,073	101,963	50,718	1,754,445	417,970	..
1845	..	..	..	..	..	24,653	85,776	110,429	8,456	2,143,530	390,619	..
1846	..	..	..	..	..	29,795	156,853	176,648	76,329	2,530,653	407,302	..
1847	..	..	..	..	..	52,940	148,021	200,961	14,313	3,083,270	552,617	..
1848	..	..	..	..	..	79,571	196,168	275,739	74,778	3,364,971	281,707	9,309
1849	25,325	..	..	..	..	142,449	198,213	365,987	90,248	3,583,628	218,651	9,661
1850	37,763	..	..	..	..	196,848	180,439	415,050	49,063	3,736,184	152,558	38,741
1851	54,200	..	20,000	..	..	257,679	214,774	546,653	131,603	4,376,183	1,139,997	37,727
1852	59,857	..	33,639	..	..	334,178	183,015	610,689	88,962	5,510,664	659,407	45,336
1853	69,007	..	29,000	..	..	533,980	231,508	862,495	252,807	5,960,639	449,975	79,510
1854	57,500	50,000	63,000	..	..	648,299	252,865	1,071,664	218,160	6,903,498	952,857	93,884
1855	66,721	50,500	1,000	..	..	664,304	287,408	1,069,933	*decrease*	7,565,980	652,492	110,586
1856	61,187	41,739	..	73,112	42,000	719,211	173,055	1,110,304	40,371	7,868,948	302,968	136,594
1857	65,201	56,538	..	110,711	78,813	564,690	238,192	1,114,145	3,841	7,545,523	*dec.* 816,322	130,355
..	496,780	198,777	146,639	183,823	120,813	4,275,277	4,532,039	9,784,129	..	77,336,544	..	691,703

STATISTICS OF THE IRON TRADE.

The smelting of iron constitutes so important a branch of industrial activity in Pennsylvania, and is moreover so fair a measure of the mineral wealth of the State, and of the rate at which this is becoming developed, that a brief statistical view of the history and present condition of the iron manufacture seems appropriate here, to complete the picture introduced by the foregoing exhibition of the comparative productiveness of the coal-fields.

The following statement, originally published in the *North American* newspaper of Philadelphia, February 6, 1858, and pronounced by that journal to be the most complete and authentic ever compiled, displays such evidence of research and exactness that I cannot better do justice to the subject than by transferring it without modification to these pages :—

PRODUCTION AND MANUFACTURE OF IRON IN THE UNITED STATES.

For the purpose of this statement, we may distinguish three principal departments of the iron production,—the first represented by the blast-furnaces, using either anthracite, charcoal, raw or coked bituminous coal; the second by the bloomeries or mountain-forges, which turn ore or cast-iron into blooms or malleable iron; and the third by the rolling-mills, which convert these into bar, rod, sheet, and nail-plate iron. Beyond this point the manufacture ramifies into an infinite number of branches among all the mechanic arts.

Of these three kinds there are about 1100 ironworks in the United States, viz. 121 anthracite furnaces, 500 charcoal and coke furnaces, 300 forges, and 210 rolling-mills.

The furnaces produced in 1856 about 787,958 tons of pig metal from the various ores, to which must be added 6500 tons produced from the ore by the bloomery forges. The entire production of iron, in 1856, was nearly 800,000 tons.

The annual change in the amount of iron produced is not so great, on the whole, as was once thought, or as is the case at the present chief centres of production. There were produced—

	Tons.
In 1854,	713,366
In 1855,	705,745
In 1856,	782,958

Yet the local fluctuations are very great. The anthracite production during these three years rapidly increased, by the enlargement and better handling of old furnaces, and the erection of new ones.

	Tons.		Tons.
In 1849 it was only	107,256	In 1855 it was	343,105
In 1854 „	307,710	In 1856 „	393,509

There was, of course, a proportionate decrease of the manufacture of charcoal iron. Where this has taken place will appear by the following Table, showing the production of iron,—

	1854.—Tons.	1855.—Tons.	1856.—Tons.
BY ANTHRACITE FURNACES.			
In Pennsylvania,	208,703	255,326	306,966
Out of Pennsylvania,	99,000	87,779	86,543
BY CHARCOAL AND COKE FURNACES.			
East Pennsylvania,	62,724	60,596	51,775
North-west Pennsylvania,	78,927	59,388	59,587
South-west Pennsylvania,	11,052	18,217	29,400
BY CHARCOAL FURNACES.			
East of the Hudson,	30,420	30,926	27,837
Northern and Western New York,	19,197	19,736	18,847
Southern New York and New Jersey,	13,435	7,901	5,683
Maryland,	35,658	36,309	30,998
North-western Virginia,	1,930	2,342	1,467
Eastern and Middle Virginia,	5,880	6,926	5,730
North and South Carolina,	1,820	1,830	1,966
Georgia and Alabama,	3,604	3,682	4,302

CHARCOAL FURNACES—(*continued*).

	1854.—Tons.	1855.—Tons.	1856.—Tons.
Tennessee,	38,596	30,000	30,000
Missouri,	5,213	6,000	13,201
West Kentucky,	5,000	5,000	5,000
East Kentucky,	22,830	15,580	21,160
South Ohio (charcoal and coke),	56,081	47,182	69,605
North Ohio (charcoal and coke),	8,289	6,025	7,901
Illinois, Indiana, Michigan, Wisconsin, and Minnesota,	5,000	5,000	50,000
Total tons,	713,366	705,745	782,958

There are ten principal centres of the iron manufacture in the United States:—

1. Northern New York, once including Vermont, and using the fine primitive ores of the Adirondac Mountains. Here are forty bloomeries and three anthracite furnaces.

2. The Highlands, a narrow belt extending through Berkshire, Massachusetts, into Southern Vermont, and through Northern New Jersey into Pennsylvania, containing forty-four charcoal and twenty-two anthracite furnaces, and sixty forges, using hæmatite and magnetic ores.

3. Eastern Pennsylvania and North-eastern Maryland, with ninety-eight anthracite furnaces, one hundred and three charcoal furnaces, and one hundred and seventeen forges; none of which last, however, produce iron from the ore. This great iron region is itself divisible into distinct smaller areas, some of them using magnetic, some hæmatite, and some fossil ores.

4. North-western Virginia and South-western Pennsylvania is a distinct region on the E. outcrop of the lower Coal-measures, with forty-two charcoal furnaces, and two or three forges, and using carbonate of iron. It includes the Cambria ironworks, which accounts for its apparent growth.

5. North-western Pennsylvania and North-eastern Ohio, with sixty-six furnaces, using the ores of the N.W. outcrop of the lower Coal-measures. The charcoal furnaces of this region are all going out, and the coke and raw bituminous-coal furnaces are increasing in number, size, and efficiency. All the forging of this region is done by the rolling-mills at Pittsburg.

6. The Hanging Rock, or Ironton region, crosses the Ohio River as a belt of charcoal furnaces about 15 miles wide and 100 long; forty-five in number on the Ohio side, and seventeen on the Kentucky side. Its ores are all from the lower Coal-measures, and at its Northern end stone-coal is beginning to be used for fuel.

7. The old manufacturing region of Middle and Eastern Virginia is a prolongation Southward of the Eastern Pennsylvania, with the same ores, but using charcoal exclusively as a fuel. East of the Blue Ridge are sixteen furnaces (only one of which remains in blast), and W. of the Blue Ridge thirty. There are thirty-five forges.

8. North-eastern Tennessee and North-western North Carolina have nine furnaces and forty-one bloomery forges in a compact area. Along the base of the Cumberland Mountains, five furnaces and fourteen forges use the Dyestone fossil (upper Silurian) ore. In the S.W. corner of North Carolina are five forges, and through the middle of the State runs a belt of five furnaces and twenty-seven forges. This whole country possesses incalculable resources for iron-making, and must become at some distant day one of the great centres.

9. In Western Tennessee and Kentucky, around Clarksville and Eddyville, lies the principal, and, at present, only important region of the Far West. It contains forty-five furnaces and some forges.

10. In Missouri a beginning has been made with seven furnaces, which must develop into a great iron-making region around the Iron Mountain and Pilot Knob, when fed by coals from Western Missouri and Kansas.

The Lake Superior iron region has been opened as a mining region only within two or three years past, though it is worked with great success at various points near the copper-mines in Michigan, and on the W. shore in Minnesota. Most of the ore is shipped to Detroit and Cleveland, for the use of the rolling-mills of the West. The total production of these ores was probably 15,000 tons in 1857. This will, at no distant day, be a principal iron-making region.

Tabulating these regions on the scale of their importance, we have:—

	Tons.
1. Eastern Pennsylvania and Maryland charcoal, 87,773; anthracite, 341,928,	428,701
2. Ironton Region, South Ohio,	90,765
3. Highland Belt,	70,672
4. Pittsburg Region,	69,488
5. Clarksville and Eddyville Region,	33,000
6. Adirondac Region,	34,464
7. Monongahela Region,	30,867
8. Missouri Region,	13,201
9. East Tennessee and Carolina Region,	6,800
10. Virginia,	5,730
Total,	782,958

Bloomery forges are small open blast-furnaces, or very large smith-fires closed in to hold a quarter of a ton of some rich ore, which when smelted is hooked out in the form of a ball of malleable iron, and hammered round or flat under a tilt-hammer. All the forges are adjuncts to the blast-furnaces, treating their pig-iron in the same manner as if it were so much ore, and preparing it for the rolling-mill. It is a great geographical feature of the manufacture that the forges are to be found almost exclusively East of the Alleghany Mountains; the geological reason for which is, that here alone are found the magnetic, primary, or high per-cent ores. Lake Superior and Missouri are the only Western forge regions. The West once had many forges for blooming pig-iron, but these have all been abandoned, and that work is now done by the puddling furnaces, squeezers, and muck-roll of the rolling-mills. There is a third division of forges, which use either trip or steam hammers for turning bloomed and rolled iron into various shapes for mechanical purposes—engine cranks and shafts, car-axles, &c.

Rolling-mills (commonly with nail-factories attached) are divided into railroad and merchant mills. The principal railroad-mills in the United States are given in the following Table, with their product in 1856:—

Bay State, Boston,	17,871 tons.	Mount Savage, Maryland,	7,459 tons.
Rensselaer, Troy,	13,512 „	Cambria, Pennsylvania,	7,533 „
Trenton, New Jersey,	about 13,000 „	Brady's Bend, W. Pennsylvania,	13,206 „
Phœnix, Pennsylvania,	18,592 „	Washington, Wheeling, Virginia,	2,355 „
Pottsville, Pennsylvania,	3,021 „	M'Nickle, Covington, Kentucky,	1,976 „
Lackawanna, Pennsylvania,	11,338 „	Railroad Mill, Cleveland, Ohio,	1,800 „
Rough & Ready, Danville, Pa.,	5,259 „	Newburg Mill, Cleveland, Ohio,	900 „
Montour, Danville, Pennsylvania,	17,538 „	Wyandotte, near Detroit,	6,000 „
Safe Harbour, Lancaster Co., Pa.,	7,347 „		
		Total,	147,507 „

The Fairmount, at Philadelphia, has been recently adapted to rolling railroad-iron, and the Palo Alto, at Pottsville, rolled about 1000 tons in 1856. The Newburg mill commenced making rails late in 1857. Most of these mills are now stopped; and a number lately about to be erected in the West (at Indianopolis, Chicago, St Louis, &c.) will have to be delayed till better times. The Western mills chiefly re-roll old rails. The extension of this business in the past four years can be seen from the following figures:—

	Railroad Iron made. Tons.	Imported. Tons.	Consumed. Tons.
1853,	105,000	298,895	403,995
1854,	121,000	288,266	409,866
1855,	134,000	127,915	261,915
1856,	147,507	155,995	303,502

NICKEL AND COPPER MINE OF THE GAP, LANCASTER COUNTY.

Since putting to press the account of the Minerals and Ores of the State embodied in PART IV. of this work, some additional information has reached me respecting the Old Nickel and Copper Mine of Lancaster County. It has been reopened, chiefly with a view to the nickel, this metal being now in demand at the United States Mint, for the manufacture of the beautiful new nickel *cent*. The lode is reached by a vertical shaft 23 fathoms deep. A gallery, about 300 feet long, follows the ore at a depth of 10 fathoms; at one end of it the vein divides into three or four branches. A wide cross-course has been cut about 100 feet E. of the shaft, intersecting chiefly sulphate of iron and actinolite. East of this occur several irregular, thin, vanishing veins of black oxide and red sulphuret of copper; but these disappear as they approach a mass of sienitic granite. At this spot, it is said, the mine was first opened, nearly one hundred and thirty years ago, and was wrought, but unsuccessfully, for the copper ore. At a short distance below the 60-feet or 10-fathom level, the lode acquires sulphuret of nickel; and at the depth of 16 fathoms it presents a somewhat rich body of nickel ores within a width of 20 feet. At this depth the principal gangstone is hornblende; but going deeper, the hornblende diminishes, and the nickel ore augments, so that not more than 20 or 25 per cent of the material raised requires washing. Small veins and bunches of yellow sulphuret of copper, yielding about 14 per cent of metal, occupy the N. part of the lode, through a breadth of some 7 feet. Towards the W., at a depth of 21 fathoms, the lode is said to yield good nickel ore, in the proportion of 18 tons of ore to each cubic fathom of the lode: it is estimated that a miner can extract about 20 tons of nickel ore per month. This lode has been explored by trial-shafts to a depth of 10 fathoms, for a length of about 600 feet, and looks well throughout.

About 90 feet N. of the lode mined, there occurs another vein parallel with it. This has been explored through a length of more than 900 feet. At a depth of 70 feet a shaft exposes sulphuret of nickel and copper ores; it dips about 33° N. Mr Joseph Buzzo, mining engineer, from whose printed statement these details are derived, estimates the quantity of "nickel ores now discovered to be at least one hundred thousand tons," and says that "the produce of the mine at present is about 200 tons of nickel ore and 10 tons of copper ore per month. There are ten miners employed, and eighteen surface-hands, including mechanics."

ADDITIONAL ILLUSTRATIONS.

A FEW woodcuts which were overlooked, or were not prepared when the pages which they were designed to illustrate were made ready for the press, are here introduced. Copiously as the text is elucidated, I am unwilling that it should lose the assistance of even these few sketches, which, however misplaced in the printing, can readily be turned to profit by the judicious reader.

Taking them nearly in the order in which they should have appeared in the book, the first omitted cut, Fig. 774, here annexed, represents a section of the Nittany or Bellefont Valley, near Jacksonville. Its appropriate place is page 497 of Vol. I., where the dislocated axis of the Nittany Valley is represented as an "upthrow on the South," lifting the Primal rocks upon the edges of the inverted Auroral limestone along the margin of the "Barrens." It exemplifies, moreover, the general description given at page 897, Vol. II., of a dislocation at an anticlinal axis-plane, where, in a folded flexure, the uninverted side of the wave is shoved upward and forward upon the inverted side.

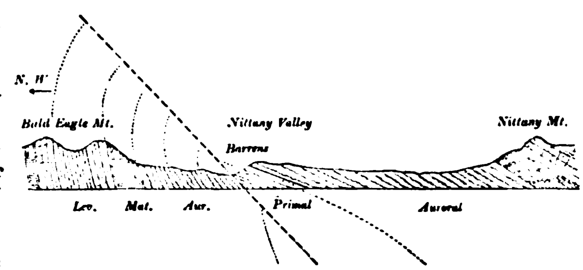


FIG. 774.

Another section, too illustrative to be overlooked, is here appended in Fig. 775. It is intended to explain the structure of a part of the interesting undulated country embraced

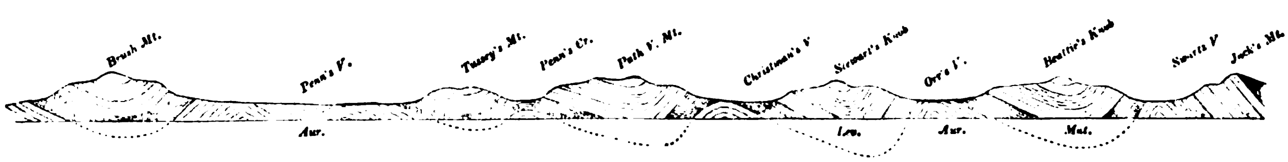
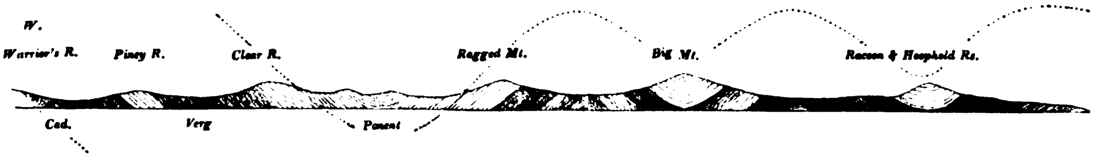


FIG. 775.—Section through Penn's Valley and East end of Kishacoquillas Valley, showing Terraced Ridges.

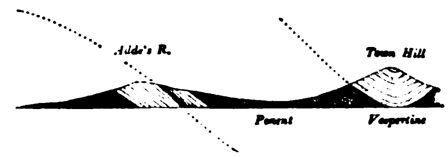
between Jack's Mountain and Bald Eagle Mountain, comprising Kishacoquillas and Penn's valleys, and the ridges protruding into them. It should have appeared at page 462, Vol. I. It illustrates well some of the prevailing laws of the Appalachian flexures, and should be consulted by the reader when perusing the Essay on the "Laws of Structure of Disturbed Zones," beginning at page 885, Vol. II. It exemplifies, too, the erosion of synclinal ridges, discussed on page 924 *et seq.*, of Vol. II.

The section here introduced (Fig. 776) illustrates the structure of the E. part of Bedford County, between the terminal knob of Town Hill and Warrior Ridge (see Vol. I., pp. 523, 527).

Fig. 776.—Section from Gap in Town Hill to Warrior Ridge, along the Rainsburg Road.—1 *inch* = 1 *mile*.



It displays three parallel nearly equidistant flexures in the Vergent strata, and exemplifies beautifully the influence of denudation in producing valleys at the summits of the waves and ridges at their troughs.



This section (Fig. 777), representing the country between Jack's Mountain and Tussey Mountain, immediately S. of the Frankstown branch of the Juniata, will assist in elucidating parts of the chapter on Stone Valley (Vol. I., p. 512). It

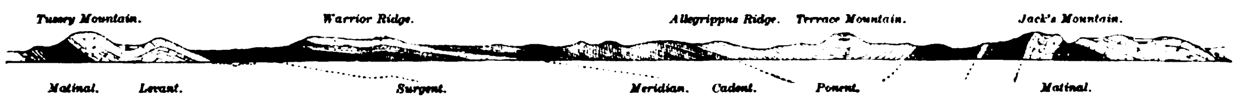


Fig. 777.—Section from Tussey Mountain, near Alexandria, to Jack's Narrows of the Juniata, 17 miles.

intersects the end of Terrace Mountain, and displays well the structure of Jack's Mountain at the river.

The annexed interesting topographical section (Fig. 778), from the Southern Anthracite basin near Tamaqua to Buck Mountain, illustrates the general structure of the Eastern Middle

Fig. 778.—Section from the neighbourhood of Tamaqua, across Locust Valley and the West ends of the Beaver Meadow and Bucks Mountain Basins.

Anthracite coal-field, and should have appeared on page 239 of Vol. I. It displays clearly the six synclinal belts into which this coal-field is subdivided by its five great anticlinal flexures, and the plateau form of the basins. The beholder is supposed to be looking N.E. from a point above the Broad Mountain.

Note.—*The allusion at page* 75 *of this Volume to the earnings of the Lehigh Coal and Navigation Company is not correct. The Report of the Managers for* 1856 *shows that in that year the earnings exceeded the expenses by rather more than* $445,000. *The paragraph crept into print through an oversight, such topics being irrelevant to the purposes of this work.*—H. D. R.

GLOSSARY.

Acephalous (Gr. *a*, without, and *cephale*, a head).—Applied to the molluscous animals, like the oyster, which have no distinct head. Most of the bivalve shells are embraced in the class Acephala.

Adit.—A horizontal tunnel penetrating from the surface into a mine, and designed as an outlet for water.

Algæ (Lat. *alga*, sea-weed).—An order of cellular aquatic plants, embracing the sea-weeds and many fresh-water species.

Alluvium (Lat. *ad*, together, and *luere*, to wash).—A deposit of materials washed together by rivers, floods, and other moving waters, upon lands not permanently submerged.

Anticlinal (Gr. *anti*, on opposite sides, and *clino*, I bend).—A term expressive of the dipping or declining from each other of two sets of strata, or two portions of one stratum, as the two slopes of a wave do.

Arenaceous (Lat. *arena*, sand).—Sandy.

Argillaceous (Lat. *argilla*, clay).—Clayey.

Auroral (Lat. *aurora*, the time just before sunrising).—The second series of the North-American Palæozoic strata. The term has been chosen to express the early morning or daybreak period of the Appalachian Palæozoic day. The Auroral limestones are called, in the New York nomenclature, the Black River and Chazy limestone and calciferous sandstone. They represent nearly the middle Cambrian or Festiniog group of Professor Sedgwick.—(See vol. ii. p. 752, and vol. v. p. 105.)

Axis (Lat. *axis*, a pole or axle-tree).—Signifies in geology the line of sharpest bending, whether convex or concave, of a stratum. The Anticlinal Axis is equivalent to the crest of a convex wave; the Synclinal Axis to the line of greatest depth in a trough or concave wave.

Azoic (Gr. *a*, without, *zoè*, life).—Applied to a group of rocks underlying the Palæozoic, and destitute of all traces of once vital organisms.

Basalt.—A common variety of the trappean rocks; usually dark green or nearly black; hard, close-grained, and sometimes regularly columnar. It is an igneous rock, composed of augite and felspar.

Basin.—A concave or trough-like form in a set of strata; sometimes applied to very wide areas, in which the strata are centrally horizontal, and rise to the surface only at the margin.

Benches.—Steps or terraces on the slope of a hill, sometimes used by miners to signify the layer in a compound seam of coal.

Bitumen (Gr. *pitus*, mineral pitch or tar).—An inflammable substance, which burns with much smoke and flame like pitch. The inflammable materials of the so-called bituminous coals are not true bitumens, but various other compounds of hydrogen and carbon.

Blackband.—A miner's term for a coaly variety of ironstone, or clay iron-ore, which contains fuel enough to calcine the ore without additional coal.

Bloom.—A large lump of malleable iron, before it is rolled or hammered into shape.

Bloomery.—A small furnace for the production of malleable iron by direct contact with charcoal or coke.

Boulders.—Large partially-rounded lumps of rock imbedded in gravel and clay, and supposed to have been rolled by water or transported by ice.

Brachiopoda (Gr. *brachys*, an arm, and *pous*, *podos*, a foot).—An order of mollusca provided with spiral arm-like organs, and for the most part enclosed in two valves or shells.

Breaker.—A mill-like structure, supplied with machinery for breaking, freeing from slate, and sorting anthracite coal at the mines.

Breast.—A miner's term to express the portion of a sloping bed of coal or other stratum, included between one horizontal gallery and another above it, or between such a gallery and the outcrop.

Breccia (Ital., a crumb or fragment).—Any rock composed of recemented angular fragments.

Bryozoa (Gr. *bryos*, moss, and *zoon*, an animal).—Minute molluscous animals congregated upon a common stock, very much as the compound polypes are, each animal residing in a separate cell. The living *sea-mats*, Flustræ, are examples of this class.

Buhr-stone.—A porous silicious rock, used for mill-stones.

Cadent (Lat. *cadens*, falling, waning).—A series or group of the Appalachian strata, metaphorically expressive of the declining of the American Palæozoic day. It is equivalent to a part of the older Devonian series of Europe.—(See vol. i. p. 107, and vol. ii. p. 755.)

Cainozoic (Gr. *kainos*, recent, and *zoè*, life).—Applied to the upper or Tertiary strata imbedding remains of recent or living forms of life.

Calamite (Lat. *calamus*, a reed).—A reed-like jointed stem, resembling the living equisetum, and found in the coal strata.

Calcareous (Lat. *calx*, *calcis*, lime).—A rock containing a sensible proportion of lime; usually in the form of the carbonate of lime; is said to be calcareous.

Cambrian.—A term applied to the oldest great series of strata embraced in the Palæozoic system of rocks. The word is derived from the classic name of *Wales*, where these deposits are largely developed.

Carboniferous (Lat. *carbo*, coal, and *fero*, I yield).—Coal-yielding or coal-bearing. Applied to the series of strata embracing the great coal-formation.

Cephalopoda (Gr. *kephalè*, head, and *pous*, *podos*, a foot).—The most highly organised class of mollusca, furnished with foot-like organs around the head. It includes the nautilus, cuttle-fish, &c.

Chert.—A rock consisting almost exclusively of silica. Buhr-stone is a porous variety of chert.

Chlorite (Gr. *chloros*, greenish).—A mineral, often in thin scales, resembling mica, and generally of a dark-green colour. It is a constituent of chlorite schist, one of the metamorphic rocks.

Cleavage.—A tendency in rocks to split in thin plates in a uniform direction, which is irrespective of lamination or original bedding.

Conformable.—Strata lying in parallel order one above another.

Crinoidea (Gr. *krinon*, lily, and *eidos*, form).—Lily-shaped. A class of fossil echinoderms supported on slender-jointed stems, and somewhat resembling a lily in outline.

Crop.—The edge of any inclined bed or stratum as it is exposed at the surface.

Cycadites.—Fossil plants allied to the living genera Cycas and Zamia.

Cypris.—A family of minute crustacean animals having two flat valves like the bivalve shells of many mollusca.

Denudation (Lat. *de*, down, and *nudus*, naked).—The cutting away of upper strata, and the laying bare or naked of underlying ones.

Devonian.—A series of rocks intermediate in age between the Silurian and the Carboniferous. Named from Devonshire, where they were first recognised as an independent group.

Diluvium, Diluvial (Lat. *dis*, asunder, and *luere*, to wash).—Fragmentary rocky matter, which has been violently strewn by water.

Dip.—The downward inclination or angle of downward slope of strata.

Dolomite (named after M. Dolomieu).—Crystalline magnesian limestone.

Dyke (an old Saxon word for a wall or fence).—A wall-like vein or intrusion of any igneous rock filling a fissure in another formation.

Echinodermata (Gr. *echinos*, urchin, and *derma*, a skin.)—A class of radiated animals covered with a firm crustaceous integument. It embraces the star-fishes and sea-urchins.

Encrinites (Gr. *krinon*, a lily).—A fossil radiate animal, having a lily-shaped body attached to a long jointed stalk. Encrinal limestone or marble is a limestone largely composed of the joints and fragments of these fossils.

Entomostraca (Gr. *entomon*, insect, and *ostracon*, shell).—Shelled insects, crustacean animals, so named in contradistinction to the mallocostraca, or soft-bodied.

Eocene (Gr. *êos*, dawn, and *kainos*, recent).—A term proposed by Sir Charles Lyell, and now generally used for the earliest-formed group of the Tertiary strata, from its showing the dawn of the recent or living types of life. Among its fossils, from three to six per cent belong to shell-fish now living.

Escarpment (Fr. *escarper*, to cut steep).—The steep slope or abrupt face of a hill.

Facies (Lat.)—A term of recent introduction, expressing a prevailing likeness or general aspect among organic remains, &c.

Fault.—Any dislocation in strata or a fissure accompanied by displacement.

Felspathic.—Composed of felspar; a mineral consisting of silica, combined with alumina and soda or potash, all in definite proportions.

Ferruginous (Lat. *ferrum*, iron).—Impregnated with oxide of iron.

Fireclay.—A clay destitute of alkaline earth, or other ingredients tending to melt it in a hot fire, and therefore adapted to resist intense heat.

Foliation.—The crystalline lamination of metamorphic strata.

Formation.—A stratum, or group of strata, insulated from others by its distinctive organic remains, definite composition, and stratigraphical position; it should be restricted to signify the product of one formative period or formative process.

Fossil (Lat. *fossus*, dug up).—Any relic of plant or animal imbedded in the earth's strata. It embraces not only buried organisms which have been petrified, but casts, moulds, and imprints of all such.

Fucoid (*fucus*, sea-weed, and *eidos*, form).—Fucus-like impressions met with abundantly in the older strata.

Gangway.—A level or nearly level alley, used as a roadway in a mine. Those horizontal alleys not used as thoroughfares are simply called levels.

Gap.—A term used in Pennsylvania for any deep sharp notch in a mountain-ridge. Water-gaps are those notches or passes which penetrate to the bases of the mountains, and give passage to the larger streams.

Gasteropoda (Gr. *gaster*, belly, and *pous*, foot).—Molluscous animals, which, like the snail, possess a distinct head, and move by a muscular foot attached to the lower part of the body.

Geology (Gr. *gê*, the earth, and *logos*, doctrine).—The science of the composition, structure, history, and forces discernible in our earth.

Gneiss.—A stratified, granitoid rock, composed of crystalline minerals, but displaying a regular bedding or stratification.

Gossan.—Any loose surface vein-stone containing traces of the characteristic ores of a mineral lode; usually hydrated peroxide of iron derived from the sulphuret of iron.

Granite.—A crystalline rock, the typical form of which is a triple aggregate of felspar, quartz, and mica.

Greenstone.—An ancient igneous rock, composed of felspar and hornblende.

Gypsum.—Plaster-of-Paris, or sulphate of lime in a crystalline form.

Hæmatite (Gr. *haima*, blood).—Red oxide of iron. Loosely applied in the United States to the hydrated brown oxide of iron.

Hornblende.—A dark-green or almost black mineral, heavier than quartz or felspar, but not so hard, and recognised by its peculiar bitter odour when breathed upon. It is a constituent of the granitic and trappean rocks.

Hydrogenous.—Containing hydrogen.

Hypozoic (Gr. *hypo*, under, and *zoê*, life).—A term for the gneissic and other rocks which lie beneath the fossiliferous strata. The term is conveniently restricted to the more ancient metamorphic rocks which underlie the Azoic or semi-metamorphic strata, which are also destitute of fossils, but which in many countries immediately support the Palæozoic, or those containing organic remains.

Igneous (Lat. *ignis*, fire).—A term applied to those rocks which have obviously been in a melted state from intense heat.

Jurassic.—The name of a group of secondary strata largely developed in the Jura Mountains, of later formation than the Triassic, and of earlier origin than the Cretaceous or Chalk deposits. It is synonymous with the Oolitic system of England.

Lacustrine (Lat. *lacus*, a lake).—Belonging to a lake.

Laminated.—Dividing into thin layers or leaves.

Lepidodendron (Gr. *lepis*, a scale, and *dendron*, a tree).—Fossil plants so named from the scale-like appearance of their leaf-scars.

Levant (Lat. *levare*, to lift; Fr. *lever*, to rise).—Rising: a term applied to the fourth series of the Appalachian Palæozoic strata, called in New York the Medina group, and of equivalent age to the May Hill Sandstone of England. It signifies metaphorically the sunrise period of the Palæozoic day.—(See vol. i. p. 105, and vol. ii. p. 753.)

Lignite (Lat. *lignum*, wood).—Wood-coal, or fossil wood, somewhat resembling coal.

Littoral (Lat. *littus*, the shore).—Of shore origin, in contradistinction to production in deep water.

Marl.—A limy or calcareous clay or shale.

Matinal (Lat. *matutinus*, morning).—The title employed in this work for the third series of the Appalachian Palæozoic strata, and intended to express the morning period of the Palæozoic day. The New York titles of the Matinal strata are Trenton Limestone and Hudson River Slate Group; the nearest British equivalents are the Llandilo and Bala rocks of the Cambrian series.—(See vol. i. p. 105, and vol. ii. p. 752.)

Meridian (Lat. *meridies*, mid-day).—Noonday; in allusion to the mid-day date of the strata to which it is applied. A term appropriated to certain middle formations of the Appalachian Palæozoic system, which are called in the New York Survey the Oriskany Sandstone, and which appear to be on the horizon of the lower Ludlow rocks of England.—(See vol. i. p. 107, and vol. ii. p. 755.)

Mesozoic (Gr. *mesos*, middle, *zoê*, life).—A great division of the fossiliferous strata, characterised by the middle forms of life.—(See vol. ii. p. 759.)

Metamorphism.—The transformation of strata by heat or chemical action. Metamorphic strata are sedimentary deposits which have been hardened and made crystalline without losing their laminated structure. Gneiss and mica-schist are examples.

Miocene (Gr. *meion*, less, *kainos*, recent).—A name proposed by Sir Charles Lyell for the middle Tertiary strata, on the ground of their containing a less proportion of recent (usually from 18 to 24 per cent) than of extinct shells.

Mollusca.—Literally, soft animals; a division of the Invertebrata devoid of bones, but for the most part encased in shells.

New Red Sandstone.—The lowest Mesozoic group, or Trias.

Old Red Sandstone.—A formation of the Devonian series, named from its lying below the Coal-formation, in contradistinction to the New Red, which overlies it.

Oolite (Gr. *oon*, egg, *lithos*, stone).—Limestone, consisting chiefly of small, spherical granules, like the egg or roe of a fish. The Oolitic structure may occur in limestones of all ages, but abounding chiefly in those of the Middle Mesozoic period, all the formations of that epoch are called Oolitic. The synonym Jurassic is getting to be more used.

Orthocerata (Gr. *orthos*, straight, *keras*, horn).—A family of the cephalopodous class of molluscs. They are straight, horn-like shells.

Palæontology (Gr. *palaios*, ancient, *onta*, beings, *logos*, doctrine).—The science of ancient or extinct animal and vegetable fossil remains.

Palæozoic (Gr. *palaios*, ancient, *zoê*, life).—The most ancient or lowest great division of the fossiliferous strata.

Pleistocene (Gr. *pleistos*, most, *kainos*, recent).—A term applied to those strata next older than those now in process of formation; the word imports that the organic remains belong almost wholly to species now in existence. Some geologists use it as synonymous with Post-tertiary or Quarternary; others, with more propriety, make it a division of the Cainozoic period.

Pliocene (Gr. *pleion*, more, *kainos*, recent).—A term proposed by Sir C. Lyell, and now much used, for an upper Tertiary group of strata, implying that they contain more of recent than extinct organic remains.

Polyzoa or **Bryozoa.**—A class of mollusca embracing animals enclosed in cells organically associated, having a receiving and discharging orifice placed near together, and a mouth surrounded by ciliated tentacles.

Ponent (Lat. *ponere*, to set).—Setting: the name of the twelfth series of the Appalachian strata, nearly equivalent in age to the Old Red Sandstone of Great Britain. It expresses metaphorically the sunset period of the Appalachian Palæozoic day.—(See vol. i. p. 108, and vol. ii. p. 756.)

Porphyry (Gr. *porphyreos*, purple).—Any igneous rock, of whatever colour, composed of a pasty mass imbedding distinct crystals.

Post-meridian (Lat. *post*, after, *meridies*, noon).—Afternoon: a term applied to the series of the Appalachian strata, which in the New York Survey has been called the Upper Helderberg or Corniferous limestone. The word refers to the part of the Appalachian day at which the group was formed.—(See vol. i. p. 107, and vol. ii. p. 755.)

Pre-meridian (Lat. *præ*, before, *meridies*, noon).—Forenoon: one of the Appalachian Palæozoic series of strata, named from the relative date of its origin. It is a synonym for the Lower Helderberg limestones of New York.—(See vol. i. p. 107, and vol. ii. p. 754.)

PRIMAL (Lat. *primus*; O. E. *prime*, the earliest dawn).—The earliest Palæozoic series of the Appalachian Basin, named from originating in the dawn of the great Palæozoic day of North America.—(See vol. i. p. 104, and vol. ii. p. 751.)

PRIMARY, PRIMITIVE.—Formerly applied to all the most ancient crystalline non-fossiliferous rocks, but fast becoming obsolete. The term Primary fossiliferous strata is sometimes used as synonymous with Palæozoic.

PYRITES (Gr. *pyr*, fire, *ites* for *lithos*, stone).—The name given to the combinations of iron, copper, and certain other metals, with sulphur.

QUAQUAVERSAL.—Dipping in all directions from a common centre.

SCALENT (*scala*, a ladder).—Climbing: applied in the nomenclature of the Appalachian strata to a series of rocks, equivalents of the Onandaga salt and water-lime groups of New York, produced in the high morning period of the American Palæozoic day.—(See vol. i. p. 106, and vol. ii. p. 754.)

SCHIST (Gr. *schisma*, division).—Applied to rocks of a foliated structure which split in thin irregular plates, and not by parallel cleavage.

SCHORL.—Black tourmaline.

SCHUTE.—An inclined trough for the conveyance of mineral matter from one elevation to a lower; employed at landings for discharging coal into boats and railroad cars. The name is also applied to narrow sloping galleries within the coal-mines, down which the coal is pushed to the gangways.

SEAM.—Strictly a line or plane of separation, but applied in geology to thin regular layers or subordinate strata, especially to beds of coal, for which it is a preferable term to the word vein, in common use in Pennsylvania.

SECONDARY STRATA.—Applied originally to all fossiliferous strata above the Primary or non-fossiliferous, and below the Tertiary. If used at all, it should be restricted to signify Mesozoic.

SECTION (Lat. *sectus*, cut through). — An actual or ideal exposure of any part of the earth's crust, showing the strata edgewise, as if they were laid open by a cut.

SERAL (Lat. *sero*, late; Fr. *soir*, night).—Late: a synonym for the coal-formation, expressing the period of the nightfall or late twilight of the Appalachian Palæozoic day.—(See vol. i. p. 109, and vol. ii. p. 758.)

SERIES.—A natural group of formations distinguished from all others by characteristic organic remains. Less comprehensive than the word system, which is reserved for the greater divisions—the Palæozoic, &c.

SHALE (Ger. *schalen*, to peel or shell off).—Applied to the clay-derived or argillaceous rocks which split or peel off in thin laminæ or scales. It differs from slate in signifying an irregular splintery cleavage—slate expressing a more regular leaf-like lamination.

SILICIOUS (Lat. *silex*, flint). — Applied to rocks containing silex or quartz.

SLATE.—A term restricted to those argillaceous rocks which possess a regular cleavage, or nearly parallel lamination.

SLOPE.—In coal-mining, means a slanting pit or shaft, descending in the plane of a coal-bed, and provided with a double railway-track, stationary steam-power, and pumping apparatus for winding up the coal and pumping the water from the mine.

SPLINT or SPLENT COAL.—A Scotch name for a firm variety of bituminous coal which breaks in elongated slabs.

STRATUM—plural, STRATA (Lat. *stratum*, strewn or spread out).—Any layer or group of layers of sedimentary matter. Unstratified rocks are such as exhibit no indications of having been formed in layers.

STRIKE.—The direction or trend of any rock traced horizontally.

SUMP.—A miner's term for a shallow pit or well at the bottom of a mine-shaft or slope, into which the water of the mine is made to drain, and from which it is lifted by pumping to the surface.

SURGENT (Lat. *surgere*, to rise).—Rising: the fifth series of the Appalachian strata, synonymous with the Clinton group of New York, and partially equivalent in age to the Silurian Wenlock formation of England. The term has a metaphorical allusion to the period succeeding the sunrise, or that of the ascending day.—(See vol. i. p. 106, and vol. ii. p. 753.)

SYNCLINAL (Gr. *syn*, together, and *clino*, I bend).—A term significant of a trough-like structure, or the dipping towards each other of two sets of strata.

TERTIARY.—The third or upper great division of the stratified rocks. Still much in use, though the synonymous term Cainozoic is preferable.

TRAP, or TRAPPEAN (Swed. *trappa*, a stair).—A name applied to certain igneous or volcanic rocks, such as tabular greenstone and basalt, which tend to assume a stair-like outline. It includes all igneous rocks, not granitic on the one hand, nor strictly volcanic on the other.

UMBRAL (Lat. *umbra*, a shade—dusk).—Shady: the name applied, in the nomenclature employed in this work, to the fourteenth series of the Appalachian strata, or that which corresponds in period with the carboniferous limestone of Europe; it expresses, metaphorically, the twilight or dusk of the Appalachian Palæozoic day.—(See vol. i. pp. 108, and vol. ii. p. 757.)

VEIN (Lat. *vena*).—Mineral or metallic matter, filling a rent or fissure in any rocky mass. The term is not applicable to a sedimentary bed or stratum, however thin.

VERGENT (Lat. *vergere*, to decline, to sink).—Declining: a series of the Appalachian Palæozoic strata equivalent to the Chemung group of New York, and of the age of the middle Devonian rocks of Europe. The term expresses, metaphorically, the descending day or period before sunset.—(See vol. i. p. 108, and vol. ii. p. 756.)

VESICULAR (Lat. *vesicula*, a little bladder).—Applicable to rocks containing minute bladder-like cavities.

VESPERTINE (Lat. *vespertinus*).—Evening: the thirteenth series of the Appalachian strata, equivalent to the lowest carboniferous group of Europe. The word expresses the evening of the American Palæozoic day.

VOLCANIC (Lat. *vulcanus*).—Igneous action at the surface of the earth, in contradistinction to plutonic or igneous action deep in the interior. The phrase is generally employed for all igneous products not granitic or trappean.

WINZE.—A schute, or sloping passage extending from one level to another in a lead or copper mine.

ZOOPHYTES or ZOOPHYTA.—Polypes; animals of a radiate structure, a gelatinous or fleshy substance provided with a crown of tentacles around the entrance to the stomach. The class embraces corals, actiniæ, &c.

INDEX.

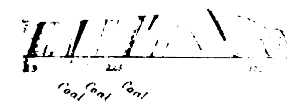
THE END.

PRINTED BY WILLIAM BLACKWOOD AND SONS, EDINBURGH.

ERRATA IN VOL. II.

Page 7, line 24, after *Part II. of*, read *the lower carboniferous strata, their, &c.*
„ 14, line 42, erase *Levant.*
„ 86, line 39, for *Mills* read *Milnes.*
„ 110, line 33, for 600 read 575.
„ 110, line 35, for 100 read 70.
„ 110, line 38, for 2 read 7.
„ 110, line 39, for 4 read 5.
„ 113, line 16, for 400 read 55, and for 450 read 470.
„ 113, line 19, for 303 read 635.
„ 153, line 20, before *White-ash Coal* insert *Anderson.*
„ 171, line 22, for 169 read 134.
„ 171, line 26, for 85 read 65.
„ 172, line 14, for 200 read 187.
„ 175, line 32, for *Crescentville* read *Cressonville.*
„ 177, line 33, for *Anderson* read *Kear*, and for *Kear* read *Anderson.*
„ 185, title of woodcut, for *Hebbard's* read *Ebert's.*
„ 193, line 29, for *Bear* read *Lick.*
„ 202, line 25, for *Old Colliery Gap* read *Old Gap Colliery.*
„ 207, last paragraph, for 180 read 122.
„ 211, line 23, after *Westward*, read as a heading, *Of the north-western branch of the Mine Hill Basin.*
„ 250, under Jeanesville, for 2 *feet* 3 *inches is coal*, read 2 *feet* 3 *inches is slate.*
„ 265, line 18, after *Big Mine* read *Run.*
„ 348, title of woodcut, for *looking N.E.*, read *looking S.W.*

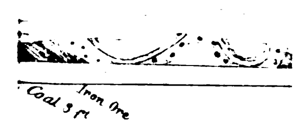
B

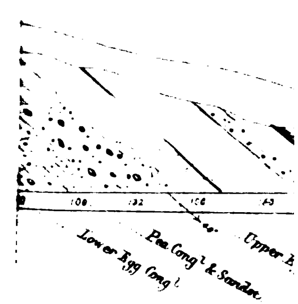

Coal
Coal
Coal

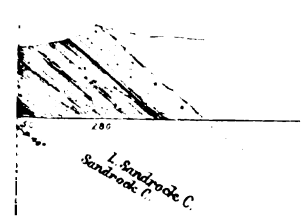
F

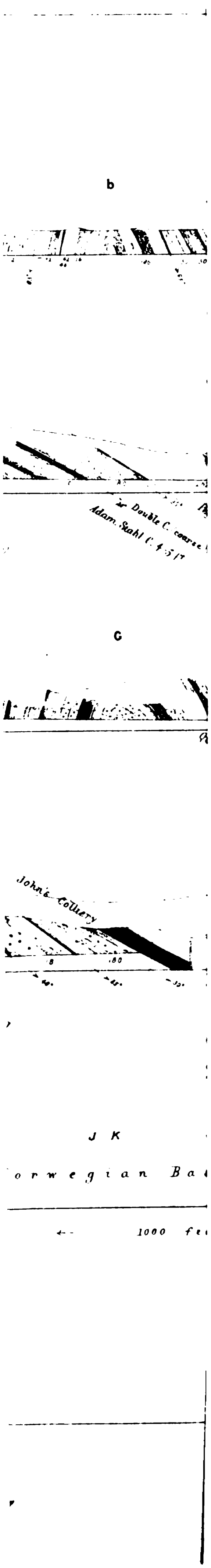

Coal
Coal
Coal

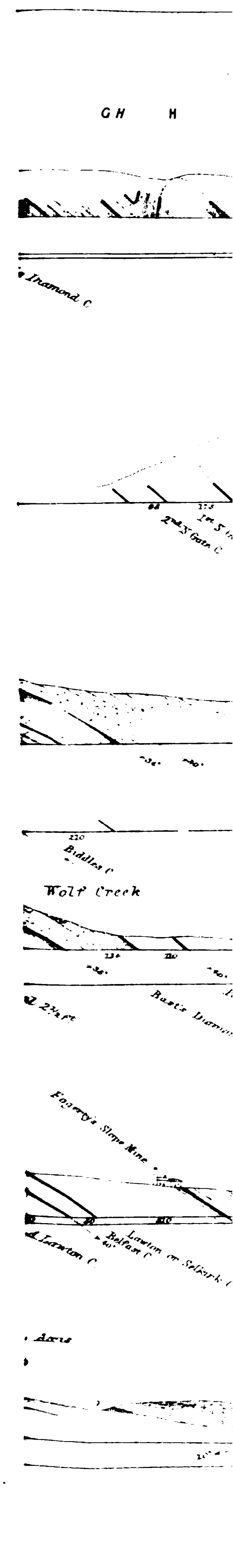
F

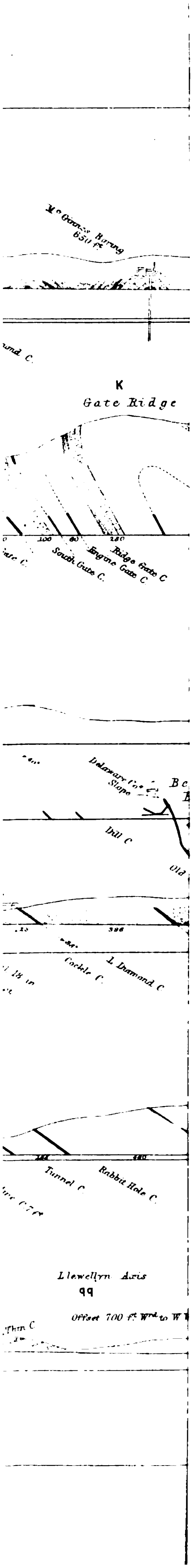

Coal 3 ft
Iron Ore


Upper
Pea Cong' & Sandst
Lower Egg Cong'

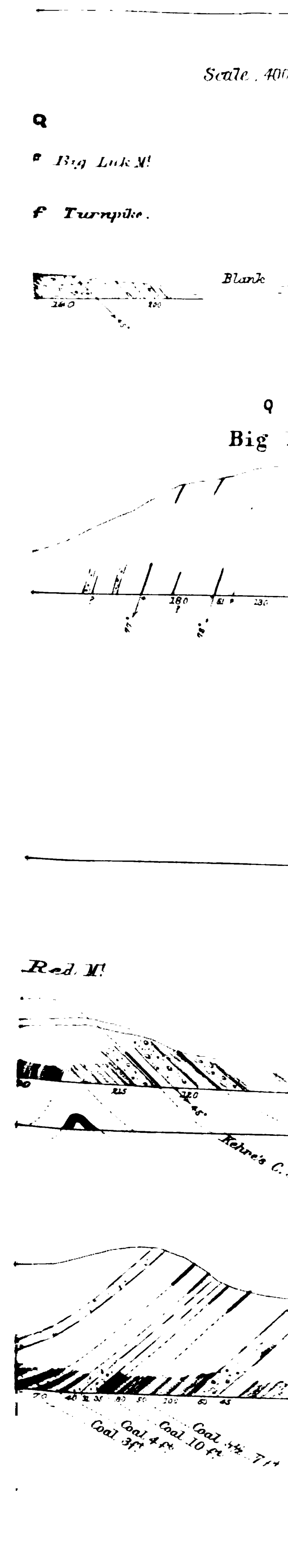

L. Sandrock C.
Sandrock C.


b
Double C. coarse
Adam Stahl C.
c
John's Colliery
J K
orwegian Ba
1000 fe


G H
H
Wolf Creek
Fogarty's Slope Mine



K
Gate Ridge
South Gate C.
Engine Gate C
Ridge Gate C
Dill C
Cockle C
L. Diamond C
Tunnel C
Rabbit Hole C.
Llewellyn Axis
99



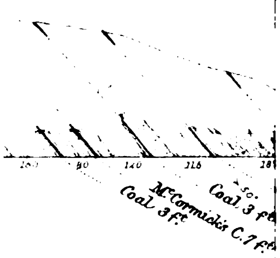
Scale . 400
Q
Big Lick M!
f Turnpike.
Blank
Q
Big
Red M!
Coal 3ft
Coal 4 ft
Coal 10 ft
Coal

1 in.

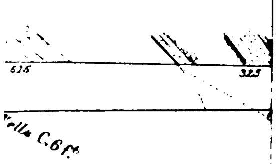
R.R. at Turnpike

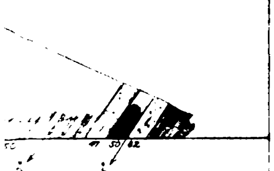
Blan

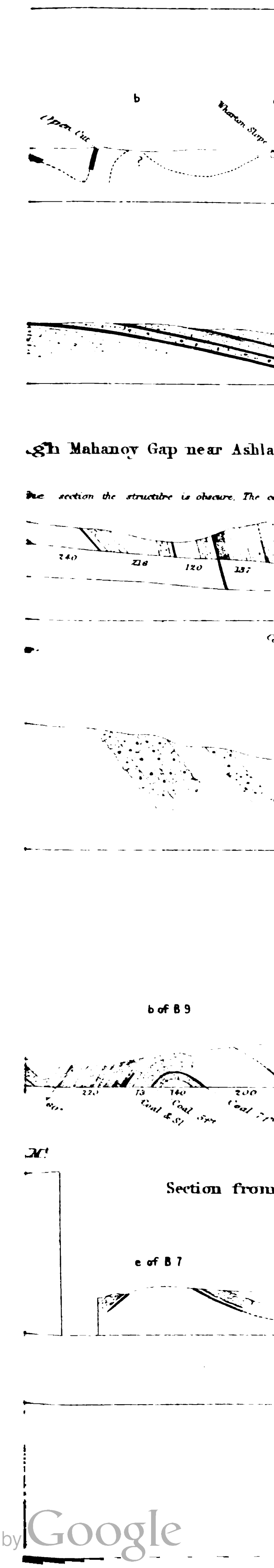
c. Mt. looking E.

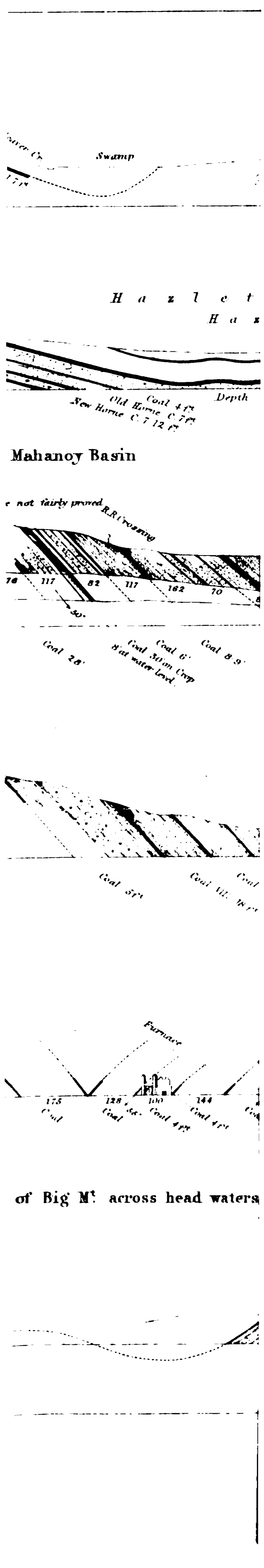


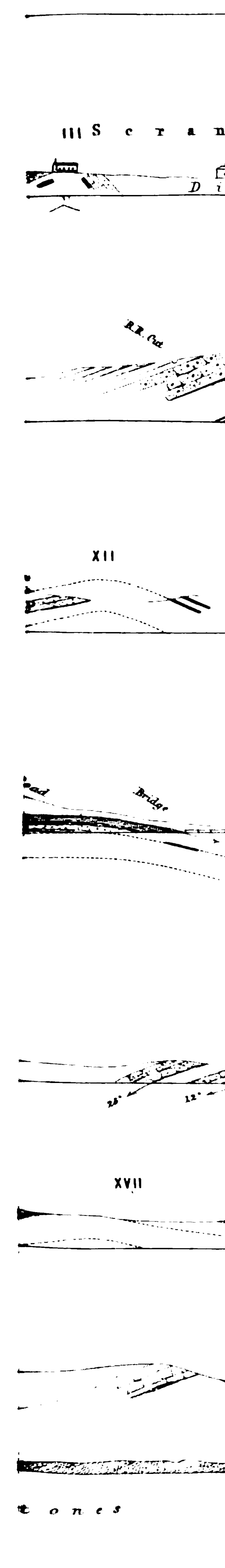
Section of S]

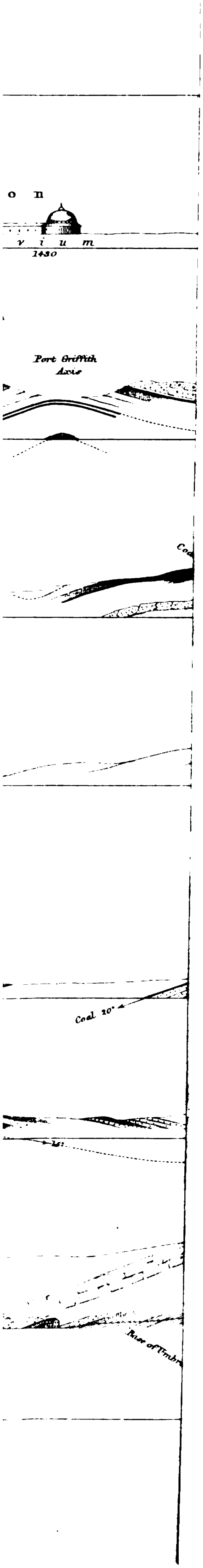




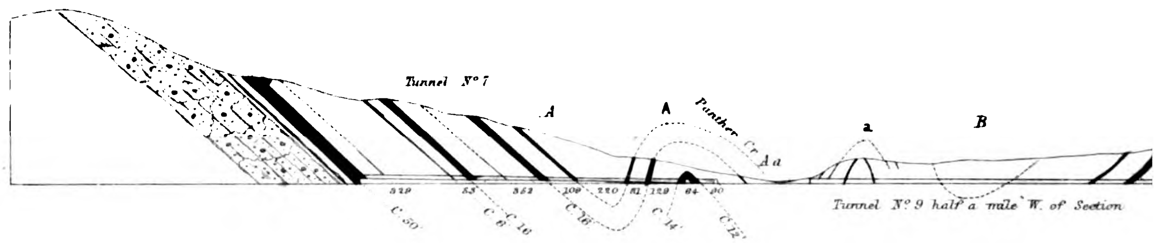

b
c
Open Cut
Wharton Slope
gh Mahanoy Gap near Ashlar
section the structure is obscure. The co
240
218
120
237
b of B 9
220
200
Section from
e of B 7


Swamp
H a z l e t
H a z
Coal 4 ft
Old Horne C. 7 ft
New Horne C. 7 12 ft
Depth
Mahanoy Basin
not fairly proved
R.R. Crossing
76
117
82
117
162
70
Coal 28'
Coal 30' on Crop
8' at water level
Coal 6'
Coal 8.9'
Coal 5 ft
Furnace
175
128
100
144
Coal
Coal 4 ft
of Big Mt. across head waters

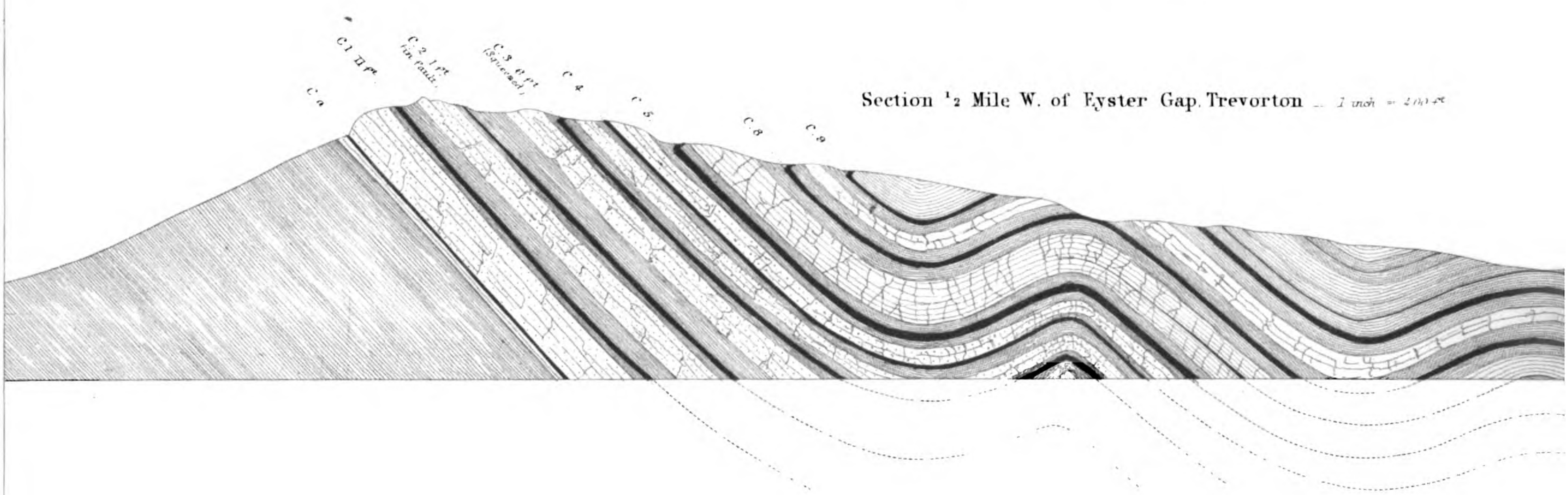

III S c r a n
R.R. Cut
XII
Bridge
XVII
t o n e s


o n
v i u m
1430
Port Griffith
Axis
Coal 20°

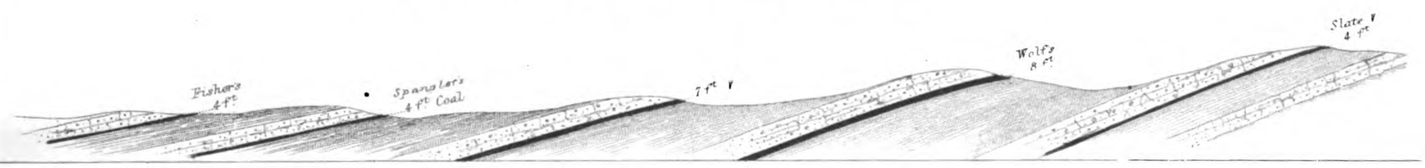
Section across the Basin at the Lehigh Summit Mines - *looking E.* — *1 inch = 800 ft*



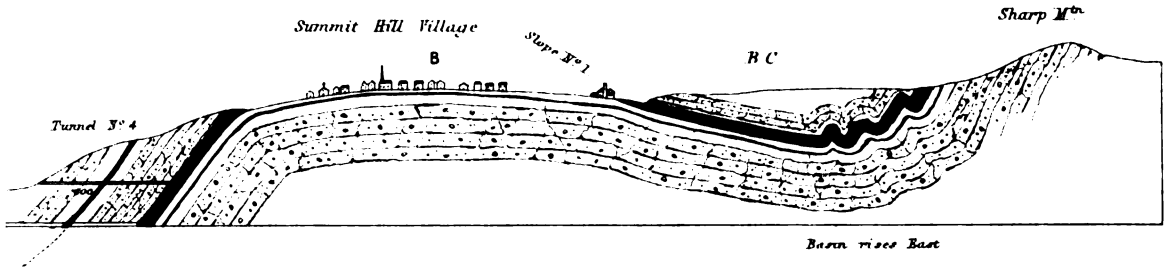
Section ½ Mile W. of Eyster Gap. Trevorton — *1 inch = 200 ft*

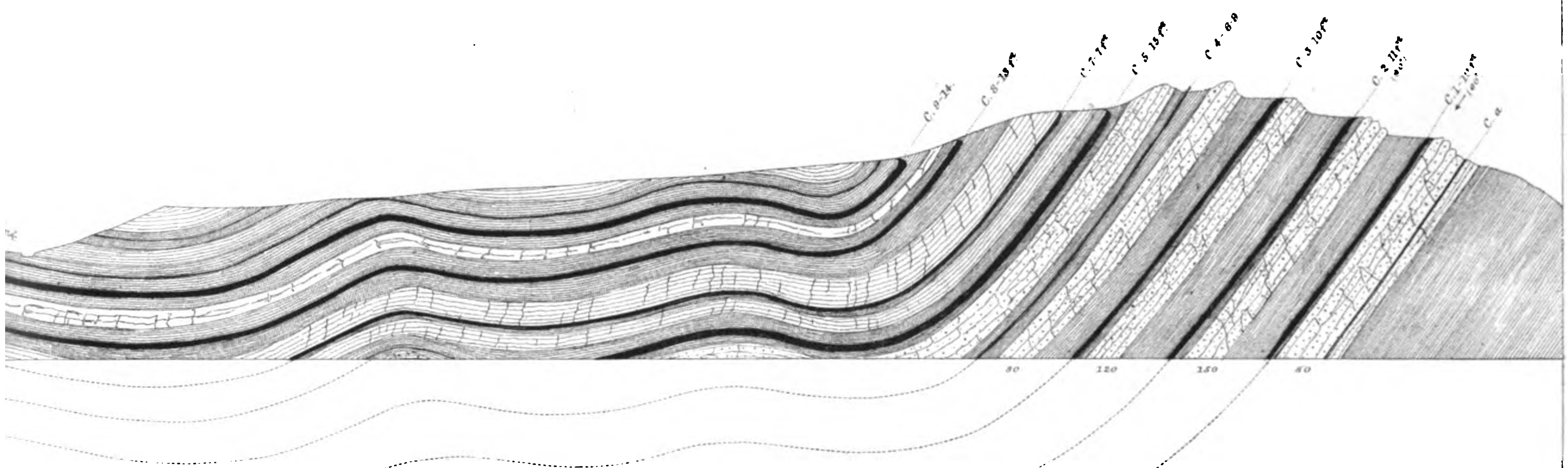


Longitudinal profile of Little Lick Mt. - *foreshortened*

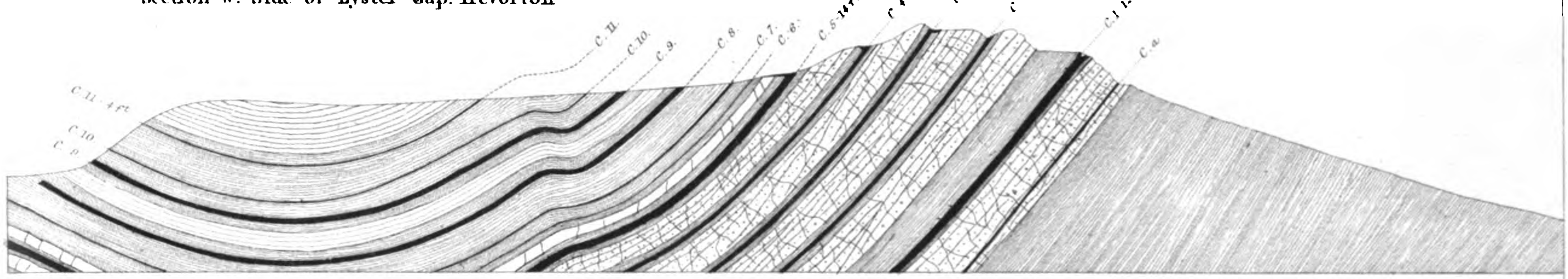


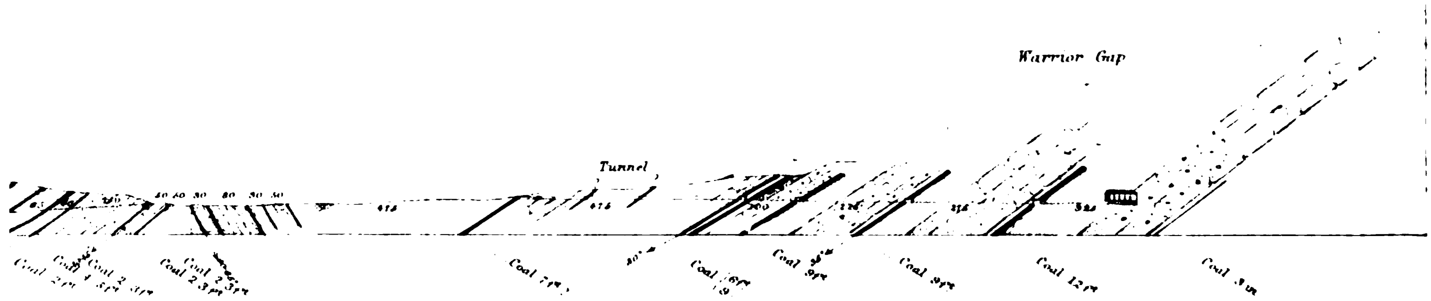
Section from Susquehanna R. to Warrior Path Gap - *looking E* — *1 inch = 200 ft*



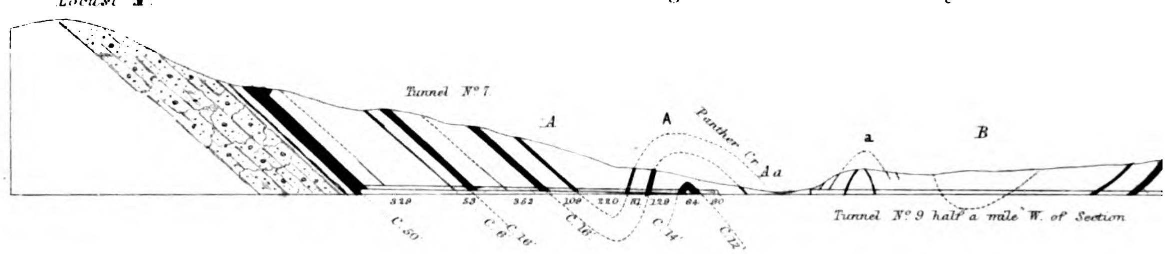


Section W. Side of Eyster Gap. Trevorton

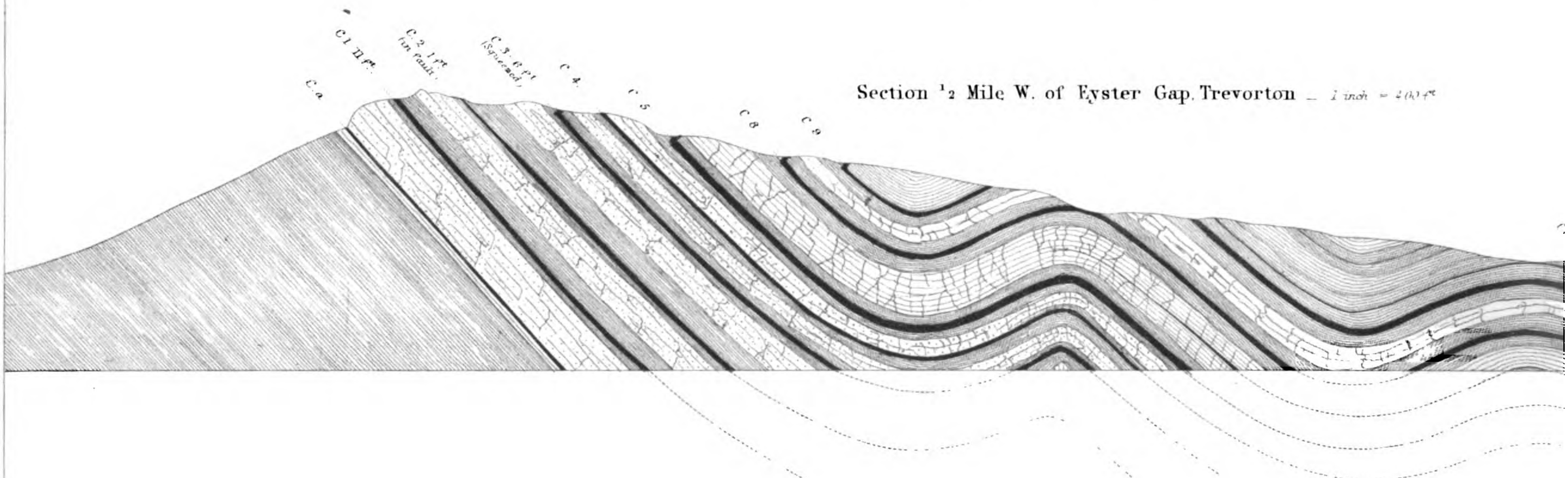




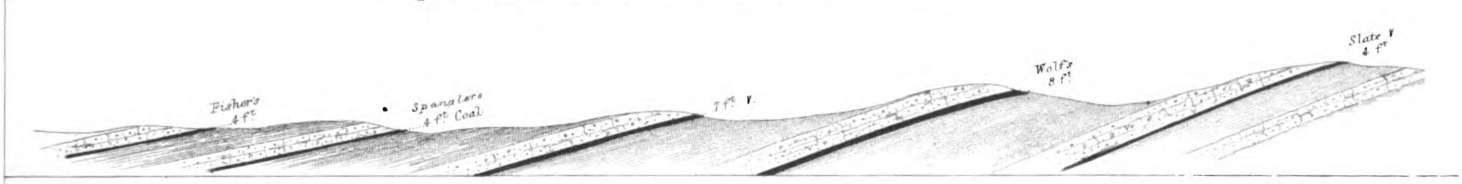
Section across the Basin at the Lehigh Summit Mines - *looking E.*



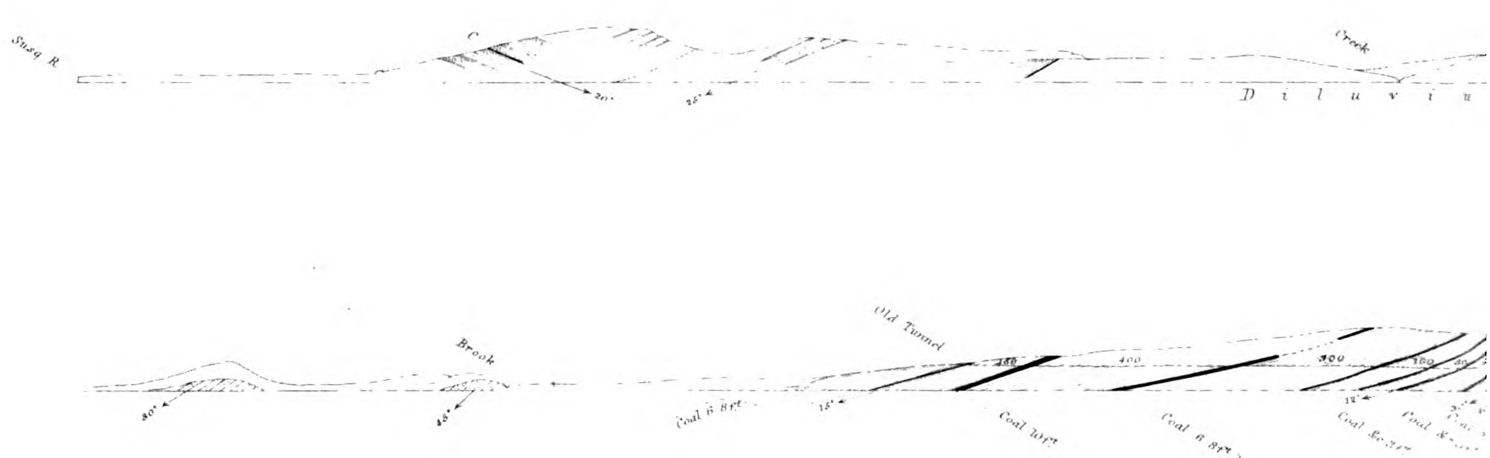
Section ½ Mile W. of Eyster Gap. Trevorton

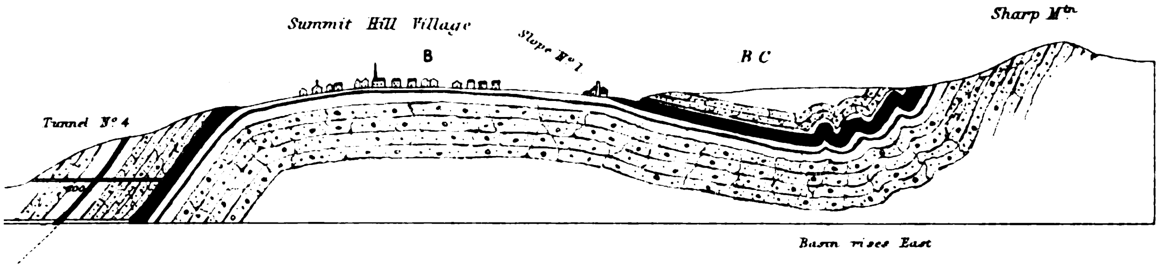


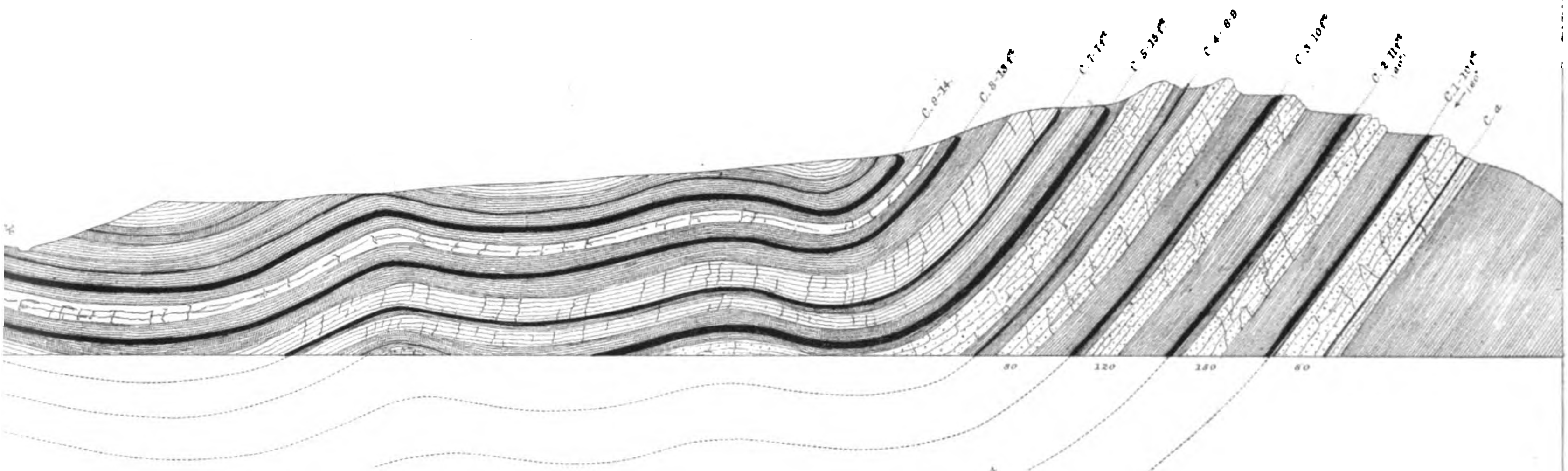
Longitudinal profile of Little Lick Mt. *foreshortened.*



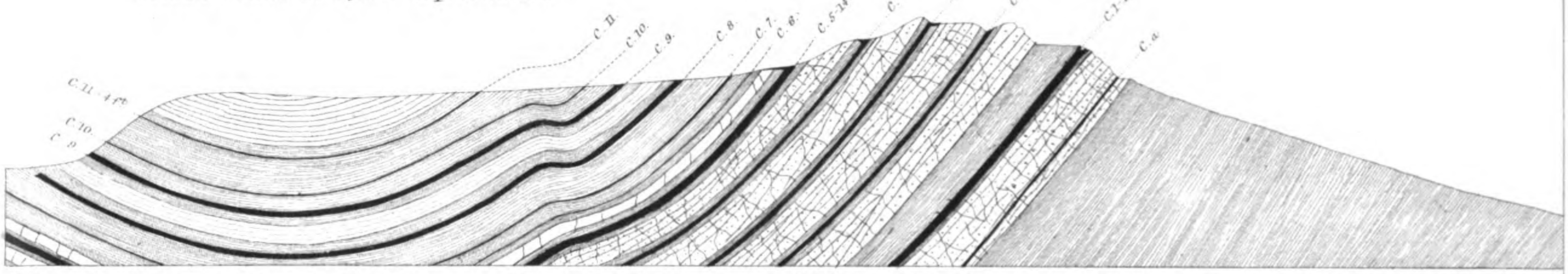
Section from Susquehanna R. to Warrior Path Gap - *looking E.*

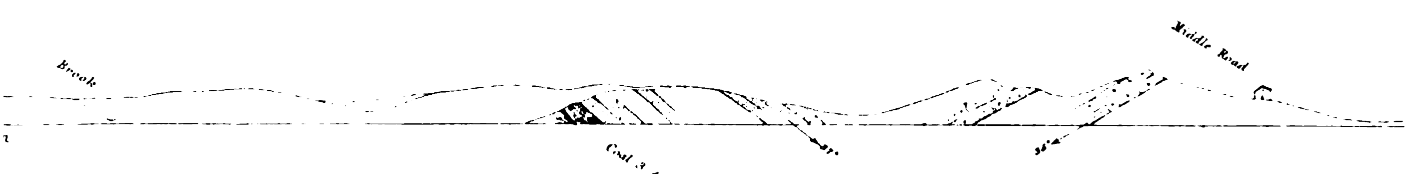


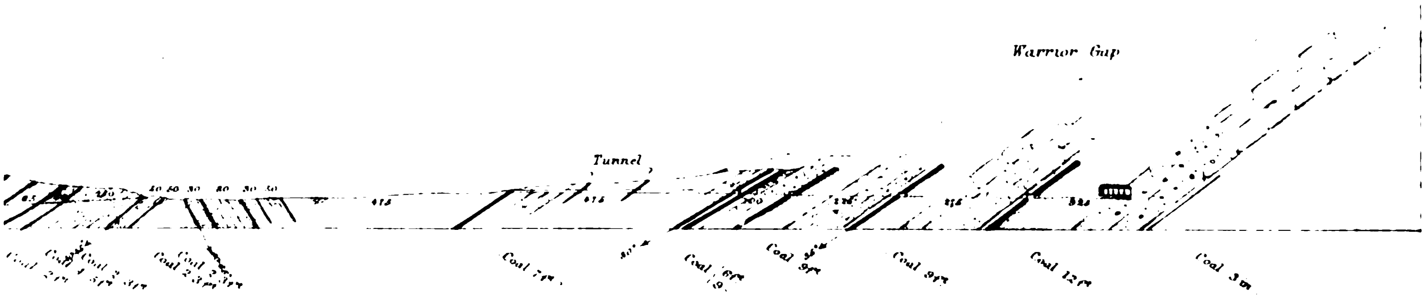


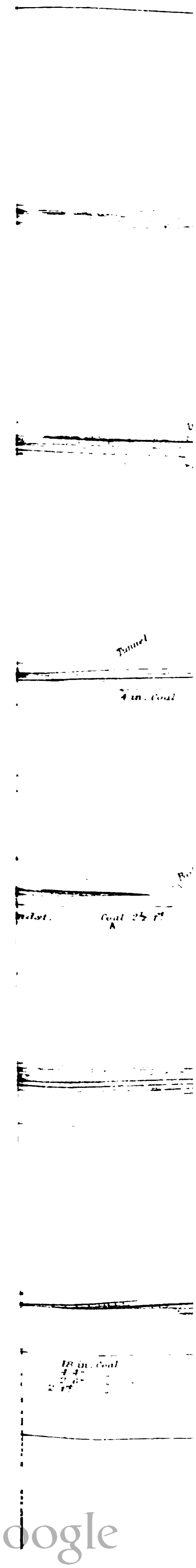


Section W. Side of Eyster Gap. Trevorton

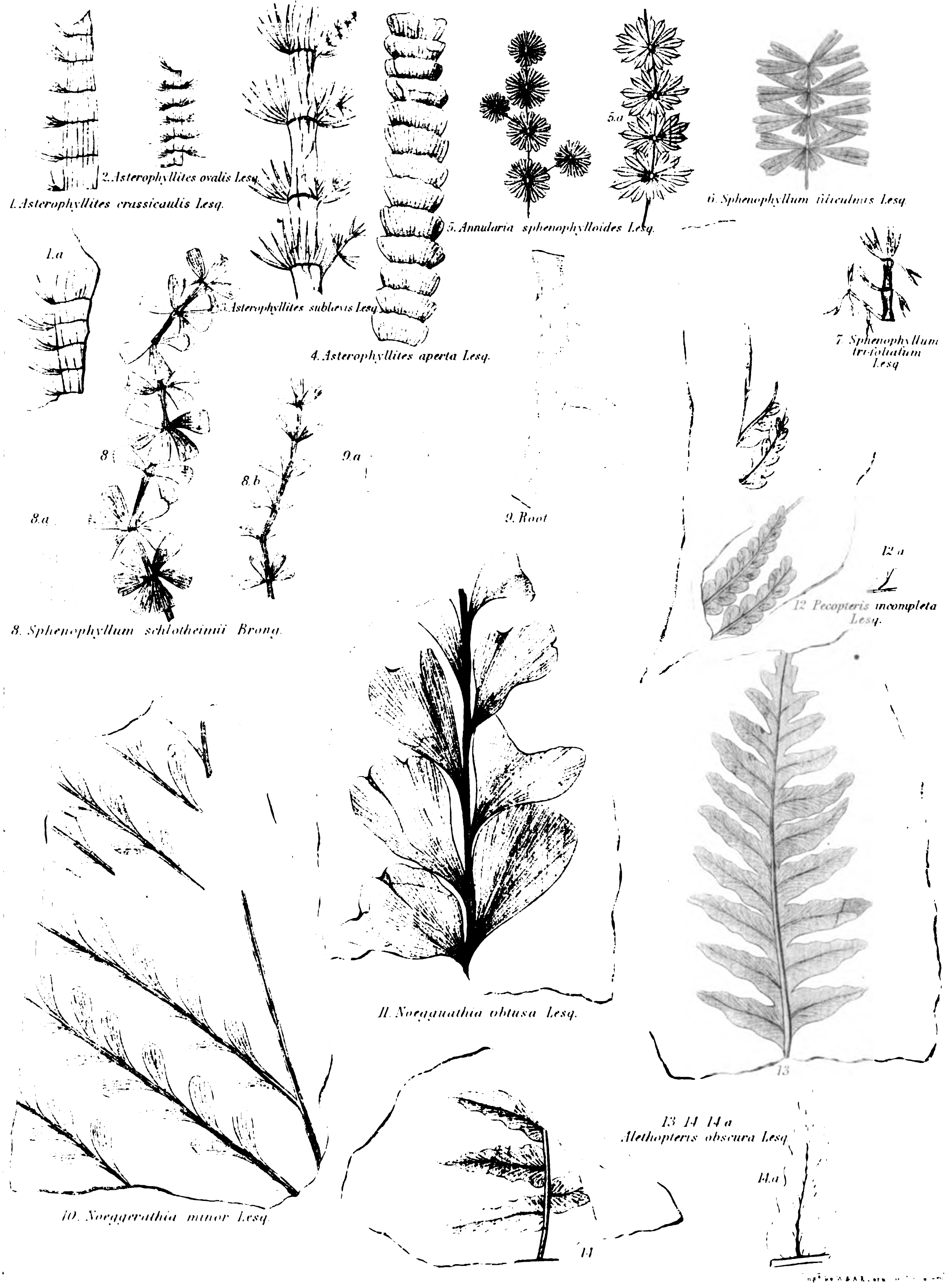




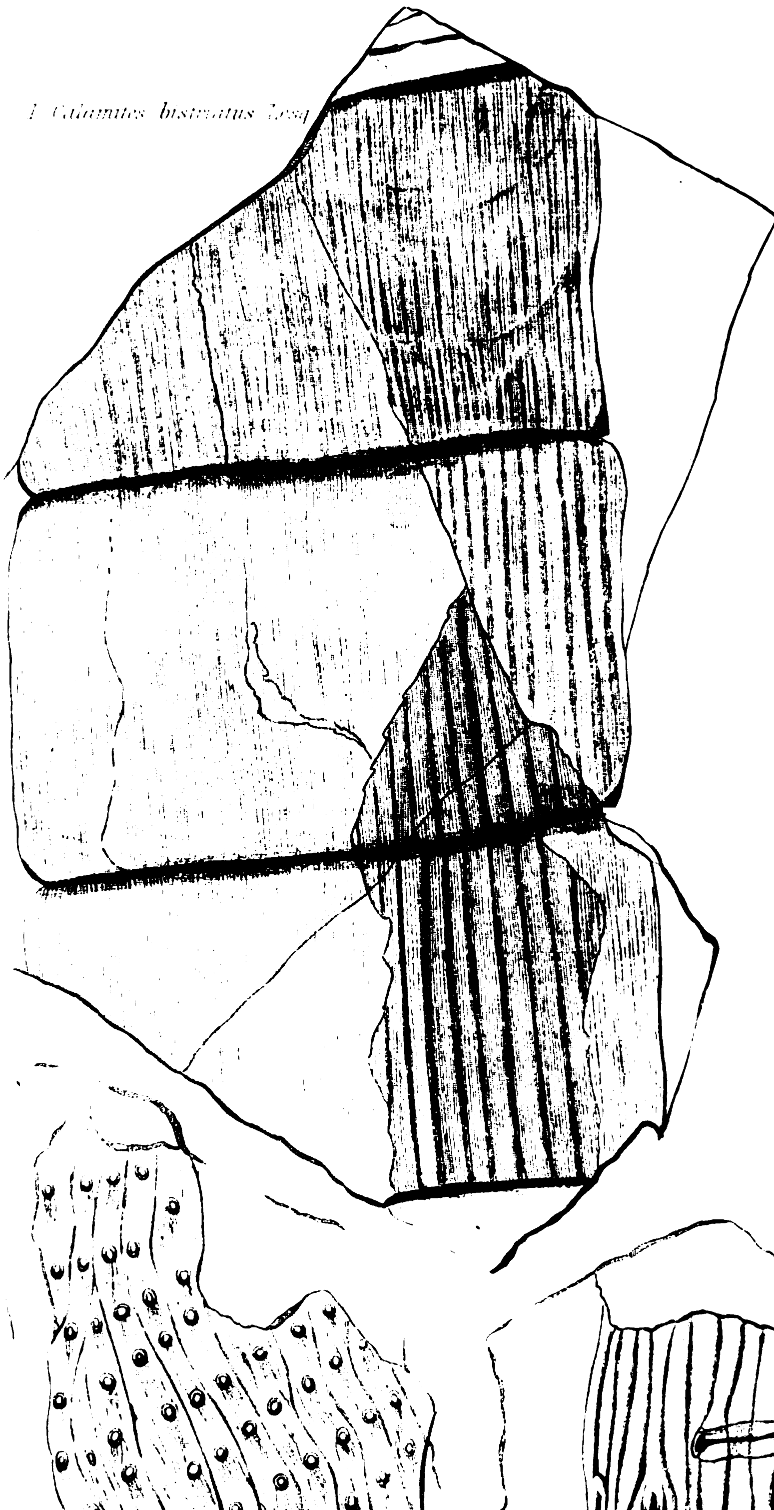



Tunnel
18 in. Coal

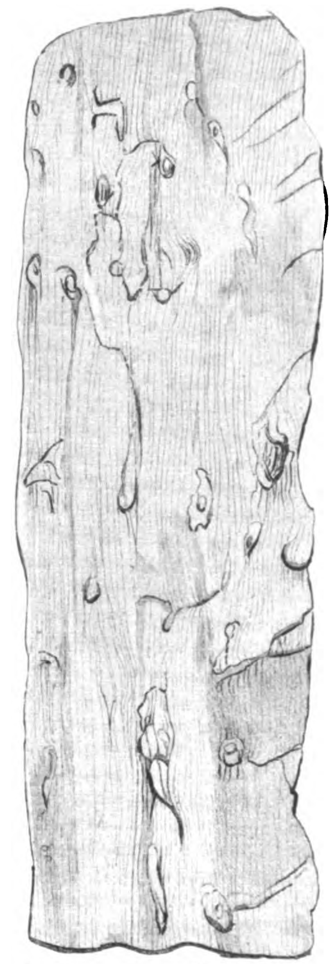

Swissvale
Johnstown
Tiley's Mines
Lilly's
Coal 4 ft 4 in.



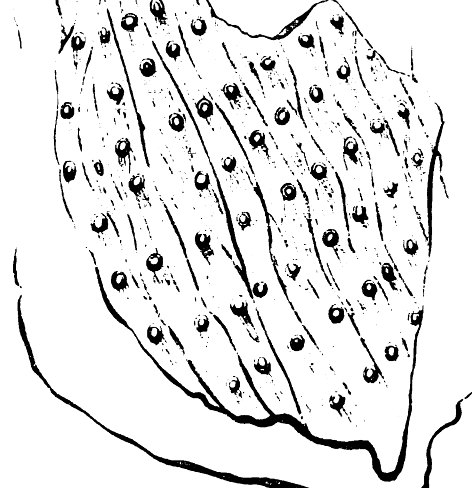
FOSSILS OF COAL FORMATION.



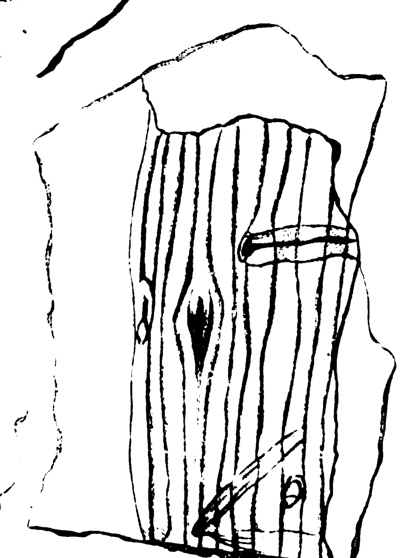
1 Calamites bistriatus Lesq



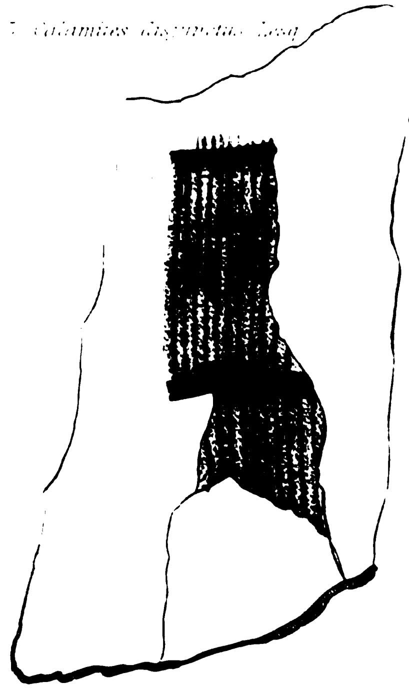
2 Stigmaria radicans Lesq



3 Stigmaria costata Lesq



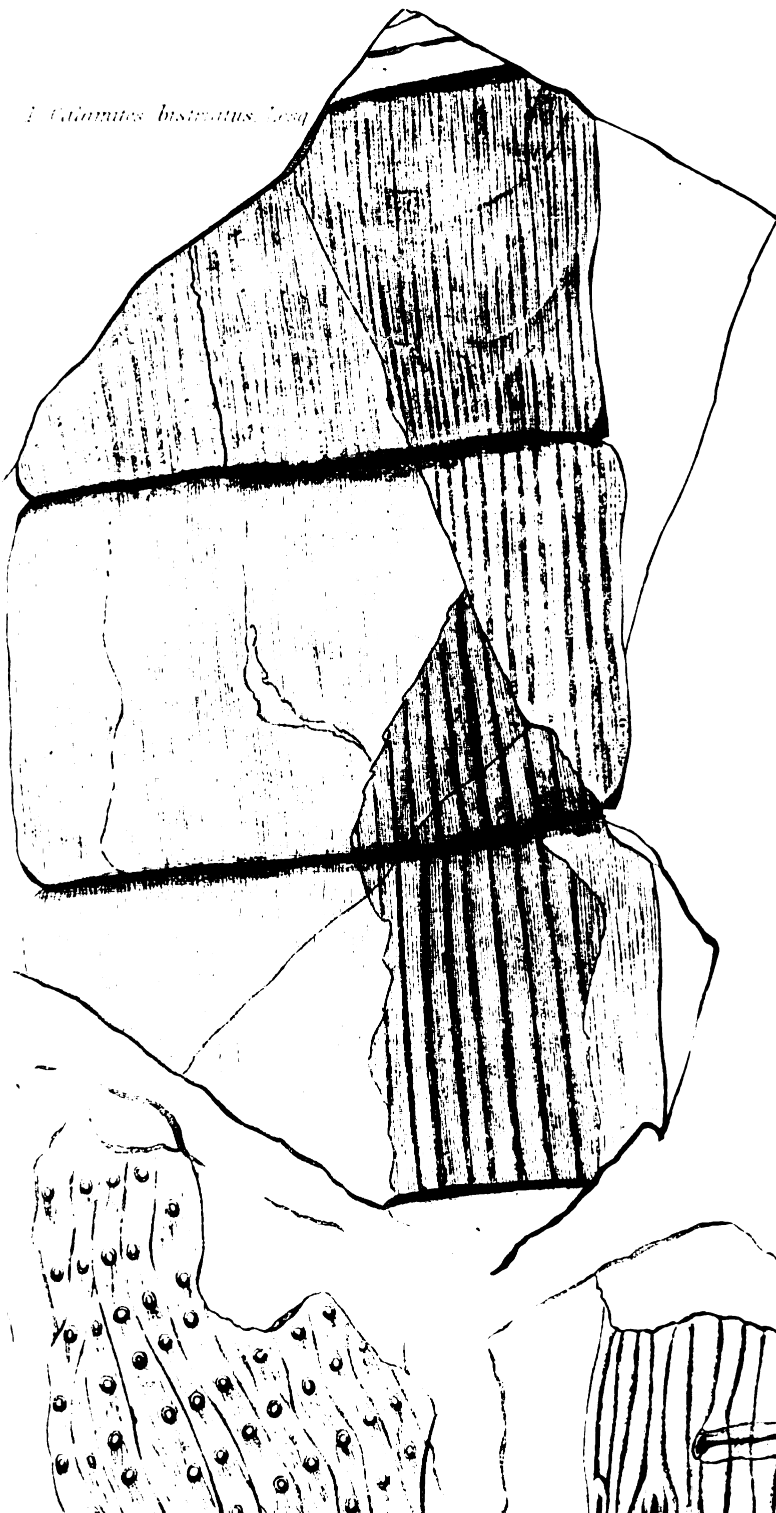
4 Stigmaria irregularis Lesq



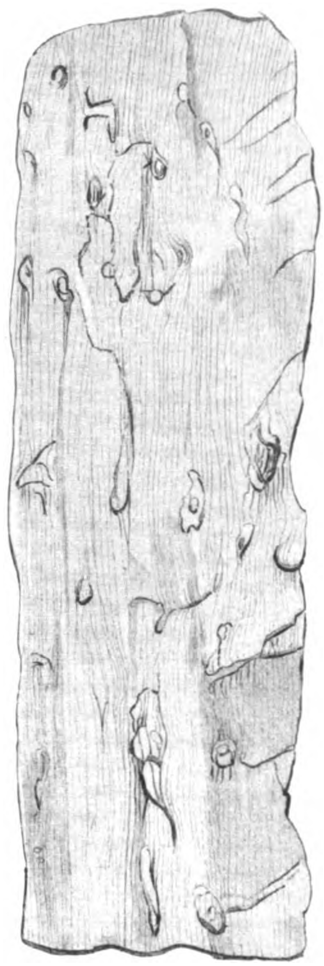
5 Calamites disjunctus Lesq

FOSSILS OF COAL FORMATION.

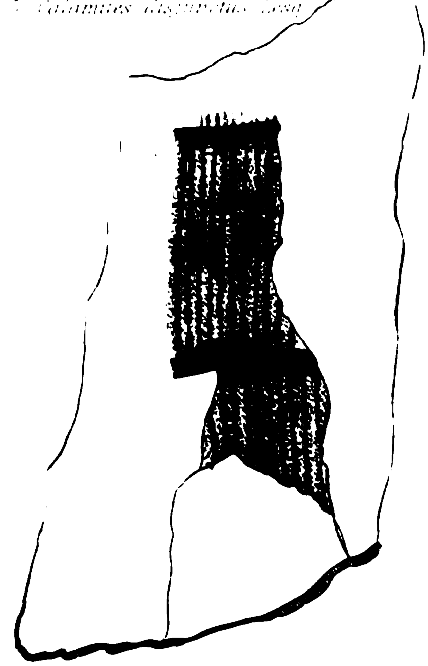
PLATE II



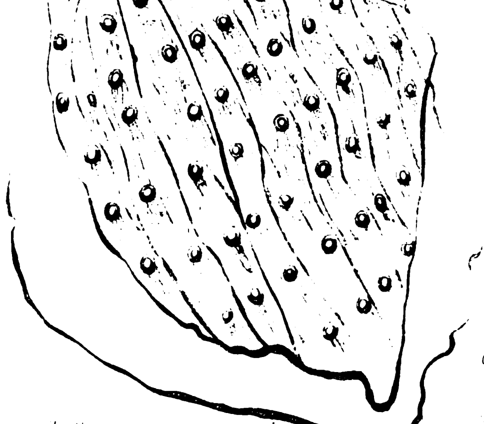
1 Calamites bistriatus. Lesq



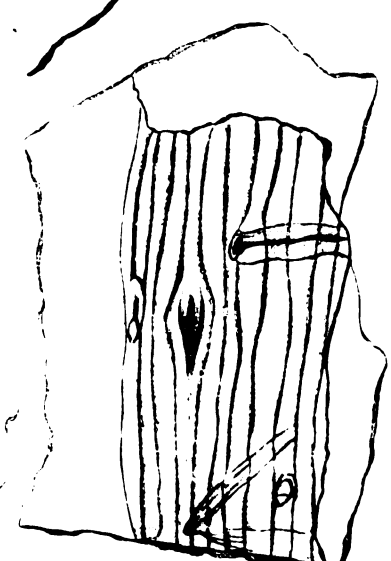
2 Stigmaria radicans. Lesq



5 Calamites disjunctus. Lesq



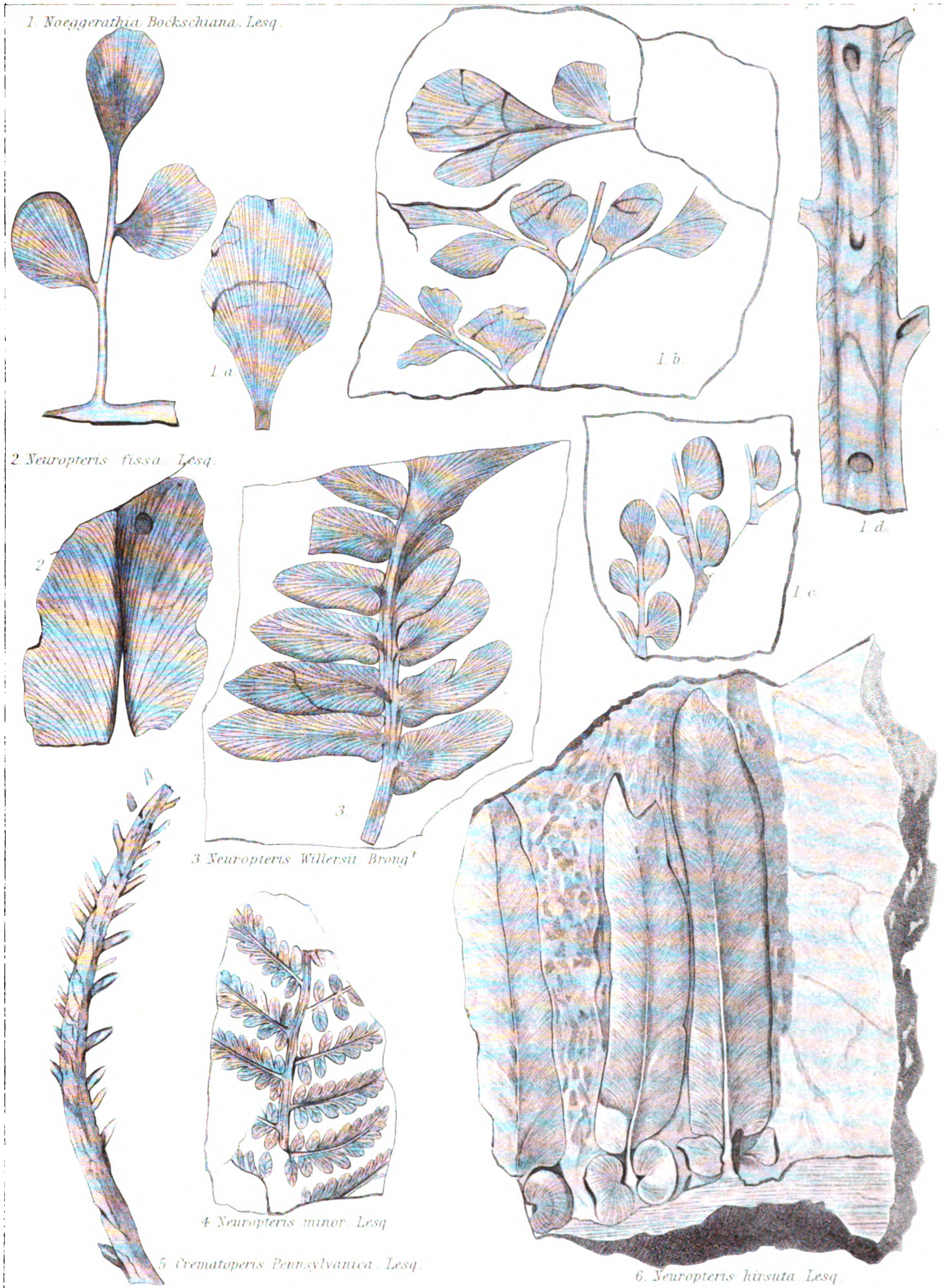
3 Stigmaria costata. Lesq



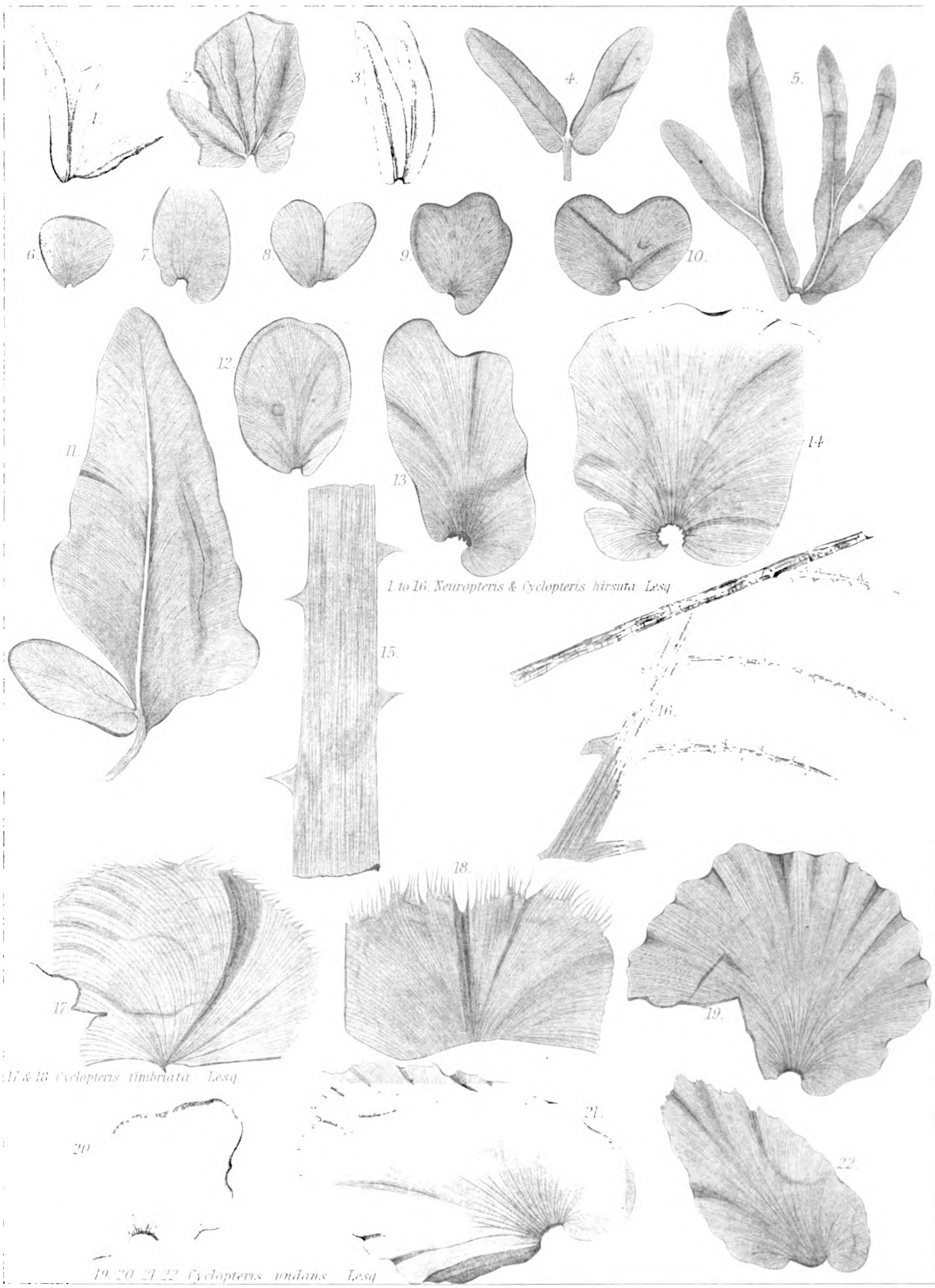
4 Stigmaria irregularis. Lesq

FOSSILS OF COAL FORMATION.

PLATE III



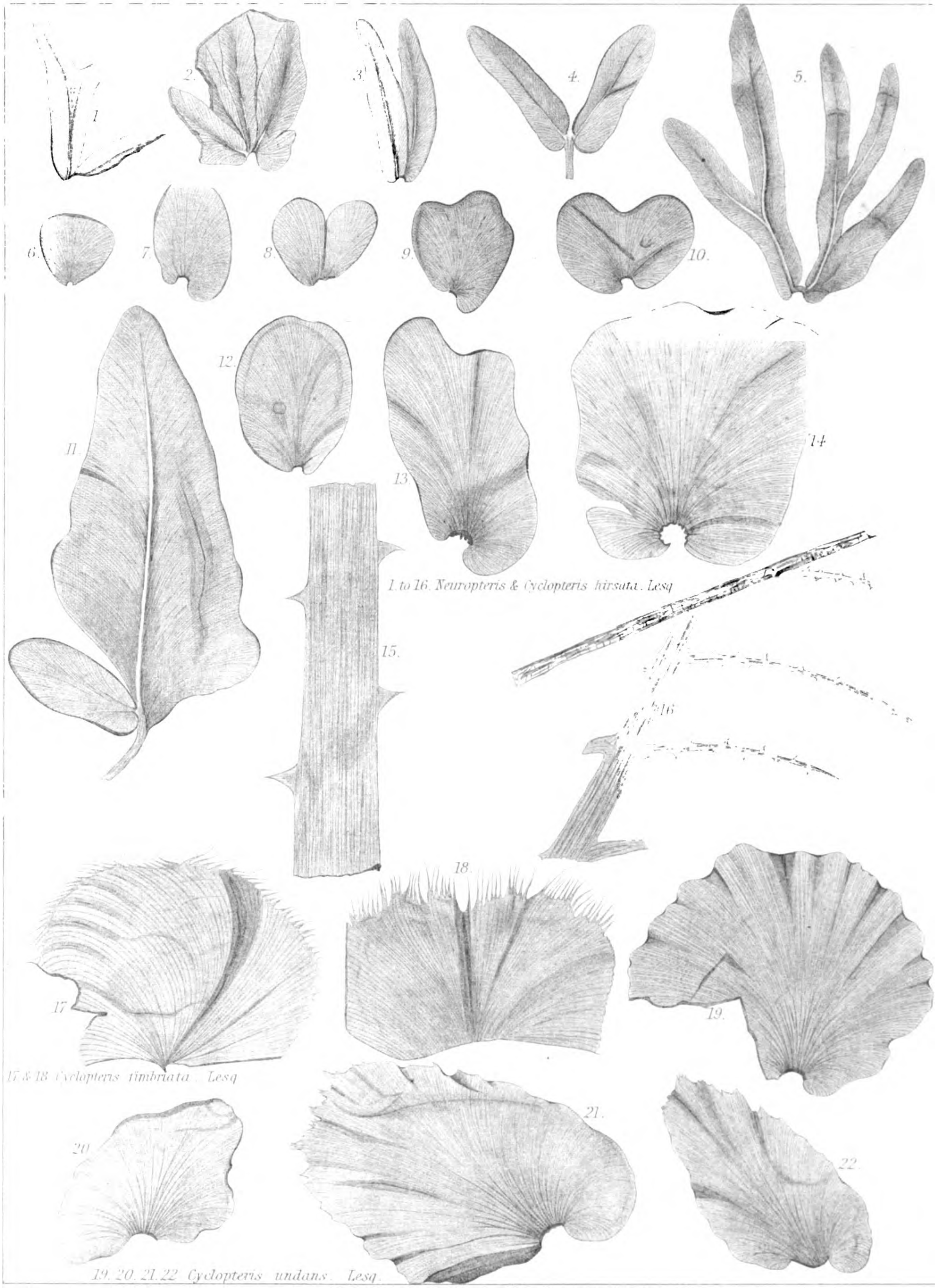
FOSSILS OF COAL FORMATION.



Engd by W. & A.K. Johnston, Edinburgh

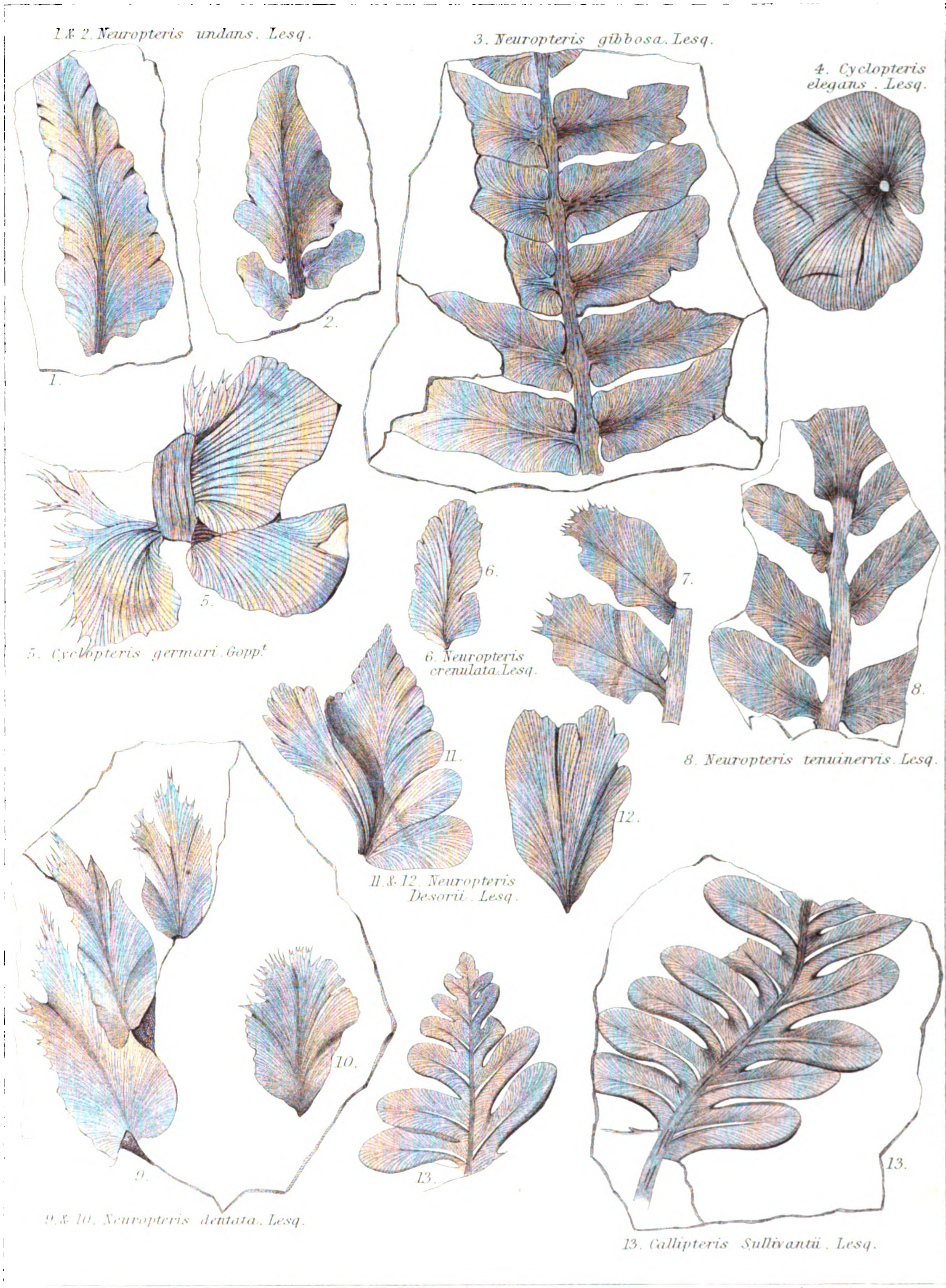
FOSSILS OF COAL FORMATION.

PLATE IV



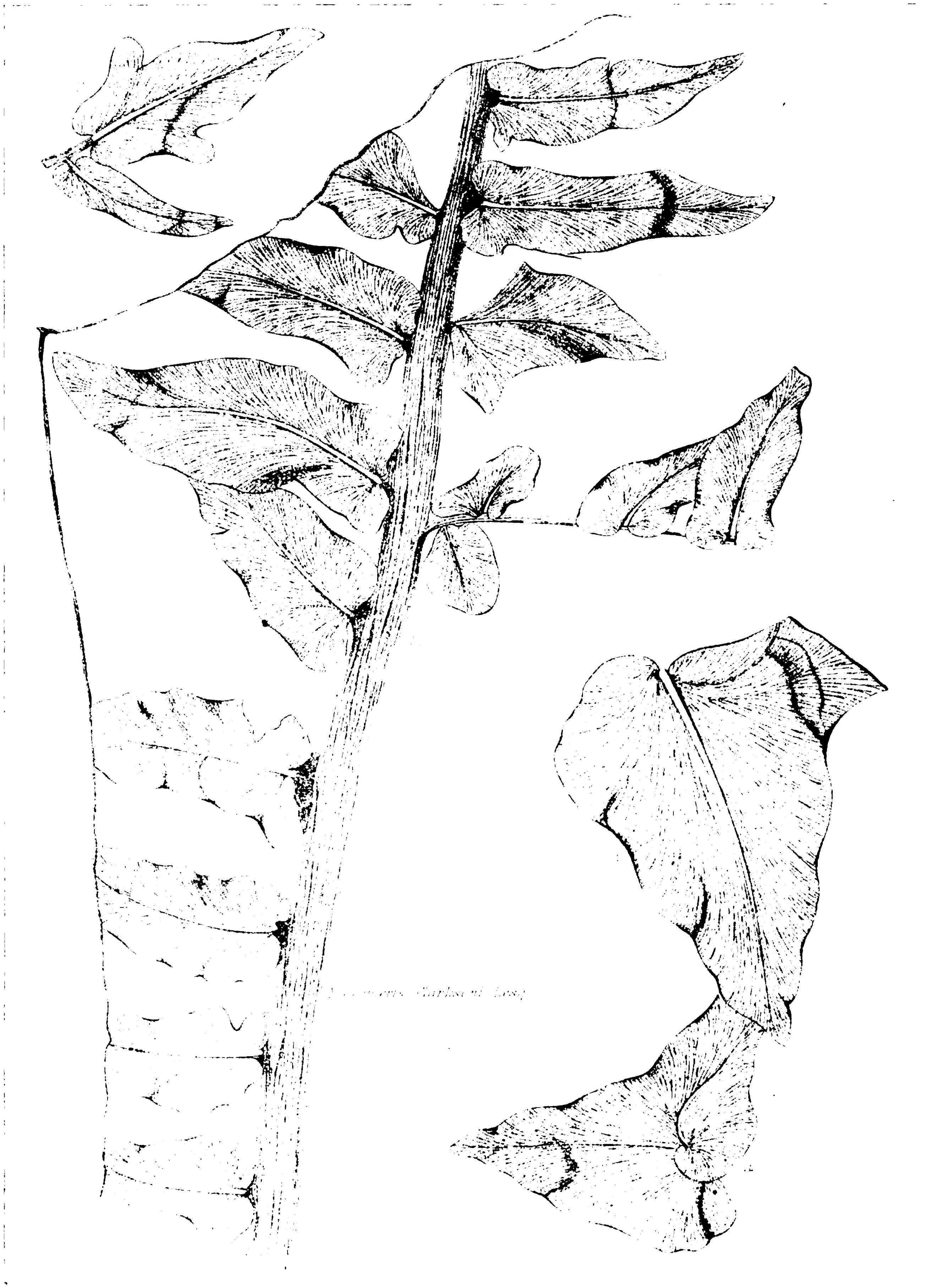
FOSSILS OF COAL FORMATION

PLATE V.



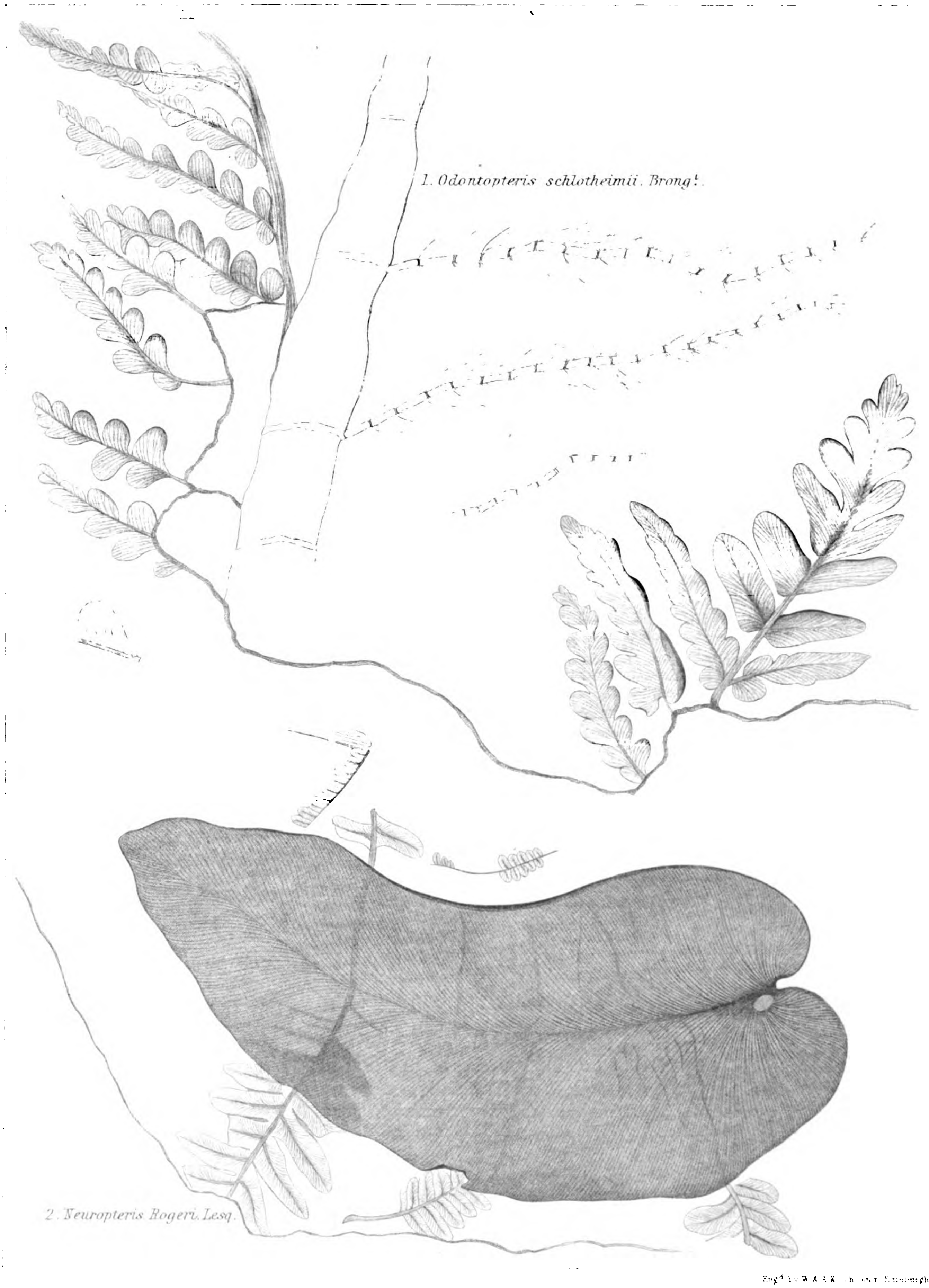
FOSSILS OF COAL FORMATION.

PLATE VI



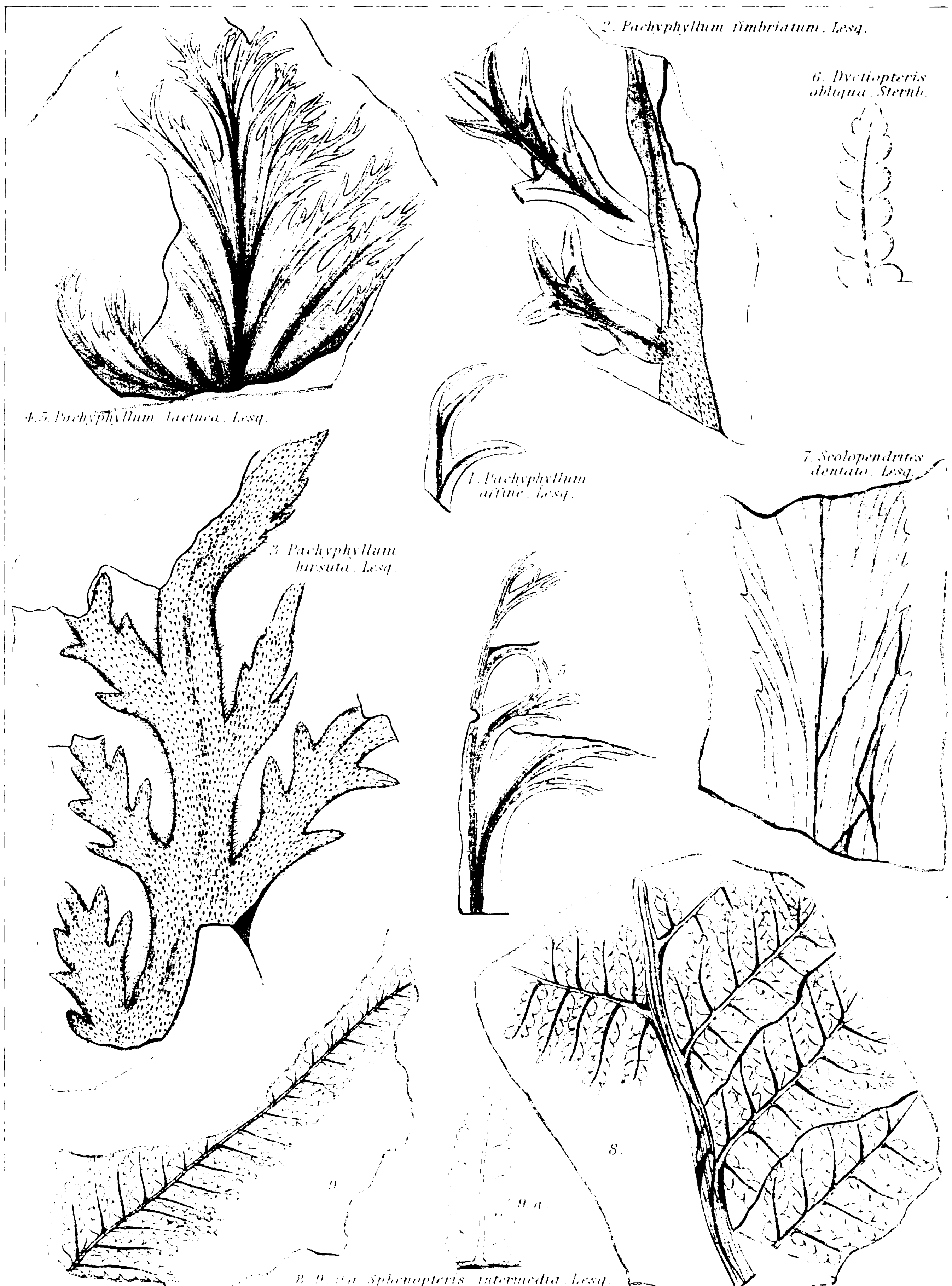
FOSSILS OF COAL FORMATION

PLATE VII

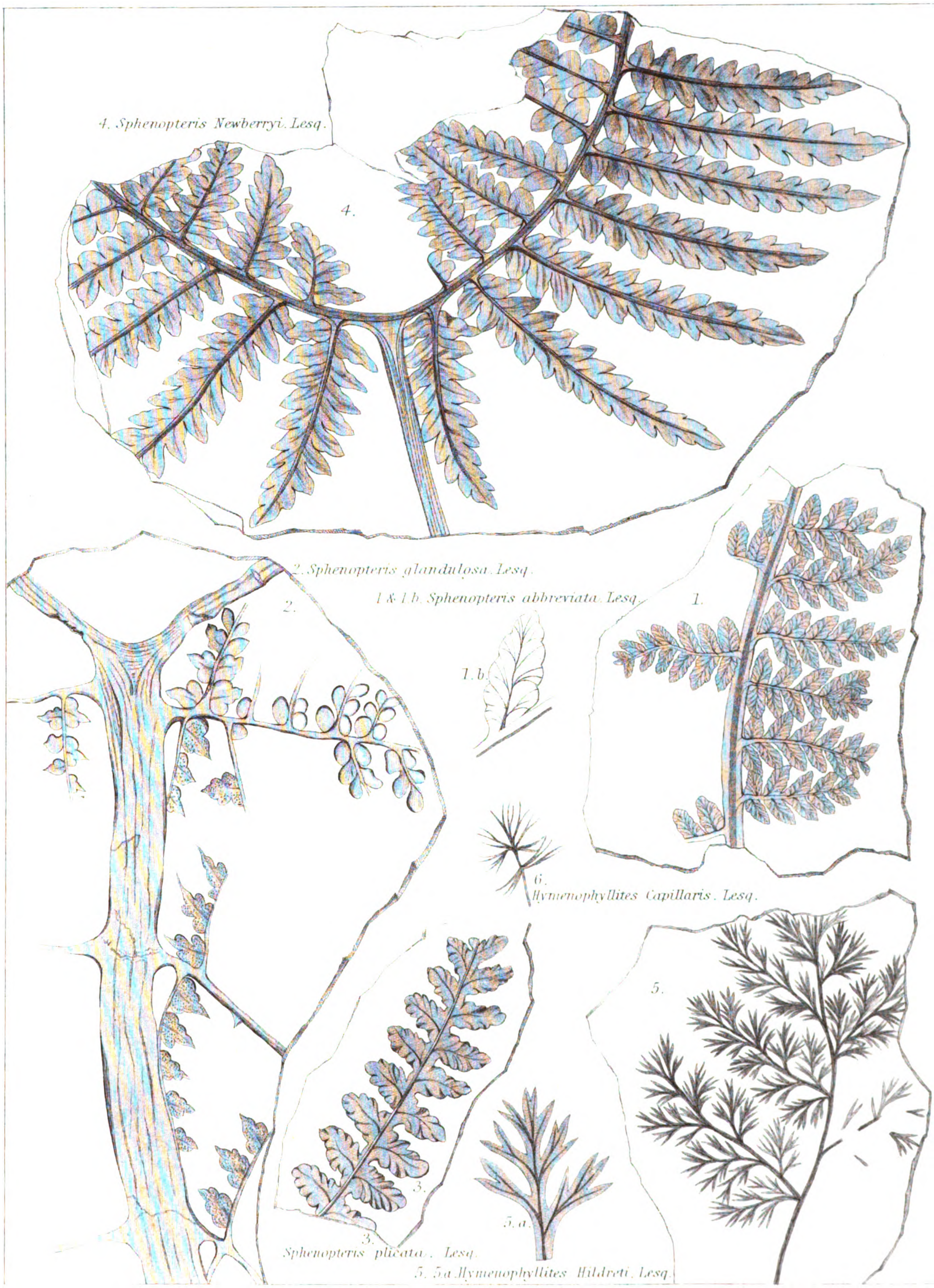


FOSSILS OF COAL FORMATION.

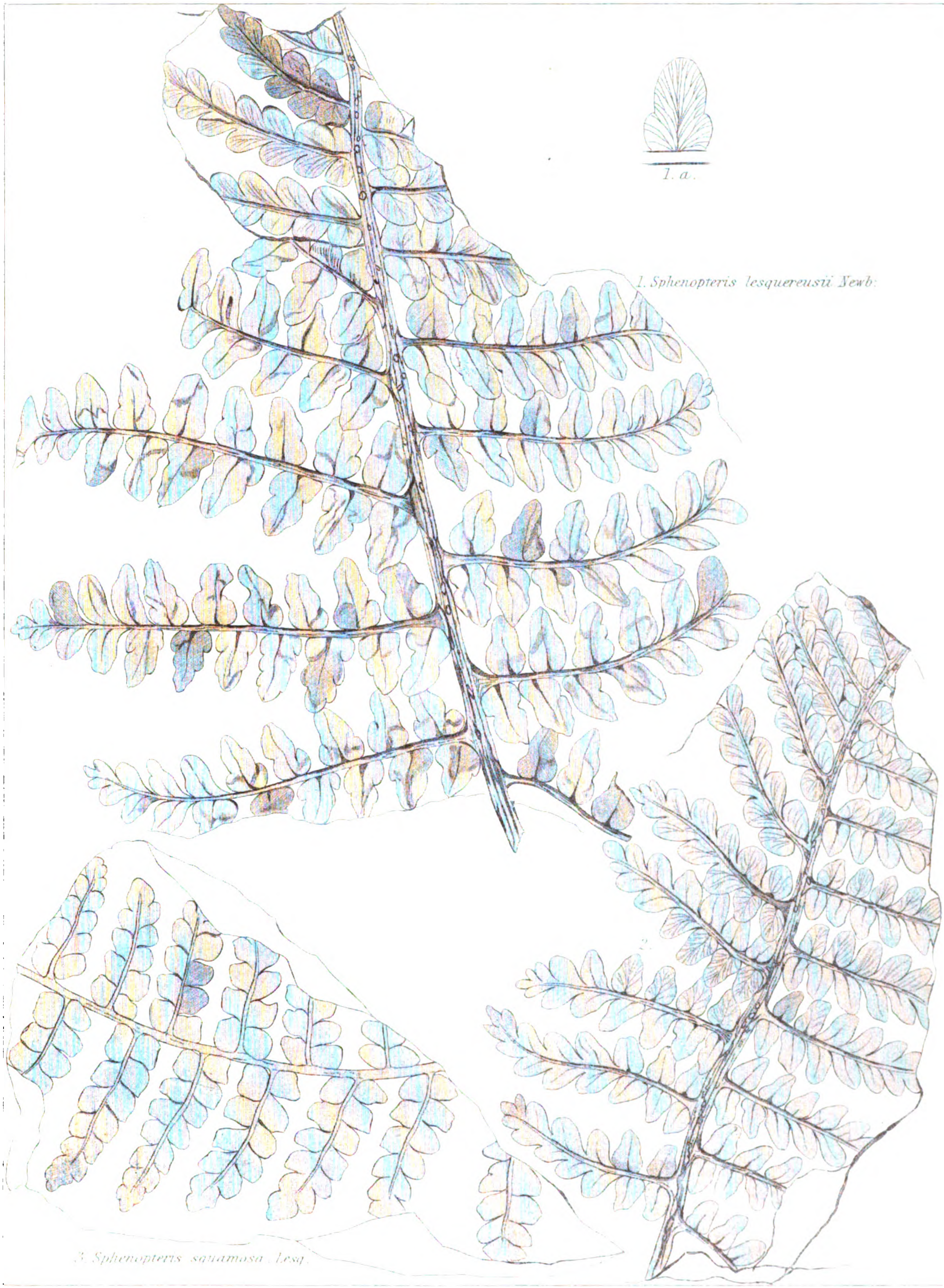
PLATE VIII.



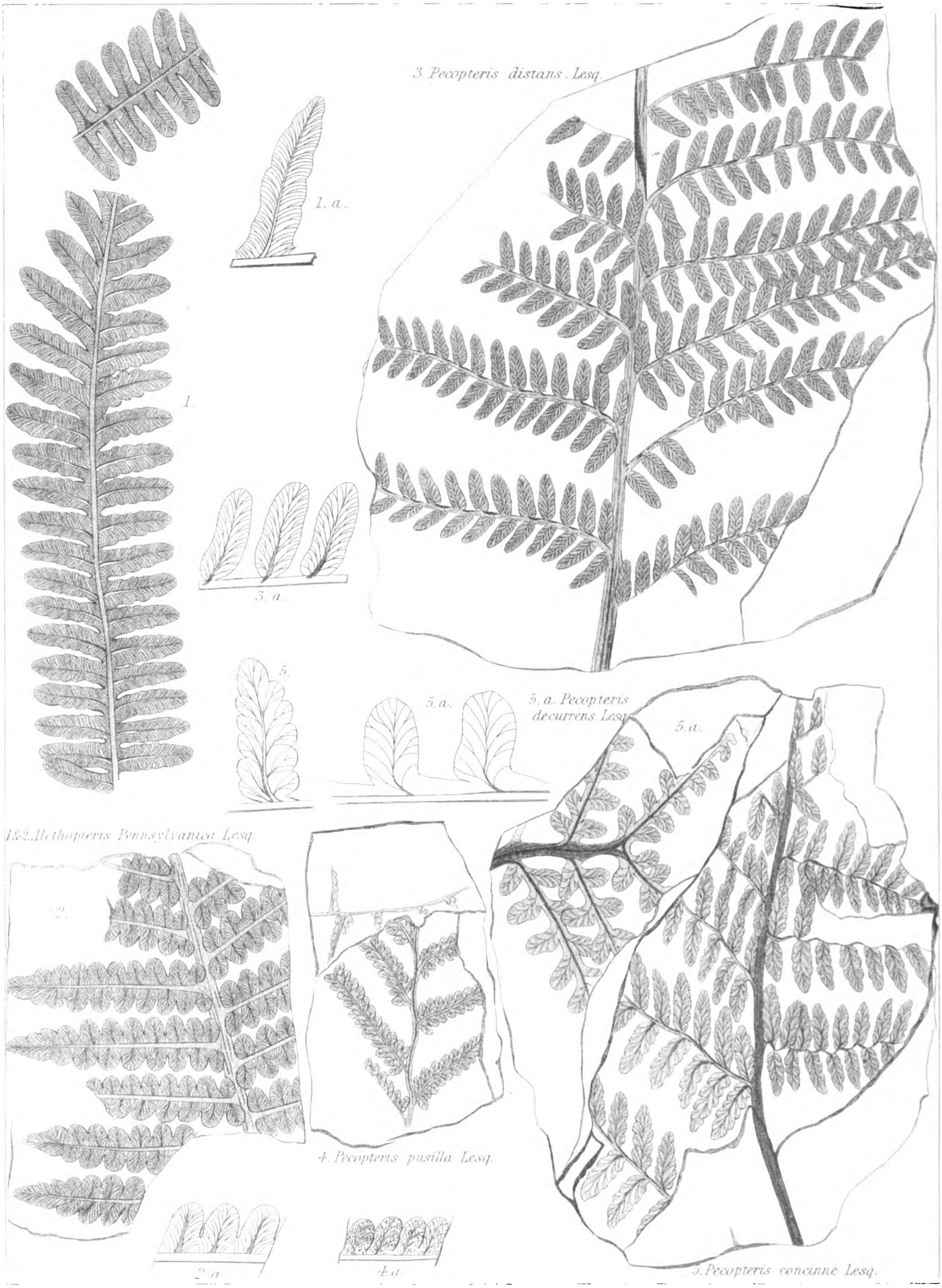
FOSSILS OF COAL FORMATION.



FOSSILS OF COAL FORMATION.

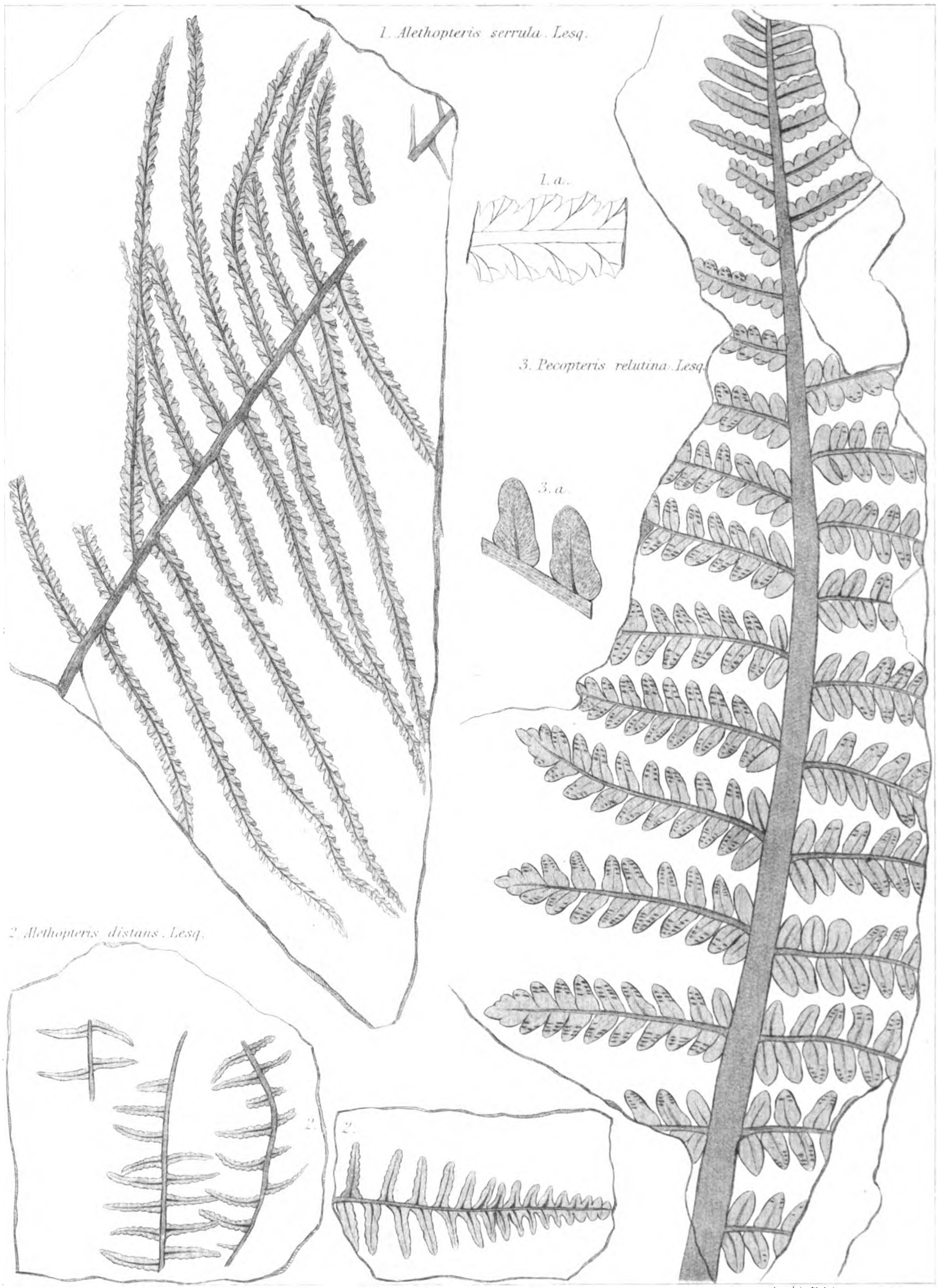


FOSSILS OF COAL FORMATION

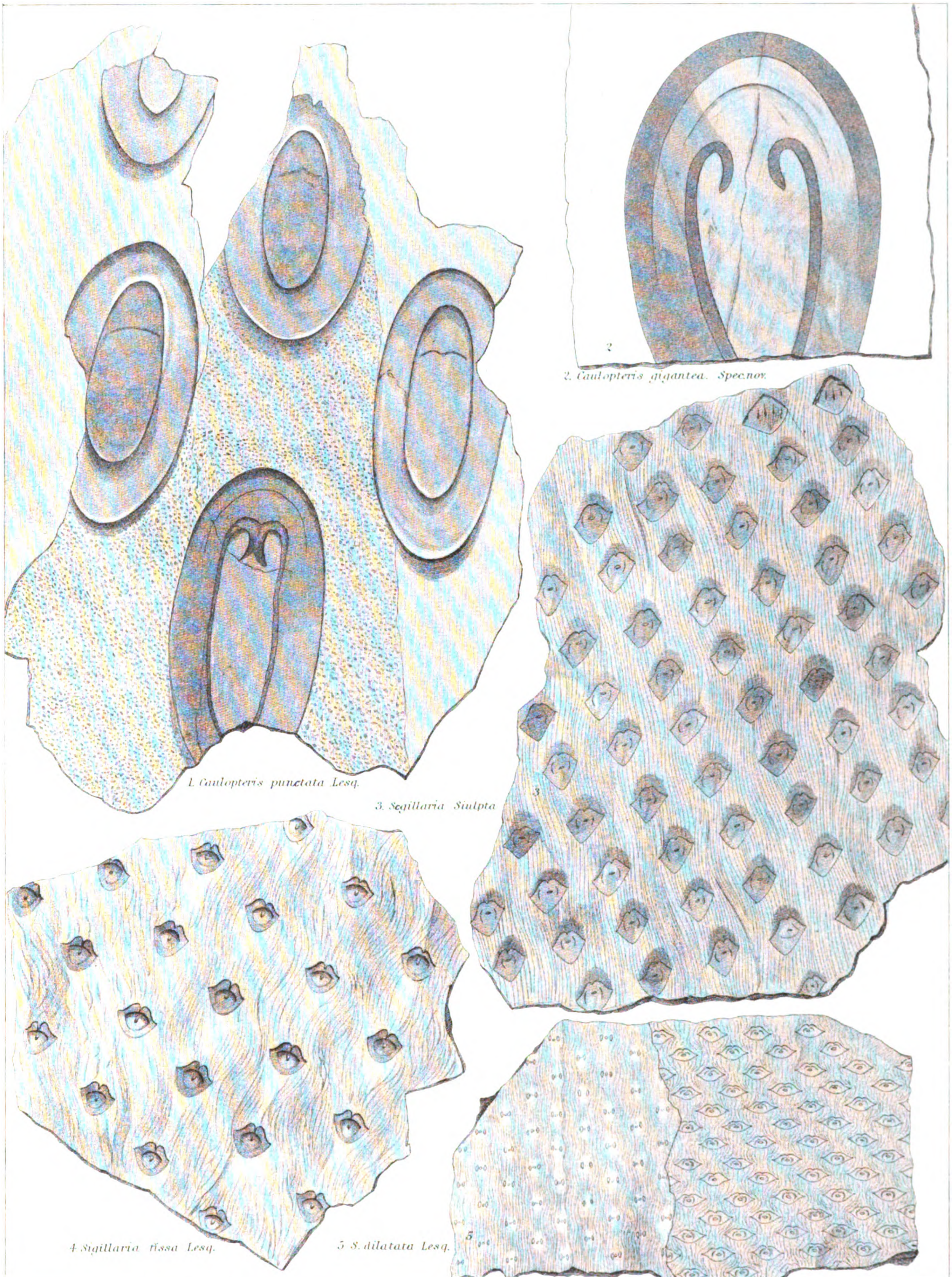


FOSSILS OF COAL FORMATION.

PLATE XII.

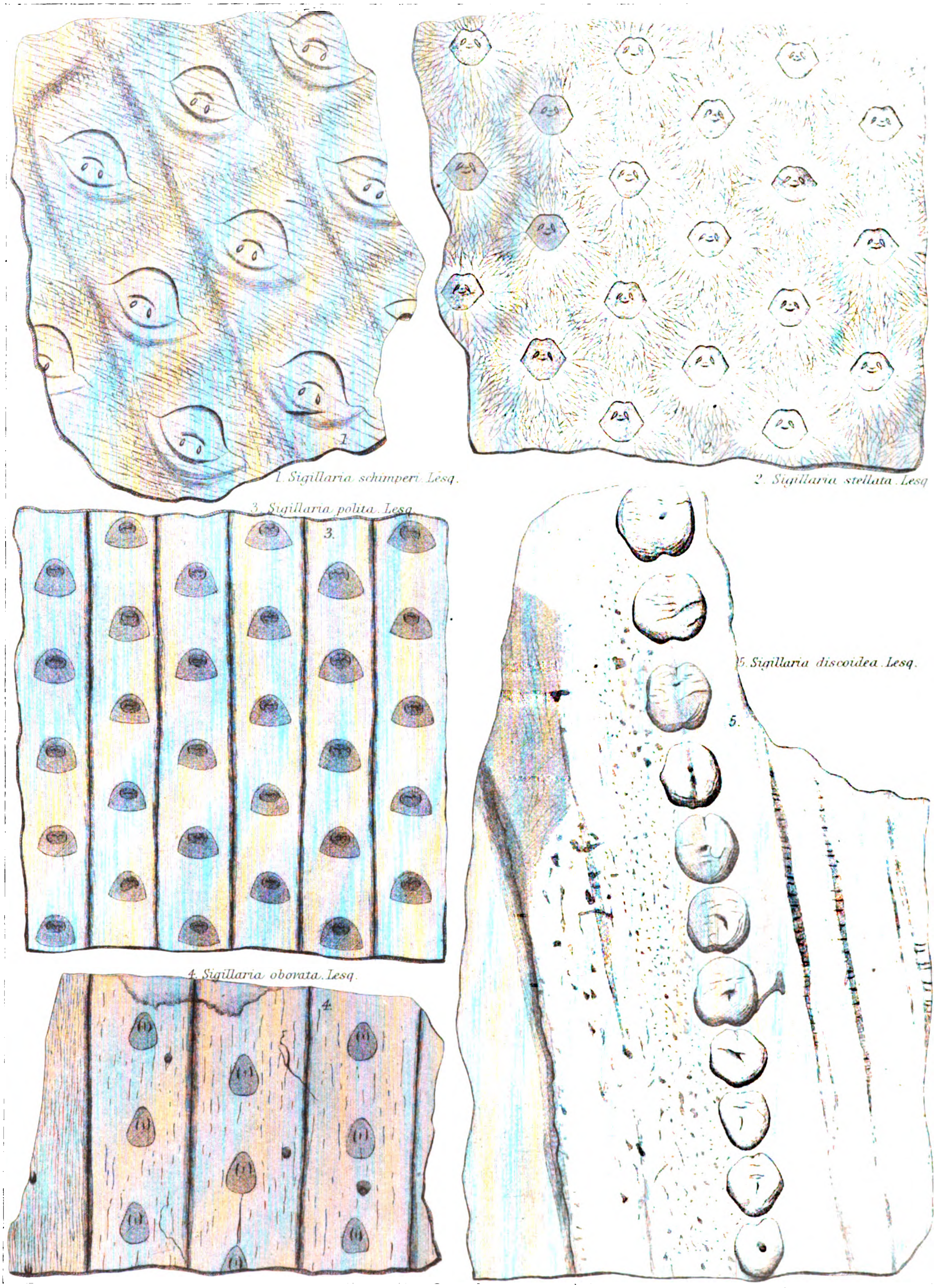


FOSSILS OF COAL FORMATION.

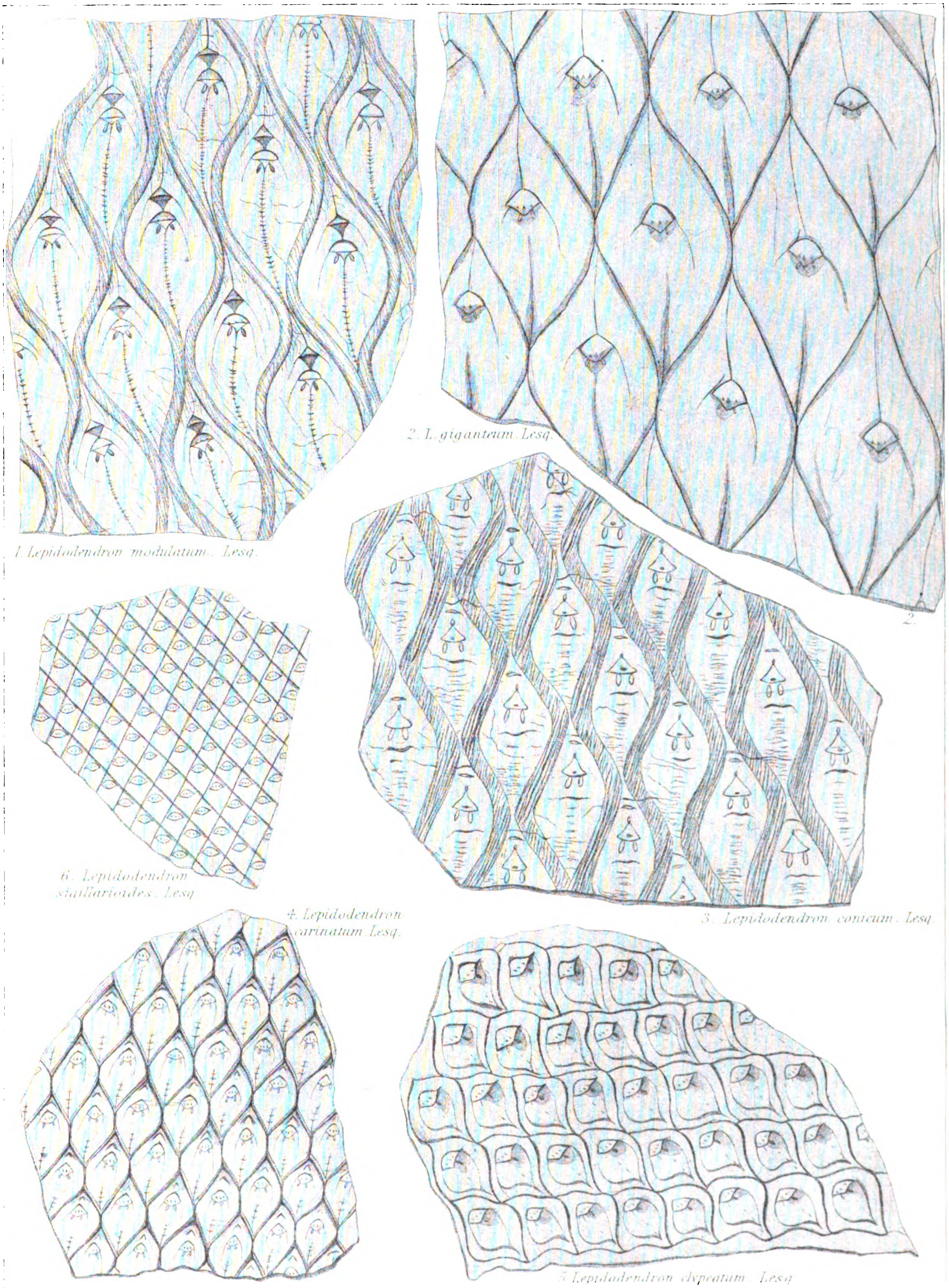


FOSSILS OF COAL FORMATION

PLATE XIV.

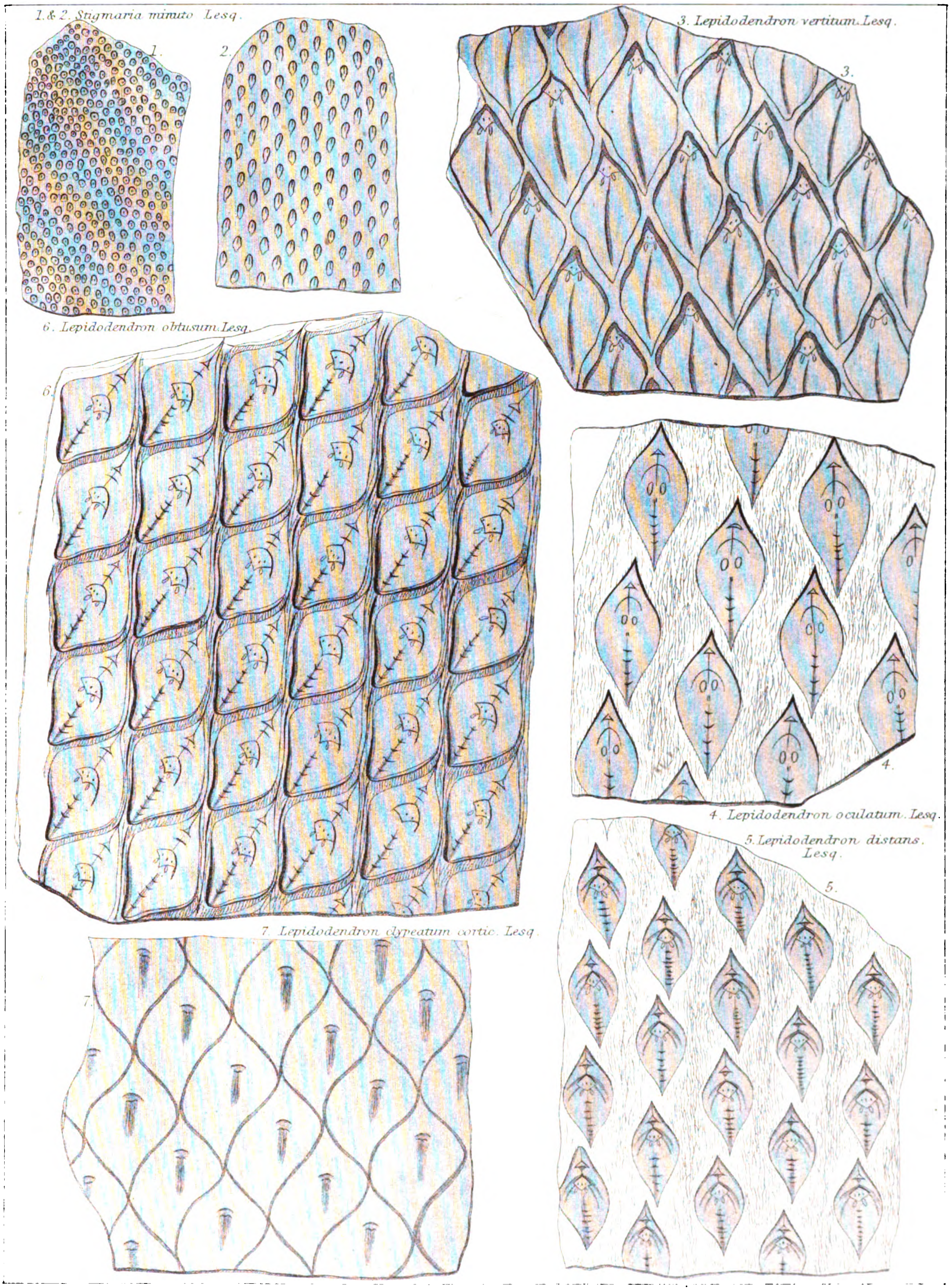


FOSSILS OF COAL FORMATION.

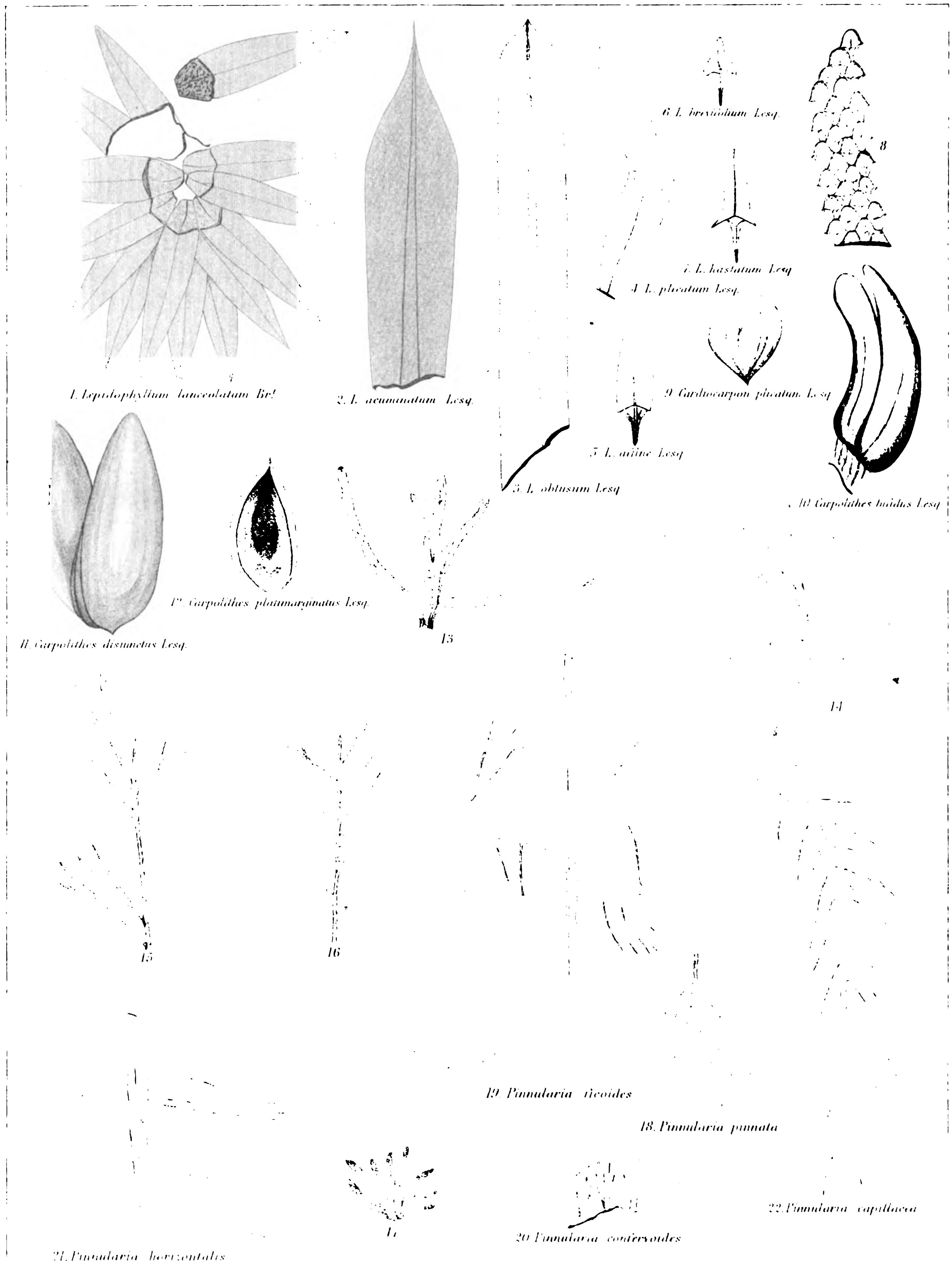


FOSSILS OF COAL FORMATION.

PLATE XVI.

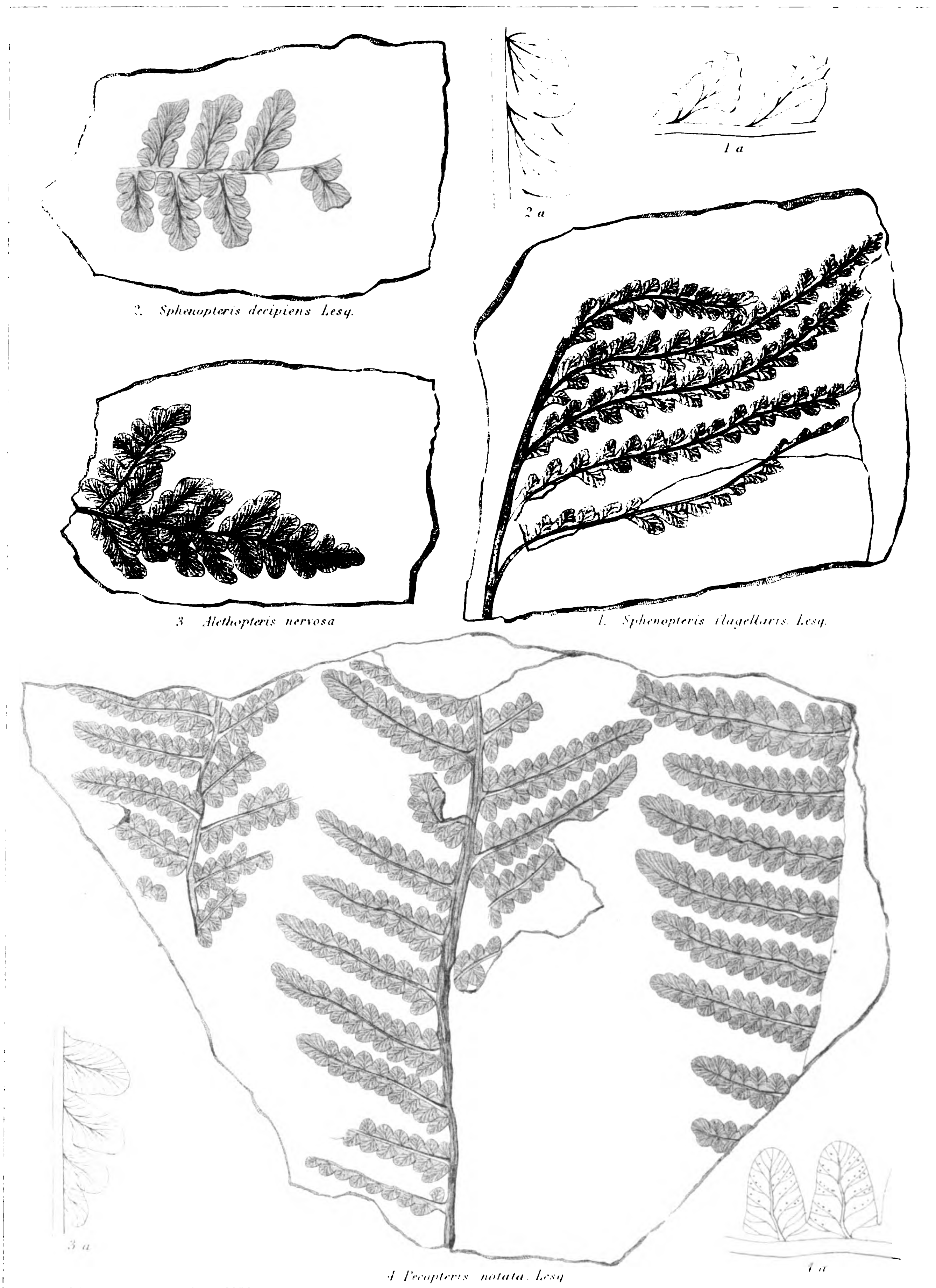


FOSSILS OF COAL FORMATION

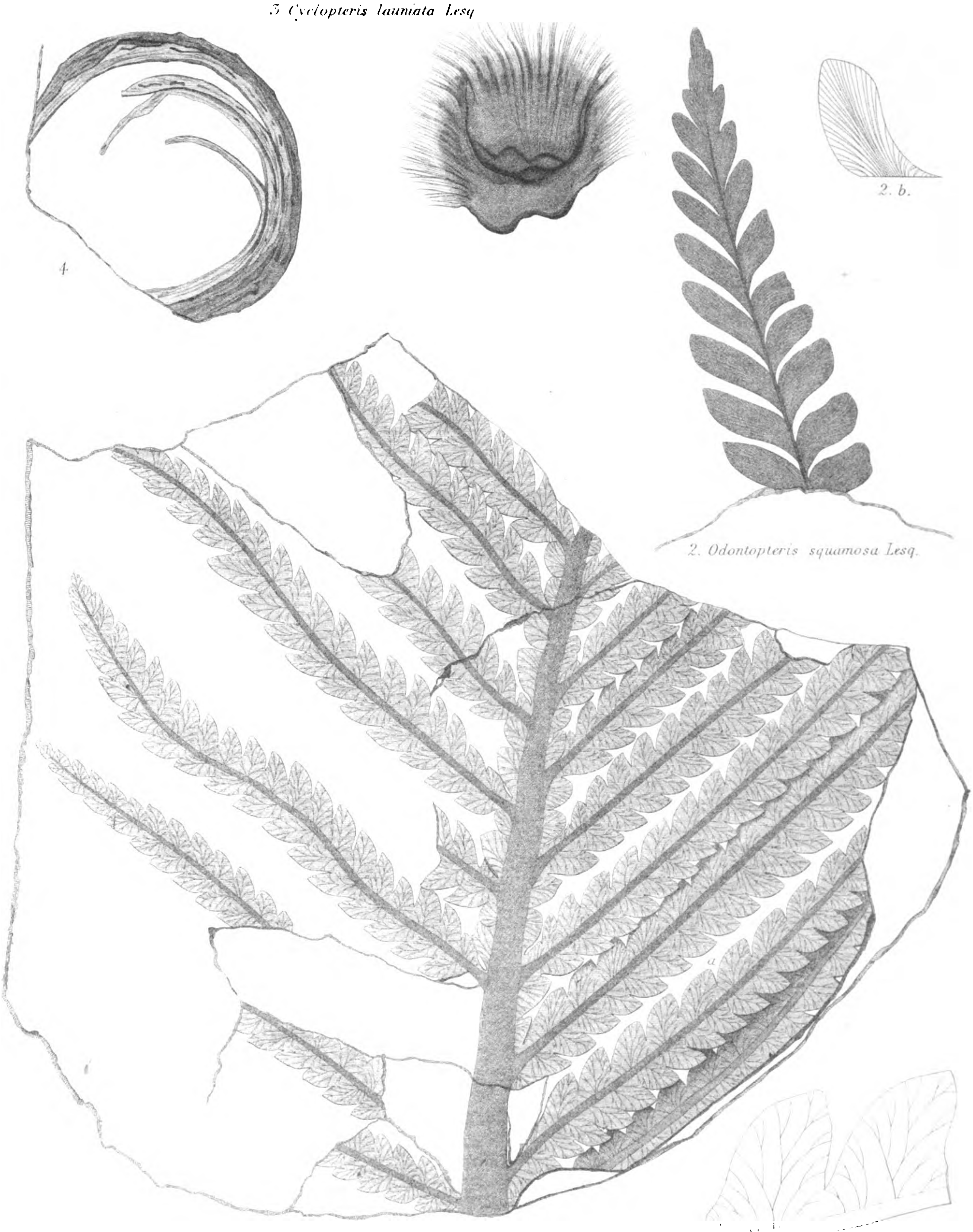


FOSSILS OF COAL FORMATION

PLATE XVIII



FOSSILS OF COAL FORMATION



3 Cyclopteris launiata Lesq

4

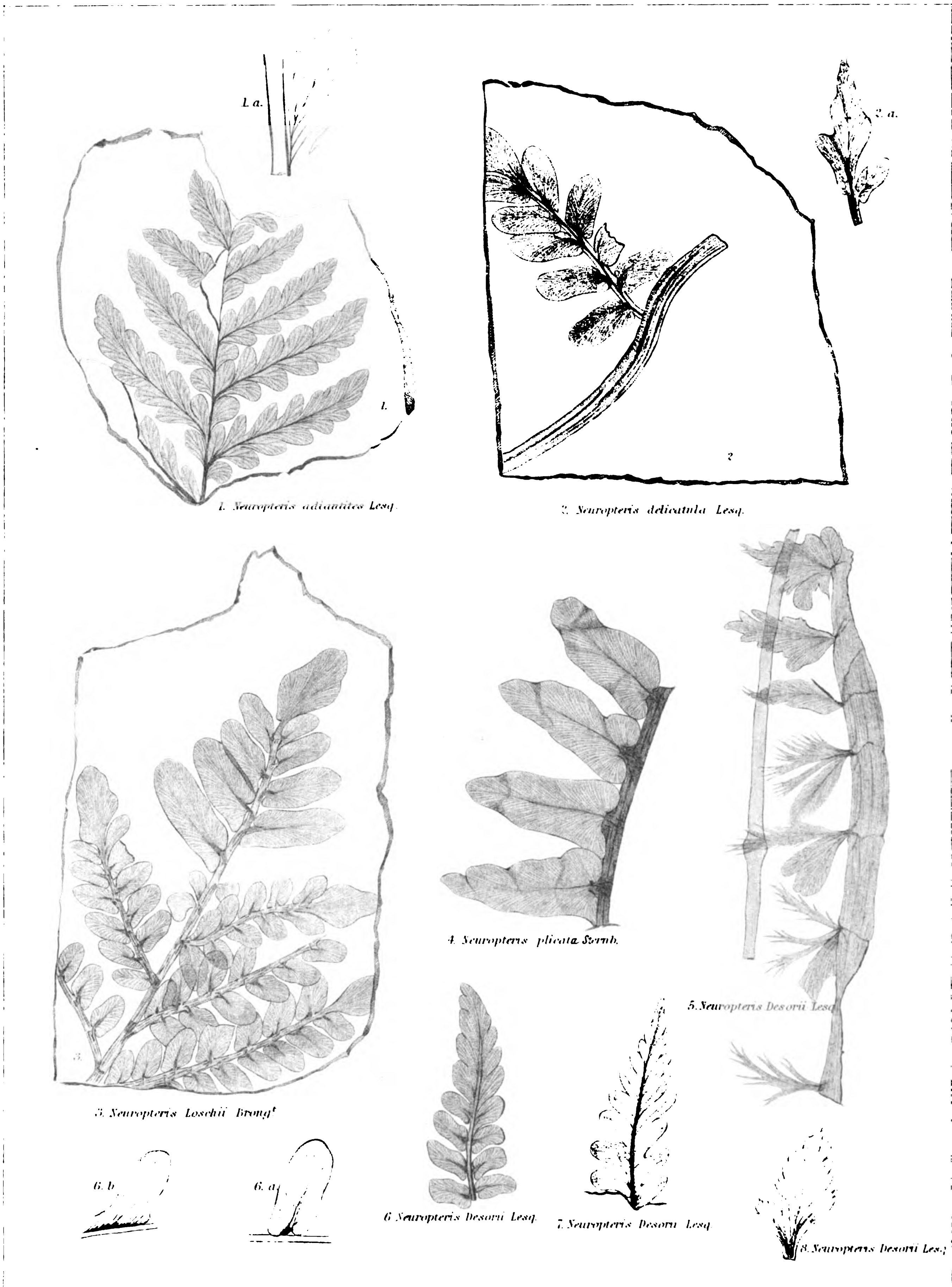
2. b.

2. Odontopteris squamosa Lesq.

1 Neuropteris moorii Lesq

1 a

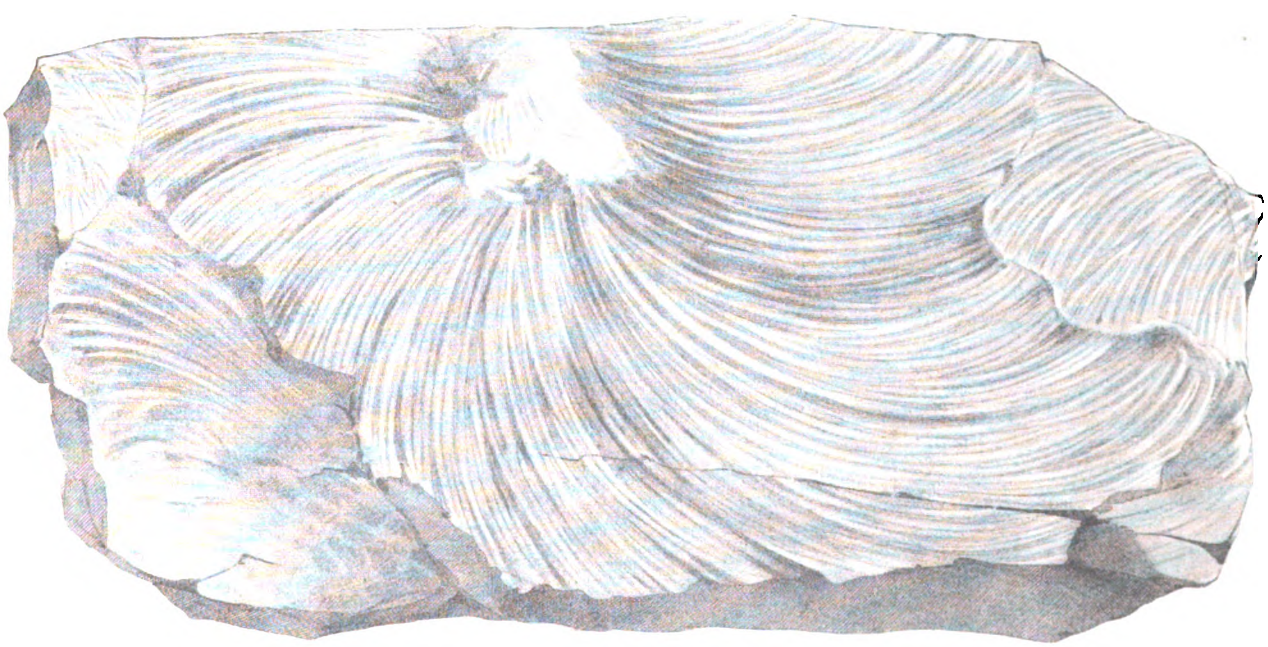
FOSSILS OF COAL FORMATION



FOSSILS OF COAL FORMATION

2

Lepidodendron Sp.? Vespertine Sandstone. Mauch Chunk



[illegible]

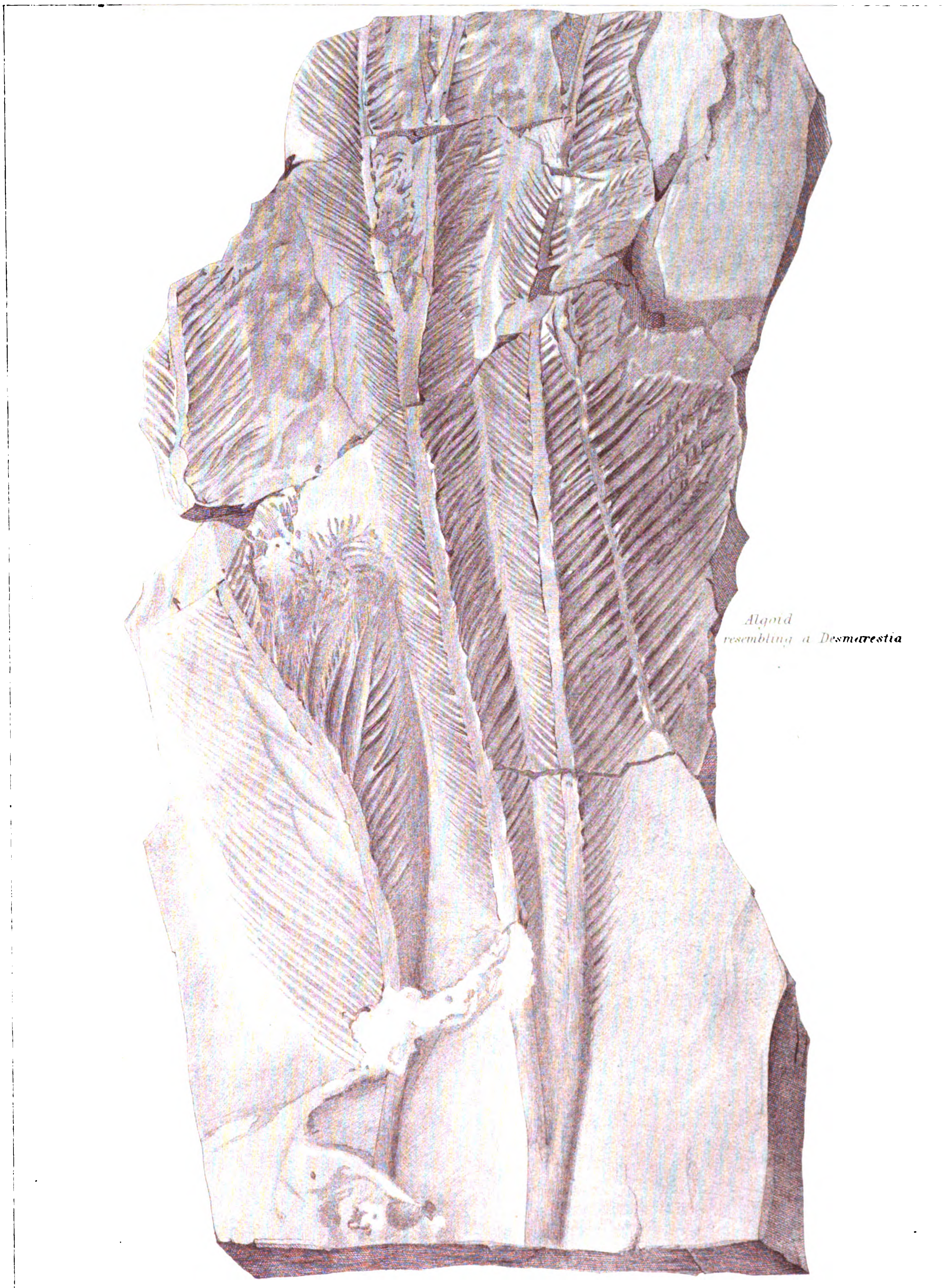
FOSSIL PLANTS

Leaf of a Gymnosperm Plant

R. K. Greville Delt

FOSSIL PLANT OF PONENT

PLATE XXIII



R. K. Greville Del.

Engd by W. & A. K. Johnston, Edinburgh.

FOSSIL PLANT OF UMBRAL