III.—*On the Geological Relations and internal Structure of the Magnesian Limestone, and the lower Portions of the New Red Sandstone Series in their Range through Nottinghamshire, Derbyshire, Yorkshire, and Durham, to the Southern Extremity of Northumberland.*

By the Rev. A. SEDGWICK, V.P.G.S. F.R.S.

WOODWARDIAN PROFESSOR IN THE UNIVERSITY OF CAMBRIDGE.

[Read November 17th, 1826; April 30th, May 18th, 1827; and March 7th, 1828.]

Chapter I. § 1. *Introduction.*

IT is my intention in the following communication to describe the principal phænomena exhibited by the great deposit of magnesian limestone which stretches on the eastern skirt of the central chain of our island, from the neighbourhood of Nottingham to the southern extremity of Northumberland. I had, in the year 1821, an opportunity of examining several portions of this deposit (especially in the county of Durham), and of verifying some interesting details connected with it which had appeared in the Transactions of the Society*. During a part of the two following summers I examined its whole western escarpment, and most of the localities which seemed likely to show its general relation, or to throw light on the structure of its subordinate parts. I venture to hope that a connected account of these observations, to which many additions have been made during subsequent visits to certain parts of the formation, may not be thought unworthy the attention of this Society.

After the production of the rocks of the carboniferous order, the earth's surface appears to have been acted on by powerful disturbing forces, which, not only in the British Isles, but through the greater part of the European basin, produced a series of formations of very great extent and complexity of structure. These deposits (known in our own country by the name of new red sandstone and red marl, and when considered on an extended scale, comprising all the formations between the coal-measures and the lias), notwithstanding their violent mechanical origin, have several characters in common,

* Geol. Trans. Old Series, vol. iv. pp. 3—10.

which enable us to connect them together, and, for general purposes of comparison, to regard them as one group. Great beds of conglomerate coarse sand and sandstone, frequently tinged with red oxyd of iron; and of red marl, associated with innumerable beds and masses of earthy salts, constitute, in many countries, the principal portion of the group we are considering. Many of these salts, though of almost constant occurrence among the rocks of this epoch, have been developed with so much irregularity, that the attempts to arrange them in distinct formations (when used for any purpose beyond local description) have sometimes, perhaps, served to retard rather than to advance our knowledge of the earth's history. The great calcareous beds which were produced during this period form, however, an exception to the last observation. They appear to have been chiefly developed in the upper and lower portions of the system we have been considering; and though possessing some characters in common, are sufficiently distinguished by their position and their fossils to be separated into two distinct formations. The higher of these (the *muschel-kalkstein* of the continental geologists) has no representative in the series of rocks which have hitherto been observed in our island; the lower is represented by the great terrace of magnesian limestone which ranges from Nottingham to the mouth of the Tyne*.

The greatest difficulties in classifying distant portions of the new red sandstone have not, however, so much arisen out of its mechanical origin and complexity of structure, as from its general want of conformity to all the inferior formations. Connected with this fact are three great sources of error.

1st. Beds of the age of the new red sandstone (even in countries where the successive depositions are complete) may rest indifferently on any of the older

* If the classification pointed out in the text be correct, the magnesian limestone and the *muschel-kalkstein* must be considered as very nearly related. In mineralogical character they also frequently resemble each other. For example, in Dr. Boué's description of the *muschel-kalkstein* (*Journal de Physique*, Mai 1822), it is stated, that cellular beds of yellowish limestone are not unfrequently observed in it, nearly resembling some varieties of the magnesian limestones of England: and the same fact is still more fully confirmed by M. L. Élie de Beaumont, in a Memoir on the secondary formations of the Vosges, which has appeared since the preceding observations were written (*Annales des Mines*, 1827, p. 450, &c.). But the constancy of position in which the two formations appear, one in the higher, the other in the lower part of the system with which they are associated, points out a considerable distinction between them, which is made still more perfect by the suites of fossils which respectively belong to them. For the more characteristic fossils of the *muschel-kalk* (*Encrinites moniliformis*, *Ammonites nodosus*, *Mytilus socialis*, &c. &c.) are not, I believe, ever found in the magnesian limestone: and in the same way the fossil fish, and the bivalves of the genus Spirifer, and the genus Producta of the magnesian limestone, have not been described among the fossils of the *muschel-kalkstein*.

formations. This has been, and perhaps still continues to be, a prolific cause of error; and has often led geologists to confound the conglomerates which are inferior to the great carboniferous order with those which are superior to it.—2ndly. When deposits like the new red sandstone rest unconformably upon the inclined beds of the older formations, the fact demonstrates that these beds were partially consolidated and mechanically tilted out of their original position before the existence of any part of the overlying mass. But we have no right to assume, nor is there any reason to believe, that such disturbing forces either acted uniformly or simultaneously throughout the world. Formations which in one country are unconformable, may in another be parallel to each other, and so intimately connected as to appear the production of one epoch*. It is perhaps on this account that D'Aubuisson and some other continental geologists have grouped the new red sandstone with the beds of grit subordinate to the coal-measures. One who had formed his notions of arrangement from the sections exhibited in the south-western coal districts of England, would never have thought of such a classification.—3rdly. When two formations are unconformable, they are separated from each other by a period of time to which we can assign no definite limit. It is impossible to form even the shadow of a conjecture respecting the interval which elapsed between the commencement of the great dislocations of the coal-measures and the completion of the next superior deposit of magnesian limestone. And not only was this period indefinite, but the mechanical agents which produced the deposit appear to have operated with every possible variety of modification. We may therefore expect to find near the lower part of the group of the new red sandstone many important phænomena in one country, of which we have no example in another. This remark may perhaps explain the enormous development in some of the Alpine regions, of a calcareous formation agreeing in its great relations with our magnesian limestone. In the same way we may

* It is perhaps unnecessary to accumulate proofs of this assertion. The position of the chalk and other superior strata in the Isle of Wight and the Isle of Purbeck offer a well known example of local disturbing forces, which operated on a great scale during the recent epoch of the tertiary deposits. In a considerable part of the Jura-chain, a system of beds composed of saliferous marls and gryphite limestone is unconformable to the superior oolitic formations. Here, therefore, we have the indications of a catastrophe immediately subsequent to the deposition of the lias, of which we have, I believe, no trace in this island. (See the memoir of M. Charbaut on the Jura-chain, *Annales des Mines*, 1826.) Lastly, in South Wales, the old red sandstone graduates into grauwacke, and is probably conformable to it. But in the northern counties of England the same formations are unconformable, and are as perfectly distinguished from each other as the dolomitic conglomerates of the western coal fields are from the rocks on which they rest.

account for the extraordinary difference between the conglomerates overlying many portions of the coal districts in the south-western parts of England, and that well developed and extensive formation of magnesian limestone which it will be my object in this paper to describe.

If the preceding views be correct, it must obviously be impossible to form any just estimate of the important deposits which connect the great coal-formation with the beds of the superior order, without many independent details derived from situations which are remote from each other, and in which the relations of the deposits are well exhibited. The history of the new red sandstone in the western coal districts may (after the admirable details published in a preceding volume of the Society's Transactions,) now be regarded as complete. The following details may, I hope, afford the materials for approximating towards a more perfect history of the same formation in some other parts of England.

§ 2. *External character of the country through which the formation ranges, &c.*

In the south-western coal-fields the magnesian conglomerates do not often by themselves form any important feature in the country. Frequently they are found immediately associated with the next superior formations of lias and oolite, and are the base of the horizontal deposits which rest upon the edges of all the older rocks*. To the formation of magnesian limestone I am about to describe, none of these characters can be applied; for it is separated from all our oolitic formations by the great plain of the new red sandstone, rests exclusively on beds of the carboniferous order, and in almost every part of its course produces a striking influence on the external character of the country.

The western boundary of the formation generally presents a lofty escarpment overlooking the lower portions of the neighbouring coal districts; and the top of this escarpment preserves nearly the same level through many parts of its range. In consequence of this structure, the profile of the formation, when seen from the west, may often be represented by a number of nearly horizontal lines, separated from each other by intervals indicating the valleys of denudation. This statement, though generally applicable to the configuration of the country, admits of some exceptions. In several places the escarpment above mentioned disappears altogether; and in some parts of the county of Durham there is no continuous terrace; but the visible boundary of the limestone is represented by an obscure chain of low round-topped hills.

* See the sections of the south-western coal districts of England. (Geol. Trans. 2nd Series, vol. i. Part 2, Plate XXXII. and XXXV.)

The escarpment at the western limit of the formation is seldom of simple structure, but is generally composed of beds of sand, sandstone, or coal shale, capped with beds of magnesian limestone of variable thickness. That the whole region which is traversed by this limestone has been ravaged by powerful denuding forces, is proved by the contour of the neighbouring districts, by the accumulations of diluvial rubbish, by the valleys of denudation, by the deep bays which have been scooped out of the escarpment, and, above all, by the outliers which in some places are found considerably to the west of the general boundary of the formation. It is, I think, plainly demonstrated by the configuration of the country, that some of the upper portions of the coal formations of Nottinghamshire, Derbyshire, and Yorkshire, have been saved from destruction by the capping of the limestone. At the same time the present drainage of these counties shows that the escarpment above mentioned opposed but a feeble barrier against the great denuding torrents which descended from the western chain to the plain of the new red sandstone; for the rivers which have their source in the higher regions to the west of the magnesian limestone are not, on reaching its escarpment, deflected from their course, but generally cut through it by a direct channel into the great central plain of England: and, near the northern extremity of Yorkshire, where the limestone abuts against a mountainous tract of country (without the intervention of any lower region of the coal strata), the descending currents have swept away large portions of the formation, which can only be traced through that district by a few inconsiderable fragments which are still found *in situ*, and indicate the general line of its original direction*. The drainage of the county of Durham might at first sight be considered an exception to the preceding remarks; for, after descending from the mountains, the river Wear, during a considerable part of its course, runs nearly parallel to the range of the magnesian limestone. The exception is, however, only apparent; for the waters descend in a natural depression of the great coal basin, and are not at all deflected by the magnesian escarpment.

* The terrace of the great oolite, on the contrary, produces in almost every part of England a striking effect upon the direction of the rivers, as will be seen by a glance of the eye over the geological map. This fact may be accounted for by three causes. 1st. The oolitic terrace is of much greater magnitude than the magnesian terrace. 2dly. The oolitic terrace is composed of more coherent materials, and is less intersected by fractures and dislocations. 3rdly. This terrace in the greatest part of its range is separated from the higher western regions by the great plain of the new red sandstone. The denuding torrents may therefore have spent a part of their fury in the central plain of our island, before they reached the base of the great oolitic escarpment. All these causes may have combined in preventing some of the ancient denuding currents from forcing their way through the escarpment of the great oolite.

A formation, which in some places stretches in a continuous terrace through a finely diversified country, and in other places is broken into outliers and modified by denuding forces, must necessarily give rise to many scenes of great variety and beauty*. But, on reaching the top of the terrace and crossing the back of the formation, the country (except where it is cut through by valleys of denudation, or covered by accumulations of diluvial matter,) is seldom found to exhibit any great diversity of surface; and most frequently forms an extended plain gradually declining towards the east. The newest portion of the deposit in some parts of Nottinghamshire and Yorkshire forms a second terrace, the beds of which dip like the former, and gradually sink below the level of the great plain of the new red sandstone; most frequently without an escarpment, or any other geological feature to mark the line of junction.

The agricultural character of the country in which the magnesian limestone prevails is various; partly from the changes of the formation, and perhaps still more from the accumulations of extraneous matter between the soil and the rock. It may, however, be observed, that when the soil rests immediately upon the rock, it is generally rather light and unproductive, and never exhibits that beautiful green vegetation which abounds in many limestone countries.

Its colours in Nottinghamshire are sometimes red or chocolate brown; and hence the name red-land limestone, given by Mr. Smith to the magnesian beds. These appearances are, however, the exception; for a red soil derived from the limestone is hardly seen in the other counties: the prevailing colours are lighter, and generally have the yellow tinge of the accompanying dolomitic strata.

Bromus pinnatus is so characteristic of the thin and magnesian soils, that in some instances where the lower sandstone is brought by a fault to the exact level of the yellow limestone (for example on Bramham Moor), the demarcation may be traced with great exactness by the help of this plant, without the assistance of a single excavation.

§ 3. *Range of the Escarpment, and general Distribution of the Formation.*

So far I have endeavoured in general terms to explain the great relations

* The outliers and the escarpment of the magnesian limestone have at different times been adorned with many noble buildings, some of which acquired a great historical interest. For example, Conisburgh Castle, Pontefract Castle, Tynemouth Abbey and Castle, rest upon outliers of the magnesian limestone; Hardwick Hall, Bolsover Castle, Knaresborough Castle, and Hilton Castle, stand close upon the edge of its escarpment. Other examples of the same kind might be mentioned if this were the proper place for entering on such details.

and the external characters of the formation of magnesian limestone. I now proceed to give some account of its geographical distribution; and, for this purpose, I shall first trace the western boundary of the deposit from the place of its commencement near Nottingham. On this subject much remains to be done, notwithstanding the excellent details supplied by the geological county maps of Mr. Smith. To these maps, as containing incomparably the best delineation of the formation which has yet been published, I shall constantly refer*.

The magnesian rock first appears in the flat district, north-west of Nottingham, close to the village of Radford. It does not cross to the south side of the canal, and it is not seen to the east of the rivulet which comes down from Newstead Abbey, being, on that side, masked by diluvium and hills of forest sand†. As the formation appears at a dead level, and makes no feature in the district above mentioned, its boundary is difficult to trace correctly, but appears to pass a little south of Aspley in a direction bearing about W. by N. to Bilborough. Near the last-mentioned place it begins to crown a distinct escarpment, near the edge of which are Strelley and Kimberley. From Kimberley it ranges along the top of an eminence, and passes a little to the N.W. of Watnall; afterwards deflects considerably to the N.E. and then returns and crowns a well-marked eminence a little to the east of Griesley. From thence, still preserving the same elevation, it runs in an undulating line towards Annesley, south of which place a valley of denudation forms a considerable bay in the outline. So far the boundary is represented by Smith, with perhaps as much correctness as is possible, without a map exhibiting a better delineation of the physical surface of the county. In the range through the remaining part of Nottinghamshire, the demarcation is not generally pointed out by any well-defined natural feature, and has been incorrectly delineated. The following *memoranda* will give an approximation to the true boundary line.

North of the last-mentioned denudation the limestone forms no escarpment, but appears as a thin capping on an elevated ridge of the coal-measures, and does not extend quite so far to the south-west as is represented in Smith's map. A similar capping of limestone stretches from Annesley in a direction about north-west, and in one place crosses the road from Annesley Wood-house to Alfreton. This projecting mass is carried too far by the same author; but the map is so ill engraved as hardly to admit of a correct delineation. Further to the north, the limestone forms the summit of an indented and lofty escarpment, not far from the edge of which stand Annesley Wood-house, Kirkby Wood-house, and Kirkby. The boundary line then sweeps round the south side of Kirkby, and turns along the summit of the hills to a point about two-thirds of a mile west of Kirkby; it then deflects considerably to the north-east, returns to the north-west, and crosses the road from Sutton to Alfreton at the distance of a mile and a half from the former place. From this point the line bears nearly due north, and crosses the road leading from Sutton to the coal-field at a point not more than half a mile from the village. In this part

* I had the assistance of Mr. Smith's county map in examining the range of the magnesian limestone through Yorkshire. Geological maps of the other counties through which the same formation passes were not, I believe, published at the time the observations were made on which the greatest part of this paper is founded.

† The sand of Nottingham forest is derived from the beds of the newer red sandstone, which rest immediately on the magnesian limestone.

of its course the boundary line cannot be laid down without a careful survey; as it forms a thin capping on the inferior strata, and passes (without making any physical feature in the district) considerably to the east, of an irregular plateau formed by the skirt of the Derbyshire coal-field*. From the point above mentioned, half a mile west of Sutton, the limestone ranges to the north-west, and caps the hill north of Hucknall Huthwaite; from thence it forms the summit of a hill which ranges to the north-east, and it crosses the road from Skegby to Tibshelf, about half a mile west of the former place. A little further to the north-east the boundary line crosses a valley of denudation, passes south of Tevershall, and ranges in a north-westerly direction into Hardwick Park, where it enters Derbyshire, and begins once more to form a lofty well-defined escarpment†.

The escarpment passes under Hardwick Hall to the east of Holt Hucknall, and then ranges nearly in a straight line immediately on the west side of the villages of Glapwell, Palterton, Bolsover, and Clown. About a mile north of the last-mentioned place, the line deflects to the west, sweeps round the village Barlborough (which stands on the escarpment), then turns to the north-east and passes a little south of the Hall, and then turns north towards Pibley Inn; but before reaching that place it deflects to the east and south-east, and wheels round a denudation near a place called Cinders.

In the latter part of the course just described, the demarcation is not well defined; but soon afterwards on entering the county of York, it forms an obscure escarpment, and passes in a north-easterly direction along the brow of the hill about a quarter of a mile to the south-east of Hart-Hill. From thence, continuing the same range, the line of demarcation descends into a valley, and crosses the canal at the Dog Kennel; from which place it deflects along the brow of the hill to the west; and above Penny Holme turns up into the south-eastern part of the Dark, from which it descends to the village of South Anston. From thence it gradually descends to the east along the brow of a hill, and crosses the rivulet about three-quarters of a mile below the village. It then returns along the brow on the north side of the valley, and encloses the village of North Anston ‡.

From North Anston to the point where the river Air cuts through the whole formation (a distance of more than thirty miles), the boundary is on the whole very correctly laid down in the geological map of Yorkshire. Through this extensive range the limestone occupies the upper part of a well-defined terrace, the bearing of which is nearly determined by the following places; viz. Dinnington, Laughton, Hooton-Lovett, Maltby, Micklebring, the hills to the east of Conisborough, Cadeby, Melton, Hickleton, Hooton-Pagnell, North and South Elmsall, Upton Beacon, and Wentbridge Hill; all of which are on the edge of the escarpment. From Wentbridge to the

* In this part of Smith's map the boundary line is erroneous. 1st, It extends too far, by about two-thirds of a mile on the west side of Kirkby. 2ndly, The spur of limestone on the road from Sutton to Alfreton is made to extend about a mile too far. 3rdly, The boundary line extends about a mile too far west, on the road from Sutton to the coal-field.

† Here also Smith's boundary line extends too far to the west. Stanley, Fackley, &c. are, if I mistake not, considerably to the west of the limestone. The demarcation is however obscure; and a variety of marlstone (which might perhaps be referred to the lower beds of the magnesian limestone) is found near Fackley, and at some other places on the west side of the line above given. This marlstone is vitrified by burning, and in that state is used for the repair of the roads.

‡ Smith's representation of the magnesian limestone in the southern extremity of Yorkshire is not accurate. 1st, The boundary line near Hart Hill is made to extend too far to the north-west. 2ndly, The limestone is extended from South Anston to Todwick, more than a mile too far to the north-west. 3rdly, The two valleys of denudation, through which the waters of the canal and the South Anston rivulet find a passage, are partly excavated in the limestone, and do not form an outlier as delineated in the map.

hilly ground east of Castleford on the river Air, the terrace gradually declines in elevation, but continues sufficiently well defined to admit of its being correctly delineated. Indeed on any map which fairly represented the great features of the country, it would hardly be possible to make any great error in the general range of the boundary line; the only difficulty would be in correctly delineating the indentations formed by the valleys of denudation*.

The beds of limestone near the boundary of the formation on the left bank of the Air appear very little above the level of the country on their western side; but they are backed to the north-east by hills of considerable elevation. Near Kippax Park the line of demarcation again begins to rise along the top of a terrace, which, in its range towards the north, is, however, devious in its direction, and in many places ill defined. Kippax, the east end of Parlington Park, Potterton, Kidhall, Scarcroft, and Rigton, are close to the edge of the escarpment. From the hill above Collingham the line gradually descends towards the Wharf, and crosses its bed a little above Wetherby. As this part of the geological county map is very inaccurate, I have subjoined a coloured outline map of the district, which will give a better general notion of the range of the magnesian limestone, and also of the position of several outliers, than can be conveyed by verbal description†.

On the left bank of the Wharf the limestone gradually ascends, in a direction nearly parallel to the river, as far as Linton; from thence it turns round the top of the hill to Linton-Spring without making any feature on the surface; then ranges to Stockeld Hall, crosses the Spofforth road, and deflects considerably to the south-east to Wetherby Grange. The boundary then ranges in the form of a low terrace to Ribston, passing about half a mile east of North-Deighton. From Ribston the line ranges along the top of the hill above Plumpton, and from thence along the crown of the hills which form the right bank of the Nid immediately to the south of Knaresborough. The greater part of this range from Ribston is difficult to determine correctly; because the limestone, without making any escarpment, only forms a thin irregular capping on the plateau of sandstone, and is in some places concealed by diluvium; and also because in the published maps of the county there is no adequate representation of the natural features of the country.

The range from Knaresborough to Ripon is very incorrectly laid down in the map of Yorkshire, and three or four outliers are omitted. The accompanying map ‡, and the following *memoranda*, will assist in bringing the delineation much nearer to the truth.

The limestone, after descending from the crown of the hills above mentioned, ranges through the woods on the south bank of the Nid, crosses the Harrowgate road in the brow of the hill immediately above the bridge, and extends along the upper part of the same bank (though in a very obscure form, and much disguised with diluvium) a few hundred yards further to the north-west. It crosses the bed of the river nearly opposite the Hall, and ascends along the north bank considerably higher, capping a part of Scotton Moor as far as the brow of the hill south-east of the village: from thence the line ranges on the edge of the *plateau* south of Scriven, to the north side of Knaresborough. It then makes a deflection to the east, and the demarcation afterwards passes, in the form of a low ill-defined terrace, by Gibbet House and Farnham, and descends into a valley of denudation a little above Okeney. On the other side of the valley the limestone occupies

* The irregularities of the line of demarcation in this part of the range are in general well represented in the geological map of Yorkshire. The line from Dinnington to Laughton is made to deflect a little too much to the north-east; and the limestone *plateaux* of Hooton-Lovett and Maltby ought to approach a little nearer to each other. Some other slight inaccuracies in the representation of the range near the banks of the Don are corrected in the accompanying map. (See Plate IV. fig. 4.)

† See the accompanying map (Plate IV. No. 2).

‡ See Plate IV. No. 1.

all the higher part of Walkingham Warren, and from thence extends along the top of the ridge into the liberty of Brearton. Its western extremity is, however, entirely concealed under accumulations of *diluvium*. From the *plateau* of the warren the line descends into a second valley of denudation, which it crosses at a point which bears about south-east from Burton Leonard*. For some miles beyond this point the range is well defined, and may be easily followed through a succession of quarries, which are opened in the escarpment to the south and west of Burton Leonard, and, afterwards, through a low ridge which crosses the Ripon road, and for some way runs near the north bank of the South Stainley rivulet. The prolonged line encloses Ingerthorpe, and may be traced to a hill about a quarter of a mile north-west of the village, beyond which place it bears away to the north.

In consequence of the enormous mounds of *diluvium*, which appear in some places to have buried the regular strata to the depth of two or three hundred feet, some remaining parts of the range to Ripon cannot be exactly ascertained. What is offered here can only be considered as an approximation; but, as far as regards this district, none of the published geological maps can lay any claim even to this humble merit. From the hill north-west of Ingerthorp, the demarcation ranges on the west of Markinfield Hall, appears to pass a little to the east of How Hill (which is one great mass of *diluvium*), to the west of Morker Grange, and a little to the east of Low Morker, near which place it passes down into the valley below Fountains Abbey, and from thence through the southern part of Studley Park to Clipthorn near Oldfield. From this place, for about two miles, no rock is visible, though the country is considerably elevated, and presents an escarpment towards the west; but in a quarry a little to the west of Linderick, the limestone breaks out from beneath the *diluvium*. The demarcation afterwards sweeps round to the N. N.E. (leaving Winksley considerably to the west), and crosses the next valley of denudation a little above Bishopton on the east side of Ripon. Some of the places mentioned above may perhaps belong to outliers of the limestone; for it is obviously impossible, in the present state of the country, to make out the entire continuity of the formation.

From the valley to the north-east of Ripon, the limestone, without making any great feature in the country, rises along the higher part of a ridge, and the demarcation passes to the west of Sutton Grange and Sutton, near Musterfield, and from thence to the top of a hill considerably to the west of Sleningford Hall. The ridge then descends in an irregular line towards the north, and the magnesian limestone crosses the Ure nearly half a mile below Tanfield. The formation then rises on the north side of the village to a commanding elevation, and ranges nearly in a straight line along the top of a lofty ridge through Gebdykes and Halfpenny-house, to a hill about two-thirds of a mile west of Watlas, where the escarpment abruptly terminates.

From Watlas to Little Crakehall there is no trace of the magnesian limestone: the whole of it is perhaps swept away; or a part of it may be buried under the heaps of diluvial gravel which are spread over all the neighbouring district. But the formation is laid bare in the bed of the rivulet between Brompton Patrick and Little Crakehall, and is continued in the same situation to a point below the latter village.

Again, for nearly five miles all traces of the formation are lost; but, on the private road from Bedale to Catterick (about a mile from the latter place), it breaks out from beneath a great mound of diluvial gravel, and is probably the base of a part of the ridge which extends towards

* The spur of limestone between the two valleys of denudation is not sufficiently extended by Mr. Smith to the south-west. It is also represented as an outlier; an error into which he has been led by the very inaccurate manner in which the courses of the neighbouring rivulets have been delineated in the map of Yorkshire.

Tunstall. It is also seen under thirty or forty feet of diluvium on the right bank of the Swale, about half a mile above Catterick Bridge*. These indications of the magnesian limestone, which are not noticed in the map of Yorkshire, seem to prove, that the formation was once continued (though probably much below its mean elevation) from Watlas to the river Swale. Indeed it appears to be generally true in our island, that the actual elevation of all the beds subordinate to the new red sandstone is greatly modified by the height of the formations on which they have been deposited in an unconformable position; and beyond Watlas there was probably no elevated ridge of the carboniferous beds to form the support of the magnesian terrace.

In the flat country to the north-east of Catterick Bridge, and along the eastern skirts of the mountain limestone hills near Middleton Tyas, there are no traces of the magnesian limestone. The formation may, however, in some places be disguised under the immense masses of gravel which are spread over the lower portions of the district †. Following the general bearing of the range, it reappears in a hill about half way between Newton Morrel and Cleasby. From thence it is probably continued under the mounds of *diluvium* near Manfield; for it is seen again on the south bank of the Tees below Pierce Bridge, and stretches on the same side a little way above the bridge, where it is capped with about thirty feet of diluvial gravel. On the same bank of the Tees and west of the Catterick road, it is seen in a highly characteristic form at Rennison quarry near Eppleby; and I am informed that it was discovered in sinking a well on the south part of Lowfield estate, and also at Chapel Houses a little to the west of the former place ‡. Whether these are separate patches of the magnesian limestone, or parts of a continuous mass, it is impossible to determine in the present state of the denudation.

After the formation enters the county of Durham, it continues to occupy for several miles a low tract of country; and, on its north side, appears to abut against a high irregular ridge of sandstone, which ranges through Bolam and Brussleton Tower. Under such circumstances the boundary can only be defined by determining a number of places which are on the western limits of the formation. I venture however to hope, that the following details will give the line of demarcation as nearly as the nature of the country admits. This line crosses the Tees immediately at Pierce Bridge, and extends on the north bank of the river into the rivulet which descends from Killaby. After ascending some way in the course of that rivulet, it appears to bear through the flat district in a north-westerly direction, encloses Headlam, and may be traced into some quarries between Hollin Hall and Langton. Langton, Ingleton, and Morton Tinmouth, are all situate on low hills, which are just skirted by the flat region of the limestone: and from the last of these places the line ranges nearly due east, skirting the south side of the ridge which extends to Houghton-le-Side; close to the south-east end of which place, the limestone is seen in some quarries abutting against the sandstone.

* Some beds of yellow marl, said to have been sunk through in excavating the ground near Hornby Church, may probably belong to the magnesian limestone; but I had no opportunity of examining them.

† I have been informed that wells, twenty or thirty feet deep, were sunk through the gravel at Scorton and Uckerby without touching the yellow limestone. At Moulton a variety of limestone is brought out by a flexure of the strata, which, from its colour and mineralogical character might be easily mistaken for a fragment of the magnesian limestone formation. Its fossils and the beds associated with it, plainly demonstrate it to be a variety of mountain limestone. Many other parts of the ridge which extends from Middleton Tyas to the north-west, partake of the same mineralogical character.

‡ The limestone of Low Field and Chapel Houses may, perhaps, belong to yellow magnesian varieties of the carboniferous limestone; for beds of that character occur at no great distance from these localities.

From these quarries the limestone rises into ridges of considerable elevation; but they are so much rounded off by denudation, and so nearly bordering on other hills to the north-west, that the demarcation is not easily traced. The line passes round the ridge of Houghton-le-Side, in a direction about north by west, crosses the turnpike road, and ranges on a *plateau* to a point about three hundred feet west of White House, from which point it returns and passes on the north side of Shackerton Hill. Under this hill there is a deep denudation, which has probably removed all the magnesian limestone. The demarcation appears to range in an undulating line bearing to the north-east, encloses Tod Fall, and crosses a rivulet a few hundred yards above Red House. On the other side of the rivulet the line ascends nearly due west, and encloses Newbiggen; beyond which place it is again deeply indented to the east by another valley of denudation, and then ascends to a point on the top of the next ridge about half a mile south of the Engine House. From thence it returns (enclosing the lime quarries of West Thickley) in a direction nearly due east, skirting for about two miles the south side of a remarkable denudation, which affords a passage to the great Stockton rail road. In this course it passes on the north side of Midderidge Grange, and crosses the rail road at Midderidge quarry.

Commencing at the last-mentioned quarry, the line passes under East Thickley, bearing nearly due west; afterwards sweeps round towards the north, forming all the higher part of the ridge which extends from East Thickley towards Shildon, and continuing its range on the summit of the high lands, passes immediately to the west of the old Shildon coal-pits and of the village of Eldon. From Eldon it sweeps round the west side of the plantation, deflects to the north-east, crosses a deep denudation where a considerable part of the escarpment has disappeared; then passes through a plantation south of Howlish Hall, and afterwards ranges considerably to the west, forming the cap of Cowndon Grange Hill. The line again deflects to the east, and the limestone forms the crown of the hills immediately west of Cowndon, and from thence ranges to Westerton. I have been the more minute in these details, because this part of the western demarcation of the magnesian limestone is not easily ascertained, and is not correctly laid down in the geological map of the county of Durham published in the year 1824.

From the neighbourhood of Westerton to Painshaw Hill near the south bank of the river Wear, the line of demarcation is much more plainly indicated by the natural features of the country; for the limestone again forms the crown of a great irregular terrace, the lower part of which is composed of beds subordinate to the Durham coal-field. To this arrangement there are, however, the following exceptions:—1. At Cowndon quarries, which are on the edge of the escarpment about a mile south of Westerton, the limestone is thrown out of its position, and made to abut against the sandstone. 2. At Westerton the escarpment is entirely composed of sandstone. The yellow limestone ranges at the same level (probably in consequence of a fault) on the north-east side of the village. 3. By a similar cause the inferior beds are brought to the top of the escarpment at Newbottle, part of which place stands on sandstone. 4. To the east of Hetton-le-Hole the limestone forms the whole escarpment; and some inferior beds of the formation extend from the base of the hills, which are in the general direction of the boundary to the western extremity of the village. With these exceptions, the magnesian terrace possesses the structure above described, and its range is defined by the following places, which stand very near its edge, viz. Merrington, Ferry Hill, Thrislington, Cornforth, Coxhoe Hall, Quarrington Hill, Cassop, Running Waters, Moorsley, Great Eppleton, High Downs, Newbottle, West Herrington, and Painshaw Hill. Black Gate, Quarrington, Sherburn, North Pittington, West Herrington, and Houghton-le-Spring, are immediately on the west side of the line of demarcation.

This part of the range is, on the whole, well represented by Smith, with the exception of a long narrow denudation, which has removed all the limestone escarpment south of Thrislington; with the exception also of a second denudation, which affords a passage for a rail-road, and has swept away all the limestone from West Herrington to East Herrington.

Neither of these two remarkable gaps in the formation is represented in the geological map of Durham. The extension of the limestone below the escarpment at Hetton-le-Hole is also omitted; and there are some other slight inaccuracies in the outline necessarily originating in the false engraving of the map.

The demarcation sweeps round the summit of Painshaw Hill, and there turns parallel to the river along the top of the escarpment, passes just to the north of Offerton, descends in an undulating line to the north of High Ford, down to Clacks Heugh, and thence by Low Ford to the bank of the Wear above Pallion. The passage of the formation across the river is disguised; but the limestone gradually ascends on the other side to the north-west, and passes close to Hilton Castle, which is at the bottom of an obscure escarpment. From Hilton Castle the line ranges for some way immediately on the north side of the road, then deviates to the north-east, and afterwards sweeps round the front of West Bolden Hills, and passes into the lower part of the village, from which place it ranges immediately on the north side of the road to East Bolden. A little to the north-east of the last-mentioned place the boundary is lost in some marshes. It appears, however, to pass near Tile-Sheds; and from that place it ranges a little way to the west of Cleadon, Harton, and Westoe. It is seen on the east side of the road from Westoe to South Shields; but it does not extend to the town, and its further range to the north-east is disguised by the hills of blown sand, which extend along the coast about two miles from the mouth of the Tyne*.

The magnesian limestone, as is well known, forms the capping of Tynemouth Castle Hill. For about two miles north of the castle hill, the cliff is composed of coal strata; but in the small headland immediately south of Cullercoats, the limestone again appears. This is the most northern point at which the formation is found on the coast. It is, however, seen in the neighbouring quarries near Whitley, of which a detailed account is given by Mr. Winch. (Geol. Trans. vol. iv. p. 4.) The masses of limestone at the three last-mentioned places are, I believe, unconnected with each other, and might without impropriety be considered as outliers †.

Such are the results of a series of observations made for the purpose of determining the limits of the magnesian limestone. The details are necessarily tedious, and may perhaps appear trifling. As however they are the result of considerable labour, and are absolutely necessary to a more correct delineation of the formation, I hope they may be considered of sufficient importance to be recorded.

Eastern boundary of the Limestone.

It appears from the details given above, that the escarpment of the magnesian limestone may generally be laid down with precision; and an examination of its range leads to the discovery of many objects of great interest.

* From Painshaw Hill on the right bank of the Wear to Tynemouth, the boundary line is extended by Smith too far to the west. A part of this line is, however, difficult to determine; for all the higher portions of the formation are seen in a chain of low round-topped hills, which stretches considerably to the east of the true boundary.

† The representation of the magnesian limestone in the geological map of Northumberland is erroneous. It is there made to extend uninterruptedly along three or four miles of the coast.

The eastern boundary of the formation presents, on the contrary, hardly a single object of any interest; and in the greatest part of the range from Nottingham to the coast of Durham, the superincumbent beds of the new red sandstone make no escarpment whatsoever. Under such circumstances (especially when the country is disguised with diluvial rubbish), it is frequently impossible to determine the precise boundary between the lower and the upper formation. To this line Mr. Smith's county maps give us the nearest approximations. The following short and imperfect notices are all which I have it in my power to add on this subject.

The southern extremity of this line commences (as above stated) close to Radford, and for some way appears to range on the west side of the rivulet. North of Basford it crosses to the east side, and is nearly defined by a chain of sand hills, which ranges parallel to the rivulet as far as Newstead Abbey. Close to that place the line deflects more than a mile towards the west, then runs nearly due south as far as Annesley Park, near the southern extremity of which it again bears towards the north, and passes round the south-west side of the village of Annesley. A great spur of the forest sand here passes over the whole breadth of the magnesian limestone, and is seen *in situ* in the village close* to the escarpment of the lower formation. The western boundary of this spur of the forest sand passes a little to the east of Annesley Woodhouse and Kirkby Woodhouse, and joins the undulating line of the sand hills, which range close on the south-east side of Mansfield. From thence the line ranges some way to the north-east; but afterwards, in consequence of the incoherent nature of the forest sand, the valleys of denudation, and the accumulations of diluvial gravel, it cannot be ascertained with any precision. Smith's line, which passes to the east of Mansfield Woodhouse and Sookholm, and to the west of Warsop, Cuckney, and Welbeck Park, is only an approximation.

The range is afterwards somewhat better defined, and passes a little to the west of Sloswick, and to the east of Radcliff, Darfould, Worksop Lodge, and Huggin-field; near all which places there are limestone quarries. The line then crosses to the north bank of the Worksop canal at Woodnook; and, in consequence of a projecting ridge of red marl, passes along the north bank to a place opposite Shire-Oaks; there it sweeps round the low projecting ridge of red marl, and passes on the west side of the village of Gateforth. Its range from Gateforth is very obscure; but it seems to bear nearly due north into a part of Cotterel Wood, and thence to the south end of Carlton; at which place the junction of the magnesian limestone and the sandstone is visible. From this point of junction the line appears to bear nearly due north through Carlton; near the northern extremity of the village crosses to the east side of the great road, and afterwards ranges considerably to the east of it as far as Tickhill, which is close upon the line of demarcation. So far the chain of sand hills, which commences near Nottingham, affords a general indication of the eastern limit of the inferior formation; but in its further range towards the north we are deprived even of this imperfect guide †.

* In a single spot on the south side of Annesley, the superficial breadth of the magnesian limestone formation disappears; and an ill-defined escarpment is partly composed of the limestone, and partly of forest sand. This projecting ridge of the forest sand is not noticed in the geological map of Nottinghamshire.

† At the village of Carlton the boundary line of the forest sand is thrown too much to the east in the geological map of Nottinghamshire. The extension of the forest sand into Sandbeck Park (as represented in the same map,) is, I think, erroneous.

Through the greater part of Yorkshire, north of Tickhill, the line is indicated, not by any prominent feature, but by the commencement of the great plain of the new red sandstone, which skirts the ridge of the magnesian limestone. In this way we may approximate to the true demarcation; but in many places its correct determination is rendered impossible, (especially where the beds of limestone are nearly horizontal,) by great accumulations of gravel and of drift sand, and occasionally by extensive tracts of turf land, which have been formed in consequence of the imperfect drainage of so flat a district. The east side of Tickhill, Hexthorpe, the west side of Doncaster, Adwick, Sutton, Askerne, the east side of Norton, Womersley, the eastern extremity of Knottingley, and the east side of Sherburn, are on the boundary line; and the upper beds of the formation terminate abruptly in a low ridge immediately to the east of Grimstone on the south bank of the Wharf. So far the general bearing of this line (with the exception of a small tract north of the Don, where it is not sufficiently extended to the east) is correctly given in the geological map of Yorkshire.

For some way beyond Grimstone all traces of the demarcation are lost in the alluvial plain of the Wharf: but the south bank of the river may be assumed as an approximate line as far as Newton Kyme. Near that place it crosses to the north bank of the river, and has a very ill-defined range; considerably, however, to the north-east of Thorp Arch, Wetherby, and Kirk Deighton. It afterwards passes immediately on the east side of Goldisbrough, and on the west side of Ferensby; crosses the valley of denudation considerably to the south-west of Staveley, and then sweeps round to the north-east side of Copgrove. From Copgrove the line passes on the west side of Bishop Monkton, thence ranges on the east side of Hollin Close, on the west side of Little Thorp, and at Ripon is lost under enormous heaps of diluvium*.

From the last-mentioned place the demarcation, as far as it can be traced in a country so much covered with incoherent matter, appears to pass considerably to the west of the road leading to Tanfield; then crosses the Ure immediately below the village of Stainley; afterwards ranges along the east side of Nosterfield and Well, skirts the east side of the road to Snape, ranges about one-third of a mile west of the village, and then skirts the road to Watlas, near which place, as before stated, the limestone ridge is abruptly cut off†.

The difficulties in determining the eastern demarcation of the magnesian limestone in the county of Durham are so peculiar, that they ought not to be passed over without a short notice. Here, as in the other counties through which the formation passes, the back of the limestone may, on a great scale, be regarded as an inclined plane dipping towards the lower region, which is occupied by the new red sandstone. The accumulations of diluvial gravel are, however, so enormous, that they not unfrequently occupy a zone several miles wide, and completely cover the boundary between the two formations. In some places, also, the colour and consistency of these accumulations make it doubtful whether we should regard them as mere heaps of diluvium, or consider them as subordinate to the new red sandstone ‡.

* The limestone is seen immediately to the west of Ripon; but in the town, wells have been sunk in diluvium to the depth of nearly one hundred feet. (See Plate IV. Nos. 1. and 2).

† Nearly the whole boundary of the magnesian limestone, to the north of Copgrove, is placed by Smith considerably too far to the east.

‡ The difficulty stated above appears to be acknowledged by Smith in his geological map of Durham. The line of demarcation is represented as very irregular in its bearings; and the formation immediately superior to the limestone is described as "red and bluish clay with alluvial matter." In the map published in the Society's Transactions (vol. iv. Plate I.), the range of this boundary line is placed, with one or two exceptions, several miles to the south-east of any spot where the magnesian limestone is visible.

As examples tending to confirm what has just been stated, I may mention,—1. That large quarries are opened in various parts of the superficial rubble, which almost covers the plains between Hartlepool and Stockton; and that at Greatham and some other places in that district, masses of magnesian limestone have drifted into the plain in great abundance, and are picked out of the quarries and burnt for economical purposes. 2. That near Windlestone, Mainsforth, and other places where small transverse valleys open through the limestone into the great plain, we find the country almost covered with lofty irregular mounds of coarse gravel or diluvial sand. 3. That on the great plain which extends several miles on all sides of Darlington, we not only meet with materials like those just described, but we find among them large water-worn blocks which have been drifted from the mountains of Westmoreland and of Cumberland.

These accumulations of diluvial matter are not, however, confined to the mere outskirts of the limestone, or to certain portions of the great eastern plain. Between Embleton and Elwick they begin to rise into elevated ridges; and from thence ranging about ten miles nearly due north over the very centre of the limestone, they terminate at Wardenlaw Hill, in a capping about two hundred feet thick, which is high enough to overlook all the eminences of the neighbouring district*.

Notwithstanding all these difficulties, Mr. Smith has given a good approximation (if we except a small tract of country on the north bank of the Tees,) to the true line of demarcation. The following short notices are all which I can add to the information which is conveyed on this head by his county map.

The rocks of High Coniscliff form the eastern boundary of the limestone on the north bank of the Tees; from thence the line ranges nearly due north, and appears to pass to the west of Thornton, to the east of Ulmby, and to the west of Walworth. Near the last-mentioned place the line seems to bear to the north-east, crosses the road leading to West Auckland about a quarter of a mile south of the fourth milestone, and thence ranges on the south side of Bracks, and on the south side of Aycliff, a little to the north of which place the ridge is interrupted by an extensive tract of low marshy land. This low tract of land extends considerably to the north-west, and is skirted by diluvial hills which approach near the western boundary of the formation.

Nearly the whole breadth of the formation is cut through by the valley of denudation above mentioned, which affords a passage for the new rail-road †. On the other side of it the range appears to be nearly due north towards Windleston, where every thing is buried under heaps of diluvial gravel.

* A detailed description of these diluvial masses does not come within the objects of this paper; but it may perhaps be worth while to state, that, in addition to a well known spheroidal block of Shap granite, about four feet in its longest diameter, which lies in one of the streets of Darlington, many other boulders of the same rock are found on the Yorkshire side of the Tees; that they occur in the village of Barton by the road side north of Newton, and in the river Tees close to Pierce Bridge; and that similar granite pebbles and boulders abound in a diluvial cliff further down the river. That at Wardenlaw Hill (which reaches an elevation of about eight hundred feet) the diluvial cap above mentioned contains rocks which have been drifted from all the neighbouring districts, mixed with masses of granite, syenite, micaceous slate, greenstone, &c. &c. some specimens of which it would be difficult to refer to their native seat.

The average thickness of the apparently diluvial hills which terminate at Wardenlaw would be difficult to determine, as they rest upon a very uneven surface of limestone. Close to Castle Eden they lately bored to the depth of twenty-six fathoms without reaching the bottom of a series of beds of loam, clay, and gravel, which appear to fill up a natural depression of the limestone.

† On the south side of the denudation through which this new rail-road descends from the West Auckland coal-field, no limestone is visible *in situ;* but it probably passes to the north side of the road under a cover of diluvium, near Midderidge quarry.

Hills of magnesian limestone, nearly bounded by the natural drainage of the country, rise on the north side of Rushy Ford, but are cut off by a valley of denudation descending from Thrislington. Along the course of this deep valley the whole formation has apparently been swept away. Beyond this denudation the main branch of the Skerne passes to the south of all the places where the limestone appears at the surface.

About Embleton and Elwick the ridges of diluvial hills above described entirely bury the formation; but in the rising ground to the south of Hart, the limestone is again uncovered, and the demarcation may be traced on the south side of Throston, and on the south side of Dyke House, till it is lost in the blown sand at the head of Hartlepool Slake. From Hartlepool to the mouth of the Tyne the magnesian limestone, as is well known, is the only rock which is visible on the coast, and is only interrupted by some inconsiderable cliffs, principally composed of blown sand, which appear to the north of the peninsula of Hartlepool, and near the mouths of the Wear and the Tyne.

§ 4. *Outliers of the Magnesian Limestone.*

After the preceding details respecting the range and external characters of the formation, it remains for me to notice the outliers which appear to the west of its escarpment.

A more careful survey of the county of Nottingham may perhaps lead to the discovery of some outliers of the yellow limestone, as there are several places where its western limit is ill defined. In the range through a small part of Derbyshire it makes a well-defined escarpment. In Yorkshire, notwithstanding the deep indentations of the escarpment, there is no outlier to the south of Conisbrough. A deep valley of denudation (which passes through a part of the village, and communicates with the Don) cuts off a plateau of the magnesian limestone. This outlying mass ranges from the crest of the hill immediately south-west of the castle, and from thence along the brow of the hill which overhangs the new road to Rotherham. The capping of limestone gradually disappears towards the south, without forming any regular escarpment: but a projecting tongue of the formation extends on the south-west side into the quarries of Hooton cliff, about half a mile from the village. The west and north boundaries of the remaining parts of this outlier are well defined, and are correctly delineated by Smith. On this plateau there is, if I mistake not, a second outlier; for a small, and apparently unconnected, patch of limestone breaks out from beneath the soil, in the fields about two hundred yards south of the turnpike gate. (See Plate I. No. 4.)

Following the range of the limestone towards the north, the next outlier is at Pontefract. It crowns the castle hill, extends through the town, caps the hill on the right of the road leading to Wakefield, and also the first hill beyond the outskirts of the town on the Doncaster road. If the colour were extended a little further to the south, the delineation of this plateau in the map of Yorkshire would be correct. There is, however, a very unusual difficulty in this delineation, arising out of the obscure separation of the limestone and the inferior sandstone: and as the capping of the upper formation appears to rest on an uneven surface, the plateau is perhaps composed of more than one outlier.

Three remarkable round-topped hills, composed of magnesian limestone, stretch in a south-westerly direction from the village of Kippax to Great Preston. The first of these hills (in consequence of a great fault which throws the Kippax limestone below its mean elevation) is probably connected with the escarpment of the formation, and cannot therefore be considered as an outlier.

The other two hills are outliers. One is immediately to the north of the angle formed by two rivulets; the other is under the village of Great Preston*.

A fine outlying cap of limestone commences close to the escarpment (near the angle made by the two rivulets which descend from Throstle-nest and Berwick in Elmet), and ranges through the village of Berwick on the east side of Scholes, and from thence to Barnlow. Its eastern boundary is very ill defined. Another small outlying patch appears to the north of Berwick, and on the west of the rivulet which descends from Kidhall. A much more remarkable capping of limestone is found about half a mile north of Seacroft. From the place where it first breaks out, it ranges about three-quarters of a mile towards Redhall; but it is much disguised with diluvium; and its greatest breadth does not appear to be more than half a mile. There are no natural features to assist in its delineation: but Pigeon-coat house and Roundhay grange are near its western boundary; and to the east it is nearly bounded by the occupation road.

To the south of the great denudation formed by the Wharf, there are three outliers: the first is seen immediately to the north-west of Bardsey church, on the top of the hill between the two roads; the second is much disguised by accumulations of diluvial gravel, but appears to crown an elevation on the south side of the brook which descends to Collingham; the third commences at the hill west of Collingham, extends about a mile on the Harewood road, crowning the hill on both sides of the road, and then deflects to the south-west, and terminates in the brow above Keswick †.

Near the banks of the Nid there are also three outliers:—1. Some highly inclined beds, apparently unconnected with any other mass of limestone, occupy for more than half a mile the right bank of the river near the north end of Bilton Park. 2. On the crown of the high land to the east of the village of Bilton, there is a large unconnected quarry of magnesian limestone; and a part of the plateau extending from thence into Bilton Park, is occupied by a marly soil, probably derived from the beds immediately inferior to the limestone. 3. A very remarkable outlier appears on the north bank of the Nid, a little below the place where the road from Harrowgate to Ripley crosses the river. It is brought down into its present position by an enormous dislocation; being surrounded by beds of the inferior formations, some of which are greatly above its present level. The great accumulations of diluvium conceal its extent: but it seems to range towards the village of Nid.

Lastly, two apparently outlying patches of limestone are seen on the south side of the rivulet which descends from Markington and South Stainley to Copgrove. The first breaks out in a quarry on the crest of the hill a quarter of a mile due south of Stainley Hall. The second extends from the hills immediately south-west of Markington to Markington lime quarries near the Ripon road. This patch is also laid bare at Wallowthwaite and one or two other places; but it is so much covered with diluvium, that it is impossible to make out its exact extent. It probably stretches in a south-easterly direction from Markington, about three-quarters of a mile. In a transverse direction it is probably not quite so extensive. It is, however, possible that both these patches may, under an enormously thick deposit of gravel, be connected with the main escarpment. (See Plate IV. No. 1.)

* Smith has placed these outliers considerably too far to the north: the map does not, however, admit of their being correctly delineated. A more correct representation of their position is attempted in the accompanying map. (Plate IV. No. 2.)

† This outlier is placed by Smith considerably too far to the west, and is in other respects inaccurately delineated. The projecting tongue of limestone at Scarecroft is also represented as an outlier, but I think incorrectly. (See Plate IV. No. 2.)

To this catalogue of sixteen outliers (only four of which are noticed in the geological maps) might perhaps have been added the patches of limestone at Little Crakehall in the hill north-east of Tunstall, above Catterick Bridge, and near Eppleby; also the three patches north of the Tyne. As, however, these apparently unconnected masses cannot be regarded as outliers from any existing escarpment, I thought it better to mention them in the former section; considering them as remnants of the formation serving to indicate the general direction of its range before it had been acted on by the great denuding currents, which have swept away some parts of it, and greatly modified the external characters of those parts which remain.

§ 5. *Relations of the Magnesian Limestone to a succession of Coal-formations.*

Having in the preceding details endeavoured to determine the superficial extent of the formation, and also to describe some of its most striking external characters, I now proceed to examine its relations to the several carboniferous deposits with which it is associated. In the coal districts of Somersetshire and Gloucestershire, the masses subordinate to the new red sandstone are obviously unconformable to every portion of the older formations on which they are deposited*.

An examination of the denudation of the river Eden necessarily leads to the same conclusion. The formation of new red sandstone extending from Kirkby Stephen to Solway Firth, is composed of materials mechanically drifted into a great depression of the strata, which was caused by the convulsion which separated the chain of Cross Fell from the calcareous zone which skirts the transition mountains of Cumberland. In some parts of this deposit are great beds of conglomerate, which in their position, their relations, and mineralogical character, are perfectly identical with the overlying conglomerates of the Somersetshire coal-fields†.

The geological relations of the magnesian limestone in its range from Nottingham to the mouth of the Tyne are much more obscurely exhibited. Through many large tracts of country (without the intervention of any con-

* See Geol. Transac. New Series, vol. i. Plate XXXII. &c. &c.

† Several masses of conglomerate, possessing the characters above described, are found in the higher parts of the valley of the Eden near Kirkby Stephen, and on the hills south of Appleby. Portions of many similar deposits are found within the limits of Whitehaven coal-field. At St. Bees Head the coal-measures are surmounted by a series of deposits in the following order:—1. A system of beds of coarse reddish siliceous sandstone. 2. Thin beds of magnesian conglomerate, surmounted by a system of hard and cellular beds of magnesian limestone. 3. Beds of red marl and fibrous gypsum containing in their lower portion some thin bands of earthy carbonate of zinc. 4. A great deposit of red freestone.

glomerate, or of any other bed indicating an extraordinary mechanical action) it rests on the coal-measures, and seems to partake of their dip and inclination. It is, therefore, only after an extensive comparison of the two formations that we can make out their general want of conformity. The fact appears however, in the first place, to be proved by the continuity and extent of the magnesian limestone, which, after ranging over the rich carboniferous deposits of Nottinghamshire, Derbyshire, and Yorkshire, comes in contact with the unproductive region of the millstone-grit; then crosses the Tees, skirts the West-Auckland basin, and afterwards crosses a productive part of the great Durham coal-field. In this range it passes over the edges of a succession of deposits which are neither continuous nor contemporaneous; it must therefore necessarily be unconformable to all of them. As these relations are of great economical importance, and have been in some respects misrepresented, the details connected with their history ought not to be passed over without a short notice.

1. The magnesian limestone is first seen near Nottingham in the form of thin and nearly horizontal beds occupying the level tract of country to the north-west of Radford. On the contrary, the coal-measures form an uneven hilly region stretching on the south-west side of the limestone. This contour tends to prove that the upper formation is unconformable to the lower; and the inference is said to be confirmed by the existence of some dislocations which traverse the coal strata without affecting the limestone. That the magnesian limestone in this region forms but a thin capping on the inferior strata, is demonstrated by the sections exhibited in a great many coal-pits which have been sunk through it. Many of them are now worked out and deserted; but some of them are still carried on near Radford and Asply*.

2. The regular range of the coal beds under the magnesian limestone is further demonstrated by a shaft near the edge of the escarpment at Kimberley, which passes through thirteen yards of the limestone, and then descends thirty-eight yards to a three-foot bed of coal.

3. The same conclusion is confirmed by the position of the Kirkby coal-works, and by the general dip of the strata in that part of the Nottinghamshire field. South of the village a deep valley of denudation encroaches on the boundary of the magnesian limestone; and in the lower part of the valley a new shaft has been sunk not far from the limestone escarpment, to the depth of more than 180 yards. The coal-measures are found to dip nearly due east at a small angle; and an excavation, formed for a rail-way, has exposed the junction of the upper beds of the series with the magnesian terrace, under which they appear to range with an uninterrupted and uniform

* I have been informed that a pit which was worked in the year 1823 near Asply, first passed through four or five yards of magnesian limestone, and then descended to the five-foot coal through seventy-six yards of the regular coal-measures. On the western side of the same coal-field near Bilborough, the measures are said to have been thicker. The old works were sunk through a few yards of limestone, descended thirty yards (through shale and bind) to a twenty-seven-inch bed of soft coal, and were afterwards carried down ninety yards to the five-foot coal. At all events, the sections near Nottingham prove that the coal beds pass under the limestone without any diminution in their value, except what arises from the greater difficulty of reaching them.

dip*. The indications exhibited by the coal works near Skegby (and we might also add by the whole coal-field extending from Pinxton to Tibshelf) lead to the same conclusion.

4. There can, I think, be no doubt that the magnificent terrace which ranges by Palterton and Bolsover, rests upon a productive part of the Derbyshire coal strata. Until, however, the neighbouring coal-field is more nearly exhausted, it is not probable that any great work will be conducted within the limits of the yellow limestone. A bed of impure coal was formerly worked under the limestone at Orscroft; and a similar impure pyritous bed is worked at Clown, close to the terrace of the limestone, under which all the inferior strata are carried by a gentle dip to the south-east †. At Knitacre Hill (about a mile and a half to the north-east of Barlborough), there are the remains of ancient coal-works considerably to the east of the terrace.

It is sufficiently evident from this short statement, that the magnesian limestone stretches over a part of the great coal formations of Derbyshire and Nottinghamshire: it also seems to follow that the same deposit must be unconformable to them; for the coal-beds which range immediately under the escarpment are not all of the same age, but belong to different successive portions of a great deposit, and therefore cannot in any sense be considered as contemporaneous.

5. After the magnesian limestone enters the county of York, it contiuues for about thirty miles to agree in its range, its dip, and its inclination, so exactly with the neighbouring coal-measures, that there seems to be little evidence in the district south of Pontefract to prove any want of conformity between the two formations. The limestone rests upon the highest known portion of the Yorkshire field, which contains some thin beds of coal generally impure and pyritous. Beds of this kind have been worked in several pits sunk on the west side of the magnesian terrace, and in a few instances the works have been conducted beneath it. At Micklebring (a village on the escarpment of the limestone about three miles south of Conisburgh) a swiftly burning impure coal, about seventeen inches thick, has been worked to a considerable extent. Some old shafts appear to have been sunk through the western skirt of the limestone; but the present works are prolonged under it by means of a level which enters the hill side below the village. The same bed of coal appears formerly to have been worked at the bottom of the hill on the road from Clifton to Conisburgh: and on the other side of the Don, between Metton and Barnborough, several shafts have been sunk upon a bed of coal, which agrees both in its quality and in its relations with that at Micklebring ‡. A similar bed was reached a few years since by a boring, which was made on Upton Moor near the edge of the limestone. Lastly, a bed of coal of like quality,

* In this part of the field the best bed of coal is about five feet thick; over it is half a yard of clunch (indurated slate clay), and above the clunch is a bed of soft coal thirty inches thick. The old pit sunk down to this deposit was six hundred yards west of the new shaft, and only 161 yards deep; from which it appears that the dip of the strata is about one yard in thirty. (See Plate V. fig. 1.)

† The following is a register of the strata sunk through at the Clown coal-shaft.

1. Vegetable matter and rubble	5 feet.
2. Yellow clay	5
3. Red sand	6
4. Marl, with a thin bed of iron-stone	6
5. Blue bind (a variety of soft unctuous slate-clay)	21
6. Dark shale (sometimes used for black chalk)	9
7. Pyritous coal	4 feet 4 inches.

Nos. 2. and 3. probably belong to the marl beds which separate the magnesian limestone from the true coal-measures. The impure coal would not have been worth extracting had it not been near the surface.

‡ A further account of the section of Micklebring will be given in a subsequent part of this paper.

though probably belonging to a lower part of the formation, was formerly worked near Water Fryston by means of a pit sixty yards deep. Though this pit commenced so far within the general limits of the limestone, the form of the country, and a knowledge of the inferior strata, may naturally have led to an expectation of meeting coal-beds at no great distance below the surface.

6. Between Pontefract and the valley of the Wharfe, the magnesian limestone ranges in a direction about N. and by W., over one of the richest divisions of the Yorkshire coal strata. In the same part of the field the average bearing of these strata is nearly N.E.; and their dip, with many flexures and irregularities, is nearly S.E.* In consequence of this relative position, the successive deposits of the coal formation necessarily range up to the base of the magnesian terrace: and that they pass under it without any change in their physical characters is proved, not merely by the analogy of the neighbouring country, but by many ancient and modern works, which, at Glass Houghton, Kippax, Church Garforth, and Parlington, have been sunk through the limestone into the lower formation.

A detailed account of the several sections exhibited at these places might form the subject of a distinct communication, but would be incompatible with the object of this paper. The following short notice of them will be sufficient for my present purpose.

There were formerly some collieries in Pontefract park; and many shafts were afterwards sunk in the low ground near Glass Houghton. As these works were exhausted, it became necessary to sink further upon the dip; and several pits were sunk on the skirt of the magnesian limestone: the newest work of this kind (at a place called High-Field) is considerably to the east of the escarpment. By these excavations, and still more by borings carried down to the lower beds of the neighbouring coal-field, it is ascertained that the whole carboniferous strata pass regularly under the limestone, with a mean dip towards the south-east of nearly one yard in twenty †.

Several extensive coal-works have been carried on in a lower part of the formation near Kippax. In consequence of a great flexure (which does not appear to affect the superincumbent limestone) the beds are tilted at a considerable angle towards the north; and the same seam of coal is found in the lower ground on the south side of the village, about twenty yards from the surface, which was formerly worked by pits sunk through the yellow limestone and other lower strata to the depth of nearly a hundred yards ‡.

Between Kippax and Aberford many ancient coal-pits (all of which are, I believe, now

* See the accompanying map. (Plate IV. No. 2.) The general bearing of the subordinate parts of the Yorkshire coal strata may be seen in Smith's valuable geological map of the county.

† The following is a rough sketch of the strata passed through by the High-Field pit.

1.	Yellow limestone	16 yards.
2.	Yellow sand	4
3.	Blue bind, with some purple-coloured sandy micaceous beds	7 or 8
4.	Light yellow and grey sandstone, containing a few concretions of sparry iron ore, and near the bottom passing into a harder brown sandstone	30
5.	A very impure coal (not worked)	5 feet.
6.	Blue bind	2 yards.
7.	Good coal	18 inches.

Forty-eight yards below the 18-inch coal (No. 7.), there is an impure 3-foot coal; and sixty-five yards still lower, there is a 5-foot coal. These two last beds have been proved by boring.

‡ One of the old pits on Kippax Hill was said to pass through thirty yards of limestone, and six feet of light yellow sand; below which were the regular coal-measures, consisting of blue bind, shale, and slaty sandstone. In general, the thickness of the limestone was not so great.

deserted) have been sunk through the plateau of limestone on the west side of the Roman road. Near Church Garforth the dip of the coal-measures is nearly due south; and, consequently, to the north of the village the successive beds rise towards the surface, and probably are only prevented from abutting against the superincumbent limestone by some beds of yellow sand and red-coloured clay, which are there interposed between the two formations. It was undoubtedly in consequence of this peculiarity of position that the ancient works commenced within the region of the limestone. Had the limestone been conformable to the coal strata, the several seams would have been most easily accessible on the west side of its escarpment; and the first excavations would have commenced in that quarter*.

7. North of the Wharfe the magnesian limestone ranges over the lower and almost unproductive part of the coal formation. On the right bank of the Nid several works have, however, been carried down to an impure bed of coal about three feet thick. The pits are seen a little to the north-west of the Bilton outlier; but none of them were sunk through it. There are also the remains of some ancient works at Winksley, a little to the west of the limestone. From the neighbourhood of Bedale the formation (as far as we can judge from the few remnants of it which are visible) appears to have ranged into the county of Durham, upon a portion of the carboniferous series which is generally classed with the millstone grit.

8. On the north side of the Tees the magnesian limestone, as appears by what is above stated, occupies for several miles a nearly level region, which terminates at the base of the carboniferous hills near Houghton-le-Side. The position precisely resembles that of the conglomerates, which are spread over the outskirts of the carboniferous limestone in the south-western coal districts of England, and is accounted for in the same way by the want of conformity between the magnesian limestone and the beds of the coal formation.

This fact is still more unequivocally shown in the range of the formation from Houghton-le-Side to Ferry Hill. The south-western extremity of the Durham coal-field is deposited in the form of an irregular trough or basin. The beds on one edge of this trough rise upon the lead-measures, and dip to the S.E.; but on the south-eastern edge they rise towards the terrace of magnesian limestone, and dip on the whole towards the N.W. Over this south-eastern-edge ranges the limestone (in the manner pointed out above); and in its whole course, from Houghton-le-Side to Ferry Hill, dips towards the S.E. It is impossible to conceive a more complete instance of want of conformity between two formations.

The facts on which this conclusion rests are indicated in all the quarries of the district, and in the sections formed by various coal-works which have been opened in the line of the limestone. At the Brussleton coal-works the average dip is about N. by E. In the Shildon works (some of which were formerly sunk through the limestone) the dip was about N. by W. At the village of Eldon the dip is nearly the same. Many old works were sunk through the limestone; and as these were exhausted, it became necessary to sink further upon the dip. The present works are on the west side of the limestone escarpment. At Coundon the coal-measures rise towards the limestone, and probably pass under it; but the present works are at some distance on the west side of the terrace. The dip of all the neighbouring coal strata is about N.N.W. Lastly, at Ferry Hill both the ancient and modern works are sunk through the plateau of magnesian limestone, which has a slight inclination to the S.E. After passing through about eight

* The present pits near Church Garforth are to the west of the limestone escarpment. This part of the field has been proved to contain twelve beds of coal; four only of which are worked. In one pit these four beds are found at the respective depths of 38, 58, 91, and 181 yards. The two lower beds (called the *high* and *low main*) are each about five feet thick.

fathoms of limestone, they reach the coal-measures, which dip about N. by E. at a considerable angle*.

Beyond Ferry Hill the coal strata decline more and more towards the east, and gradually acquire a dip which nearly conforms to that of the overlying formation. But near the Tyne the whole system of the coal strata is, by a great flexure, made to rise to the north-east; and in that position they appear to pass under the northern extremity of the magnesian limestone. In this part of the range there were formerly no coal-shafts sunk through the limestone; only because the productive beds were more accessible on the west side of it. But in the year 1822, a most magnificent work was completed near Hetton-le-Hole, which, after passing through fifty yards of magnesian limestone, descended down to the *Hutton-seam* at the depth of 297 yards from the surface: and several similar works have been since undertaken in the same neighbourhood †. (See Plate V. fig. 3.)

From all these details it follows, that the productive portions of the Nottinghamshire, Derbyshire, Yorkshire, and Durham coal-fields, which are covered by the magnesian limestone, are in no respect deteriorated in quality by its presence. The formation in its long and generally unconformable range sometimes passes over rich, and sometimes over barren parts of the great carboniferous deposits; but these are mere accidents of position, and not effects in any way attributable to the existence of the limestone. Inclined beds of coal when very near the surface may have sustained some injury from the mechanical action which accompanied the deposition of the superior formation: but the supposition of any other injury generally affecting the productiveness of the lower beds, seems to involve nothing less than a physical impossibility.

These conclusions are in strict conformity with the facts connected with our south-western coal-districts, which are detailed in a former volume of the Society's Transactions (Second Series, vol. i. p. 249—280); and they are

* The assertion "that no coal-mine had been seen in Northumberland or Durham under the magnesian limestone" is certainly erroneous. (Geol. Trans. First Series, vol. iv. p. 8.) The principal beds worked under the magnesian limestone in the county of Durham in the places above mentioned are, I believe, the *five-quarter-seam* and the *high-main*. That the coal-beds generally pass under the limestone cannot admit of doubt; and there does not appear to be any good ground for supposing that when in such a position they are deteriorated in quality. As this fact is of great importance, it may be proper to add, that at Nunstainton (a few miles to the S.E. of Ferry Hill) a good bed of coal was reached, at the depth of about fifty-eight fathoms, after boring through about forty fathoms of magnesian limestone.

From the sections near Cowndon, it seems probable that the coal-measures, after passing under the limestone, make a saddle and dip to the S.E. At Ferry Hill, on the S.W. side of all the present works, the coal strata are traversed by a fault, beyond which they are supposed to dip towards the S.E., a direction nearly opposite to that which was stated above. Should this great flexure of the coal strata under the limestone be true, it makes the want of conformity between the two formations still more remarkable, and at the same time explains the appearance of the coal-beds under the limestone at Nunstainton.

† For the number, relative position, thickness, and provincial names of the several productive beds in the great northern coal-field, see Mr. Winch's paper (Geol. Trans. First Series, vol. iv.), and Mr. Westgarth Foster's section of the coal-measures.

further borne out by the workings of the Whitehaven field; some of the richest of which are sunk through a covering of magnesian limestone.

Within the limits of this formation many more works will be undoubtedly attempted when our present fields begin to be exhausted. Its unconformable position will, however, throw great difficulties in the way of such undertakings; for in the districts where it is present, the surface of the ground can seldom give any indication of the contour of the carboniferous beds below, or of those flexures and dislocations by which they may have been affected; and without such knowledge mining operations must often end in disappointment.

Considered on a great scale, the magnesian limestone in the county of Durham may be described as a dam passing over the south-east side of the coal basin, and cutting it off from all direct communication with the sea, except in two places, where the dam is broken through by the channels of the Wear and the Tyne. The richest parts of the coal-field bordering on these rivers are already beginning to be exhausted; and some of the more remote parts are, by means of rail-roads, now brought into communication with these navigable outlets.

The rail-road from West Auckland to Stockton is twenty-three or twenty-four miles in length; and the coals are dragged out of the basin by a fixed steam-engine, over an elevation which is 472 feet above the high-water mark at Stockton.

At the single pit of Hetton-le-Hole (the works of which are carried on both in the *High-main* and *Hutton-seam*), more than a thousand tons of coal are each day raised to the surface*. After being driven by moveable steam-engines along the base of the magnesian terrace, they are, by the power of two fixed engines dragged to the top of it, along a system of inclined planes which reach an elevation of 350 feet above the first level from which they started. From thence they descend along a second system of inclined planes, and are afterwards rapidly transported by moveable steam-engines to the banks of the Wear.

An excellent line of communication (and as far as regards the mere transport of coals to the coast, a much better one than that which has been effected from West Auckland) might be established between Stockton and a rich part of the coal-field, through a natural depression of the limestone terrace immediately to the south of Howlish Hall.

But the singular denudation of Thrislington gap (where a chasm has been

* These facts relate to the state of the colliery in the summer of the year 1826.

formed completely through the terrace) offers the best line of communication between the sea coast and the part of the coal basin to the south of Durham. From this part of the great field, coals might be conveyed to the sea by a series of nearly dead levels not more than twelve or fifteen miles in length, on which it would not, I believe, be necessary to use a single fixed engine. Millions of tons of coal are destined in future times to descend through this gap to the neighbourhood of Stockton. Indeed before long, all the remote parts of the coal basin will be intersected with rail-roads, which will rise over the escarpment of the yellow limestone, and meet, like converging rays, at the nearest sea-ports.

§ 6. *Faults affecting the Limestone and the Coal Strata, Trap Dykes, &c. &c.*

The unconformable position of the magnesian limestone being admitted, it follows of course that many faults and dislocations which traverse the coal strata will not affect the overlying formation. As, however, the causes producing these dislocations are not confined to any one epoch, many faults are common to both formations, or at least pass out of one into the other without any visible interruption. Of this kind there are two examples on the coast of Northumberland: the first, in Tynemouth Castle cliff, is not of great extent, but is well exposed in a fine natural section (Plate VI. fig. 1.); the second, which is much more remarkable, is seen at Cullercoats. The *ninety-fathom-dyke* there cuts through the cliff, and produces an enormous down-cast to the north, by which the magnesian limestone is once more made visible, and brought down to the level of the beach (Plate V. fig. 2.)*.

Another and a very interesting class of faults which intersect the coal strata, are marked by the presence of trap dykes. It has been assumed that, in the country above described, these dykes are strictly subordinate to the coal formation; and from thence it has been inferred that they never pass up into the beds of overlying limestone: the conclusion may generally be true, but it is not borne out by any satisfactory evidence. Many dykes of trap were probably injected among the coal strata at the time of their first dislocation, before the existence of any part of the overlying formations. Such dykes cannot possibly traverse any part of the magnesian limestone; but we know

* If the fault at Cullercoats be identical with that which is supposed to pass under the quarry of Whitley, it will be difficult to reconcile the fact, stated in the text, with the section of Whitley quarry, given in the Society's Transactions (First Series, vol. iv. Plate IV.). At all events the yellow limestone is certainly dislocated by the great dyke at Cullercoats. No trap is there visible. The word *dyke* is applied by the miners of the north of England indifferently to all highly inclined faults, whether trap be present or not. An ignorance of this use of the word *dyke* has led to occasional mistakes.

from examples in the north of England, in the north of Ireland, in the Hebrides, and in many other parts of the world, that trap dykes are not confined to the carboniferous order. They are found in very great abundance in many deposits of a much newer epoch. Hence, many of the trap dykes in our coal-fields may belong to a comparatively recent age; and the only examples of any direct value in proving the first conclusion (viz. that such dykes do not pass up into the overlying beds), are those in which the trap cuts through portions of the coal strata in immediate contact with the magnesian limestone.

In Nottinghamshire, Derbyshire, and Yorkshire, I never found a single example of a trap dyke near the great overlying terrace. In the counties of Durham and Northumberland (notwithstanding the common occurrence of trap in the coal formation) there are but two examples of dykes which bear upon the present question; and they appear to lead to opposite conclusions. 1. The well known dyke which descends from Bolam to Houghton-le-Side, comes to the eastern edge of the magnesian limestone, and is lost under the alluvial and diluvial covering. But beyond the eastern boundary of the formation another dyke, agreeing both in its direction, inclination, and mineralogical characters with the former, breaks out from beneath the diluvium, and ranges without interruption into the moors south of Whitby. If these two trap dykes form one continuous mass (which is at least very probable), they must undoubtedly cut through the magnesian limestone. 2. The next example is at Quarrington Hill (three or four miles south-east of Durham), where a trap dyke rises almost perpendicularly through the carboniferous beds, but does not penetrate the capping of limestone. It is therefore probable, though by no means certain, that this dyke assumed its present form before the limestone was deposited*.

The trap dyke at the south-west end of Tynemouth Castle cliff is unfortunately of no assistance to this inquiry; because the capping of yellow limestone does not extend to that extremity of the cliff where the dyke is present.

Such is the imperfect evidence, or rather such is the absence of all direct evidence in favour of the conclusion, that the trap dykes in our northern coal-fields belong to an age which is anterior to the deposition of the magnesian limestone. That in some instances there may be probable reasons in favour of this conclusion I do not pretend to deny; but this is not the proper occasion for discussing them.

* For a detailed account of the two trap dykes mentioned above, see Transactions of the Cambridge Phil. Soc. vol. ii. pp. 21, 40.

CHAPTER II.—*Internal Structure of the Formation of Magnesian Limestone, &c. &c.*

Having described in general terms the range and extent of the formation of magnesian limestone, the external character of the country through which it passes, and its relations to the strata of the carboniferous order, I now proceed to give some account of its internal structure, and of the composition of its subordinate parts. In doing this, it appears necessary, for reasons already stated, to regard it as a complex formation subordinate to the group of the new red sandstone; in which case it admits of the following natural subdivisions.

1. Lower red sandstone.
2. Marl-slate, associated with grey, thin-bedded, and nearly compact limestone.

2*a*. Variously coloured marls, with thin beds of compact and shelly limestone.

3. A great deposit of yellow magnesian limestone; often cellular and earthy, sometimes hard and crystalline.
4. Lower red marl and gypsum.
5. Grey thin-bedded limestone.
6. Upper red sandstone.
7. Upper red marl and gypsum.

A detailed description of the two last of these subdivisions (which together constitute what has generally been called the new red sandstone formation) will not be attempted in this paper. They are only introduced for the purpose of explaining the relations of the inferior groups.

§ 1. *Lower red Sandstone.—Pontefract Rock of Mr. Smith.—Rothe-todte-liegende of the German Geologists.*

By the lower red sandstone, I mean the lowest member of the group of the new red sandstone, which in Yorkshire and Durham is interposed between the carboniferous order and the strata of magnesian limestone. During my first visit to the county of Durham, I examined many sections which exposed the junction of this limestone and the coal-measures, in the hopes of discovering the existence of beds of conglomerate resembling those which, in the neighbourhood of the south-western coal districts, are spread over the inclined edges of the older formations. In this hope I was generally disappointed; but I found that the lower beds of limestone were occasionally arenaceous, and that in some places they reposed upon, and seemed to pass into a yellow incoherent coarse siliceous sand. It appeared, therefore, that those mechanical agents, which in many parts of England had acted with such destructive violence, had here operated upon the carboniferous strata much more feebly, and only produced a number of irregular masses of drift sand, on which the formation of yellow limestone was subsequently deposited.

During the same year I had an opportunity of observing in a part of Yorkshire, that the magnesian limestone rested upon a system of beds of very peculiar character, which in some places resembled coarse millstone grit, and in others had more the appearance of new red sandstone. As, however, I had at that time no means of ascertaining the extent and continuity of this deposit, and as I found that its upper surface was in some places unconformable to the limestone which rested upon it, I erroneously concluded that it was a peculiar formation of gritstone subordinate to the Yorkshire coal-field.

Not long afterwards I became acquainted with Mr. Smith's geological map of Yorkshire (which was published in the year 1821), and then, for the first time, I saw the importance of the above-mentioned deposit in that county. It is there shown to be coextensive with the magnesian limestone, from which it follows that it must be unconformable to the coal-measures. Hence, notwithstanding its mineralogical character, which in some places almost identifies it with the inferior strata, it is absolutely necessary to separate it from them, and to regard it as the first term of an entirely new series of deposits, of which the magnesian limestone forms so prominent a part. To Mr. Smith, therefore, belongs the honour of having added this member to our English secondary formations. In classing it with the coal-measures he, however, deprived it of its real importance: and Mr. Conybeare was, I believe, the first who published an opinion that it was analogous to the *rothe-todte-liegende;* and therefore formed a new connecting link between the physical history of our own country and that of the continent.

During several subsequent visits to various portions of the escarpment of the magnesian limestone, I had an opportunity of verifying many of the details given in the geological map of Yorkshire, and of ascertaining that the beds of incoherent yellow sand which I had before observed in the county of Durham, are nearly coextensive with the limestone which rests upon them. As the result of all these observations, it appears that, with a few interruptions, a formation of sand and sandstone of variable structure and thickness may be traced between the coal-measures and the magnesian limestone, from the mouth of the Tyne to the confines of Derbyshire*.

* In the geological map of the county of Durham no notice is taken of the lower red sandstone.

Like most deposits of mere mechanical origin, the lower red sandstone is in many places of so complex a structure, that a correct notion of it can only be conveyed by a series of detailed sections. Considered on a great scale it is, however, found to preserve a general uniformity of character, and may be resolved into the following principal varieties.

1st. Conglomerate, resembling the newer red conglomerate which overlies the western coal-districts. Of this variety there are some imperfect examples at the upper surface of the sandstone near its junction with the magnesian limestone; but in such situations they may perhaps more properly be associated with a superior division of the formation. (See Plate VI. figs. 1. 2. 3. 5.)

2ndly. An extremely coarse siliceous sandstone, sometimes containing round pieces of quartz more than an inch in diameter, which are generally ranged in lines nearly parallel to the planes of stratification, though they are in other respects very irregularly disseminated. This variety is so usually of a red or purple tinge, that the colour may be regarded as characteristic of it. There are, however, many local exceptions; as the rock is in some places of a light grey, and in others of a yellowish brown colour. It almost universally contains a considerable portion of earthy felspar, which in some localities abounds so much, that the whole rock becomes nearly incoherent. In these cases the formation decomposes into irregular grotesque forms, and the face of the country through which it passes is covered with rude concretionary blocks which resemble decomposing boulders of granite or syenite. It is not possible to mistake the nature of the earthy constituent; because crystals of red felspar, sometimes exhibiting all their faces and angles, but most frequently rounded or otherwise altered by attrition, are (in various stages of decomposition) studded over the rugged surfaces of the sandstone blocks above mentioned. At the same time it is extremely difficult to account for the abundance of this mineral, as there are no granitic rocks near the range of the sandstone; and the millstone grit and other beds of the contiguous coal-measures do not appear to have contained felspar in such abundance as to supply the *kaolin* and crystalline fragments which are imbedded in the superior formation. In the places where the preceding variety predominates, the stratification is generally obscure; and there are constant examples of that kind of false bedding in which the planes of separation of the principal masses are not parallel to the planes of stratification.

3rdly. A variety chiefly differing from the preceding in being smaller-grained and more regularly bedded. Most of the beds are micaceous, and some of them form a good stone, which is extensively quarried*. In this, as

* In some parts of Yorkshire, especially between Wetherby and Knaresborough, these beds

in the last variety, a red or purple tinge predominates: but these colours pass through every variety of shade; in some places are only seen in the form of cloudy spots, and in others disappear altogether. The rock then becomes a brown or grey micaceous sandstone, which sometimes cannot be distinguished from the gritstone beds of the coal-measures.

4thly. Fine-grained sandstone, much less coherent than the preceding, and less regularly bedded. In composition and colour it sometimes resembles the most ordinary varieties of new red sandstone.

5th. Nearly incoherent sand. In this state it is very extensively developed, and sometimes alternates with the preceding variety. These incoherent masses are seldom much tinged with red oxyd of iron, but more frequently exhibit a grey or yellowish brown colour. They sometimes contain small spherical calcareous concretions; and the upper portion occasionally becomes calcareous and cellular, and passes insensibly into the superior deposit of limestone.

6th. Sandy micaceous shale, often variegated with stains of a red or purple colour. This variety not unusually alternates with some of the preceding. The argillaceous earth which produces this variety is hardly ever in such abundance as to entirely destroy the ordinary type of formation: for there is perhaps not a single locality where it could be mistaken for a characteristic mass of slate-clay subordinate to the coal-measures. Near the upper part of the formation it is often associated with red marl and soft red micaceous slaty sandstone.

7th. Marls, much varied both in colour and composition. They have generally a red tinge, or are variegated with red and purple blotches. They are frequently interposed between the beds, but they are chiefly developed at the higher part of the formation, immediately under the yellow limestone. In that situation they are of very common occurrence, though seldom of any great thickness. Notwithstanding their extent, and the many sections in which they are exposed, I never observed in them any beds of fibrous gypsum like those which characterize the upper marls of the new red sandstone; but they contain, in a few rare instances, crystals and crystalline nodules of selenite*.

It appears from the preceding details that iron, either in the form of a hydrate or red oxyd, is commonly diffused through all the subordinate parts of

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are extensively quarried for troughs, coping-stones, and coarse flagstones, &c. &c. At Hart Hill, near the southern extremity of the same county, some of them are used as a rough building stone, and the finer beds are ground down into scythe-stones.

* The most remarkable instance of this kind which fell under my own observation occurs on the right bank of the Nid, a little above the bridge which leads from Knaresborough to Harrowgate.

the formation above described. In some of the beds, especially in the harder varieties of sandstone, it is disseminated in the form of yellow and red ochreous concretions, which rarely pass into a true hæmatite; and it often gives a deep red tinge to the argillaceous bands which are interposed between the strata. In the escarpment under the yellow limestone at Micklebring, a few miles south of Doncaster, it is deposited in the form of an earthy red oxyd in beds of considerable thickness, which alternate with a red-coloured micaceous sandstone.

Such are the leading characters of the inferior red sandstone; and an attempt at a further subdivision of it in a more general description, which has no immediate reference to individual sections, would not, I think, be attended with any advantage. In the arrangement of the subordinate parts there does not appear to be any constancy, if we except the red and variegated marls which are so commonly found immediately under the limestone, and also the obscure conglomerates above mentioned, which, in a few instances, occur in the same position.

Range and extent of the Lower Red Sandstone, &c. &c.

From the edge of Derbyshire to the river Air, this deposit is generally confined to the middle or lower part of the terrace, which is crowned by the magnesian limestone. Its superficial extent may therefore be represented on a geological map by a shade of colour traced on the western border of the limestone. This is the mode adopted by Mr. Smith, whose delineation of the range through the southern parts of Yorkshire is extremely accurate.

In tracing the formations from the south towards the north, the inferior red sandstone is, I believe, first seen in a characteristic form near Barlborough, not far from which place a quicksand is found immediately under the escarpment of the yellow limestone. Following the demarcation into the county of York, we find the deposit well exhibited at Hart Hill in the form of a coarse red micaceous sandstone, the upper part of which becomes more thinly bedded and of finer texture, and is surmounted by marl beds and the inferior strata of the yellow limestone. In the two next valleys of denudation, and on the hills above North Anston and South Anston, the coal-measures and limestone are separated from each other by a coarse variegated sandstone, in some places of a dark brick-red colour, which has innumerable false planes of division, and is surmounted by slaty red sandstone and red marl. At Maltby and Micklebring the deposit has the same general characters; but a little further to the north, between Clifton and Conisburgh, the beds are more coarse and indurated, and have been extensively quarried.

In all this part of the range, though the mineralogical characters are nearly constant, the thickness of the deposit is extremely variable: for in some localities it forms a mere band, ranging through the mid region of the escarpment immediately under the magnesian limestone; while in others it occupies all the lower part of the terrace, and probably extends considerably to the west of its base.

At the village of Cadeby (on the north bank of the river Don) it becomes of complex structure, and of great thickness. The lowest parts of the formation are not exposed, being buried under the incoherent materials which have descended from the upper part of the escarpment; but a series of strata are laid bare in a hollow road nearly in the following order, beginning with the lowest. 1. Beds of loose micaceous sand with grey sandstone partings; whole thickness not exposed. 2. A freestone about fourteen feet thick, very irregularly bedded, and variegated; some parts being light grey, and others greenish red with cloudy spots. 3. Beds of sandstone and sandy shale, with some partings of ochreous marl. 4. Beds of bluish marls, with bands of variegated and red micaceous freestone. 5. Red and yellow marls immediately under the limestone. If the whole system of these beds were laid bare, their united thickness would probably amount to more than one hundred feet.

In following the remaining part of the escarpment as far as the river Went, it appears to recover its more usual characters; as the portions of it which are visible consist of coarse-grained sandstone, more or less stained with red oxyd of iron, and of slaty micaceous sandstone, generally red and variegated; alternating with, and surmounted by, marls of the same prevailing colours. In one or two places (especially on the line of the road from Doncaster to Wakefield), it spreads out considerably to the west of the limestone, and forms a low but well-defined escarpment.

Again, between the valley of the Went and Pontefract the deposit becomes of greater thickness and more complex structure; containing much incoherent micaceous sand, which, by its degradation, forms a narrow zone of light unproductive soil in the lower part of the terrace, between the limestone and the highest beds of the coal formation.

Immediately round Pontefract it is well exposed in several characteristic sections, especially under the regular escarpment which ranges on the south-east side of the town, where several quarries have been opened in a coarse grey sand and sandstone, which is micaceous, irregularly bedded, partially tinged with red, and contains a few concretions of hydrate of iron, but does not exhibit any of the usual red, blue, or variegated marls. The soft yellowish grey sandstone under the Castle must be referred to the same formation, as well as several of the sandstone quarries near the south-western extremity of the town. There is, however, a peculiar difficulty presented by some of these localities, arising out of the absence of the separating marls, and the apparently gradual passage of the sandstone into the limestone, which makes it almost impossible to ascertain their precise limits. The difficulty does not, however, end here; for on the road leading from the outskirts of the town towards Wakefield, a strong yellowish brown siliceous grit (which, if I have not been misinformed, has been proved by boring to the depth of at least eighty feet) appears below all the beds before described. At first I took for granted that the whole mass of this grit represented the lower portion of the inferior red sandstone; but a subsequent examination of the strata at High Field colliery, a few miles north of Pontefract (where the several beds were cut through by a pit sunk in the year 1823, from the magnesian limestone to the coal-measures), made me at least doubt the propriety of this conclusion*. I have been the more particular in referring to these sections, as Mr. Smith designates the formation I am attempting to describe by the name Pontefract Rock,—a term which ought on no account to be retained; because the sand rock, for the reasons above given, is not there developed in a manner sufficiently distinct and characteristic to be considered as a good general type of the deposit.

After the terrace crosses the Air, there are for several miles no denudations which exhibit the junction of the magnesian limestone and the coal-measures. But in various parts of the low terrace which extends by Kippax and Church Garforth towards the Abberford rivulet, we have

* See the High Field section, ante p. 58. It is, I believe, impossible in that section to draw any well-defined line between the lower red sandstone and the coal-measures.

a proof, both in natural sections and in various coal-works, that the deposit occupies its proper place, though in a very imperfect form. Further north it is much more developed; and at Scare-croft Mill, Rigton, and the hill above Collingham, is seen in its most characteristic form. It is also laid bare in a very singular denudation on Bramham Moor, and the south-eastern extremity of Bramham Park, considerably within the limits of the limestone, where it is chiefly composed of a singularly coarse grey sandstone, which contains such an abundance of *kaolin* as to be in many places incoherent*. The deposit is in this district of very unequal thickness, and probably extends in irregular patches considerably beyond the western limits of the escarpment, accompanying the various outliers which have been enumerated in a former part of this paper.

In the greater part of the range from the Wharfe to the Nid, the sandstone forms an advanced terrace, which ranges considerably to the west of the plateau of the magnesian limestone; and its prevailing character is that of a coarse irregularly bedded purple-coloured sandstone, sometimes nearly approaching the appearance of a conglomerate, and decomposing into irregular masses presenting many complicated forms of great picturesque beauty †. Possessing nearly the same characters, it is laid bare in many of the noble sections which are presented in the great cleft, which, on the south side of Knaresborough, allows a passage to the waters of the Nid. In some of the quarries it consists of the usual coarse sandstone, with *kaolin* and fragments of felspar crystals; in others it passes into a strong red or variegated sandstone, often falsely bedded, with bands of red marl, occasionally with concretions of ochre; and near the top it here and there presents thin beds of micaceous incoherent sand mixed with red marl.

To the north of Knaresborough it is seen in scattered blocks in a few quarries on Scotton and Breareton Moors; and again in Scara quarries north of Ripley, and on both sides of the rivulet below South Stainley. It is therefore extended, though probably in unconnected masses, several miles to the west of the limestone terrace. It is however difficult, and perhaps impossible, to determine its precise limits; as it makes no escarpment, and can hardly be distinguished from some varieties of millstone grit which range through the same district. The remaining part of the terrace, which terminates at Watlas, is so much disguised with diluvium, that it is hardly possible to trace the beds I am describing. We may, however, conclude from the indications of a few natural sections, and still more from the number of loose blocks in the diluvial detritus, which agree in character with the inferior red sandstone, that the formation is probably coextensive with the limestone.

The extensive destruction of the superior formations between Bedale and the banks of the Tees, and the accumulations of incoherent matter, make it almost a hopeless task to seek for the red sandstone in that district. At the same time the low position of the few patches of magnesian limestone which remain, make it probable that the sandstone was very imperfectly developed before the denudations were effected.

In the flat region immediately north of the Tees, it appears hardly possible, for want of sections, to ascertain the nature of the beds which range under the limestone: and the relations of the lofty sandstone hills which pass along its north-western skirt between Houghton-le-Side and Brussleton Tower, are far too obscure to be easily determined. These hills are chiefly composed of a grey sandstone rock of very varied texture, but affording some excellent quarries which have been used

* See Plate IV. No. 2.

† The scenery in the neighbourhood of Plumpton shows the character of the rock in great perfection; and if an unmeaning designation is to be given to it, merely borrowed from some locality where it is well exhibited, I think the term *Plumpton sandstone* might be adopted with advantage.

in the construction of the Stockton rail-road. The mineralogical character of this sandstone, its great elevation, and its apparent want of conformity to some parts of the limestone terrace, might seem good reasons for placing it in the carboniferous order. The sections presented at Houghton-le-Side in the quarries on the east side of Brussleton Tower Hill, and in the quarries near East Thickley on the north side of the rail-road, made me however doubt the propriety of such a conclusion, and induced me to regard a portion, at least, of the sandstone hills in question, as an unusual development of the lower red sandstone. The part of the terrace extending by Eldon, Cowndon, &c. to Ferry Hill, does not in any way assist in clearing up these difficulties: for in two or three places when the escarpment is not disguised, we find a light grey sandstone immediately inferior to the limestone, which by some may be regarded as one of the most ordinary members of the coal-measures; by others, as an exhibition of the inferior red sandstone, though under an unusual form.

In the range of the escarpment from the north-east side of Ferry Hill to the banks of the Wear, there is a formation of sand and sandstone, about the true relations of which it seems impossible to doubt; for, notwithstanding its very variable thickness, it is seen at so many places under the limestone, that it must form a nearly continuous mass stretching obliquely over the successive portions of the Durham coal-field*. It must therefore be unconformable to them, and can only be referred to the lower red sandstone.

Notwithstanding the absence of a continuous terrace, and the want of numerous natural sections, there can be little doubt that the same sandstone is continued from the banks of the Wear to Tynemouth Castle Hill: for it is well exhibited in the hill near Hilton Castle, under West Bolden, and in the cliff under Tynemouth Castle†; and two quarries of micaceous sandstone on the road from Westoe to Jarrow belong apparently to the same formation.

Its mineralogical character in this part of Durham is, as before stated, very different from the more usual type of the same formation in Yorkshire. It is most usually seen under the form of a yellow micaceous sand; or of a yellow sandstone so imperfectly coherent, that it falls to powder under the shock of a blast, or the blow of a heavy hammer. Traces of red sandstone and the subordinate marls are not, however, altogether wanting. For example, in the escarpment at Rough-dean near Houghton-le-Spring, the following beds are exposed.

1. At the bottom a strong grey freestone. About twenty feet are visible; and near the top it passes into a soft slaty micaceous variegated sandstone.
2. Yellow and light blue unctuous clay, four feet.
3. Red and black clay, about one foot.
4. Yellow incoherent sand, twenty feet.
5. Over the preceding are marl beds, and the yellow limestone; but they are not exhibited in this section. I was not able to determine the true place of No. 1. with certainty: the other beds evidently represent the lower red sandstone.

Again, there is at Clack's Heugh, on the south bank of the Wear, a magnificent natural section of the deposit, in the form of a yellow sand, of a great but unknown thickness, supporting the limestone, and in consequence of a fault abutting against the coal-measures ‡. But on the opposite bank of the river it is exhibited under a more complex form in a succession of beds of

* In proof of what is stated above, I may refer to the following localities, where the inferior sandstone is well exhibited. Thrislington Gap, Coxhoe Hill, Quarrington Hill, in the various coal-pits near Hetton-le-Hole, Houghton-le-Spring, Painshaw Hill, and the sections on the banks of the Wear near Clack's Heugh. (See Plate VII. fig. 3. and Plate V. fig. 1.)

† See Plate V. fig. 2.

‡ See Plate VII. fig. 1.

great thickness. The lower part consists of the usual yellow sand and soft sand rock; over them are various irregular false-bedded red masses containing concretions of reddle, and resembling the most ordinary varieties of new red sandstone: and over these are beds of yellow sand and sandstone immediately supporting the limestone.

Such are the mineralogical characters and geological relations of the lower red sandstone, which I have given with the more detail, because no general description of it has yet been published. Indeed before the appearance of Mr. Smith's geological map of Yorkshire, it seems to have been almost overlooked in our own country, though it occupies the precise place of the *rothe-todte-liegende*, which has been so often described by the geologists of the continent. By it we are, therefore, enabled, not merely to add a new member to the series of English secondary formations, but to establish a new term of comparison between the physical history of our own country, and that of the remote parts of the European basin.

During my two first visits to the county of Durham, I did not meet any practical men who appeared to have the least knowledge of the existence of the remarkable formation I have been describing. But since the prosecution of the great coal-works within the limits of the magnesian limestone, they have become acquainted with the existence and continuity of the inferior sandstone; and now count upon its appearance in the sinkings of the shafts like any of the more regular strata of the district. Unfortunately, from its incoherent nature, it affords so free a passage to the water, that we might assert, without much exaggeration, that great subterranean rivers circulate in some parts of the county between the limestone and the coal-measures. Through these strata of incoherent sand and of water most of the coal-shafts must necessarily pierce, which commence in the higher formation. To the success of operations of this kind one situation may be more favourable than another: the inferior sandstone may be of inconsiderable thickness, or may perhaps be wanting altogether; but no one would be justified in anticipating such a result before trial. And it is not I think too much to assert, that whoever shall undertake to sink any coal-shafts on the east side of the limestone escarpment, between Thrislington Gap and the Wear, must be prepared to encounter very great difficulties, and to overcome an enormous discharge of water*.

* The subject hinted at in the text is undoubtedly one of great practical importance. I therefore think it right to state one or two facts in support of the opinion I have advanced. 1. In the sinking of the Hetton pit, though the lower sandstone was reduced to the thickness of a few feet, there was a great discharge of water between the limestone and the coal-measures, which was only reduced by iron tubs at an enormous expense. 2. At Eppleton pit (about three-quarters of a mile N.E. of the former) the lower sandstone was 126 feet thick, and discharged water at

In the preceding details I have frequently mentioned the irregular thickness of the lower sandstone. The fact is proved by the general details already given in the description of the escarpment: but as the fact is one of importance, it may be expedient to place it in a stronger light by specific reference to one or two extreme cases.

1st. On Bramham Moor (in the denudation which extends into the south-east corner of the park) there is a quarry which exposes a few beds of yellow limestone, and about twenty feet of the lower red sandstone, without reaching the coal-measures. In a second quarry, a few hundred yards further west, the upper beds agree with those of the preceding locality; but the inferior sandstone is represented by an irregular bed not two feet thick, resting on a coal-grit with vegetable impressions. 2nd. The three great shafts of Eppleton, Hetton, and Ellemore are within two miles of each other. In the first, the equivalent of the lower red sandstone was found to be 126 feet thick; in the second, only four or five feet; and in the third, about sixty feet thick. 3rd. In the cliff under Tynemouth Abbey, the same sandstone does not appear to be more than twenty-five feet thick; while at Clacks Heugh, and some other places on the Wear, the whole thickness is perhaps not less than two hundred feet*.

It is unnecessary to accumulate more examples. We may, however, naturally inquire whence arises this extraordinary irregularity? It has been produced by three causes. 1st. The beds on which the lower red sandstone rests do not always present an even surface. For example, in the two quarries above mentioned on Bramham Moor, the coal strata, probably in consequence of the intervention of a fault, appear at different levels. Under such circumstances it is not possible that superior unconformable strata should preserve an uniform thickness.

2nd. The deposit appears to have been produced by the irregular action of mechanical forces; and, consequently, to have presented an uneven surface at the commencement of the more tranquil formation of the magnesian limestone.

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the rate of 48,000 gallons an hour. In the hopes of reducing this, they were, in the summer of 1826, constructing pumps capable of lifting 54,000 gallons an hour.

3. In the new water-works at Bishop Wearmouth, after passing through 108 feet of limestone and 36 feet of indurated sand, they reached a very copious spring of water. 4. In a well sunk on the property of Mr. Grimshaw in the same neighbourhood, the following beds were cut through. (1.) Limestone, 3 fathoms. (2.) Dark blue clay, 1 foot 6 inches. (3.) Brown and yellow indurated sand, 3 fathoms. (4.) Quicksand and water.—Similar results are given in the wells sunk near the Wear by the proprietors of the Hetton coal-works.

At the present time a pit is sinking on the north bank of the Wear, between Southwick and Sunderland Bridge: but the success of the attempt must be extremely doubtful; because the lower sand (which they must pierce through before they descend to the coal-measures) passes under the bed of the river, and is proved by all the neighbouring sections to be of incoherent texture, and of great thickness. The interior part of it may therefore probably contain such an enormous quantity of water, that no engine will be found capable of keeping it under.—N.B. The preceding remarks apply to the state of the works in 1826.

* Some details connected with the preceding sections will be given in a subsequent part of this paper. (See Plate V. fig. 3.)

An ideal longitudinal section through the Eppleton, Hetton, and Ellemore coal-pits will assist in explaining this statement. (Plate V. fig. 3.) Its best illustrations may, however, be derived from the magnificent sections on the banks of the Nid near Knaresborough. Under the castle the inferior sandstone is seen at the base of the cliff supporting a lofty precipice of yellow limestone. A little way below, the sandstone disappears, and the limestone descends to the bed of the river. But a few hundred yards below the second bridge, the plane which separates the two formations rises above the level of the river, makes a succession of rapid undulations, and lifts the beds of limestone to the top of the escarpment. Again, this plain descends below the bed of the river, and again (below the third bridge on the Ribstone road) rises in an irregular arch, and passes through the middle of a precipice, the higher part of which is composed of yellow limestone, the lower part of the lower red sandstone.

3rd. The lower red sandstone appears in some places to have undergone considerable degradation prior to the deposition of those beds of limestone which now rest upon it. I have before alluded to the thin beds of an imperfect conglomerate, which in a few places (for example, Maltby, Bramham Moor, the escarpment west of Kirk Deighton, one or two of the sections near Knaresborough, and the cliff under Tynemouth Castle) separate the yellow limestone from the inferior sandstone. They seldom contain pebbles brought from any great distance, but most frequently exhibit a kind of recomposed rock, containing fragments of yellow limestone and siliceous sand, held together by a more or less pure magnesian cement*. These phænomena seem to prove, that the interval between the formation of the lower red sandstone and the deposition of the lower beds of magnesian limestone was not one of complete repose, but that the continuity of the deposits was partially interrupted by mechanically disturbing forces. If this reasoning be correct, we might expect, without any more evidence, to find traces of those degradations to which I have alluded, and a consequent partial want of conformity between the sandstone and the lower beds of magnesian limestone. This local want of conformity is well exhibited in the quarry on Bramham Moor, to which I have before referred; in the sandstone quarries west of North Deighton, and in one or two of the sections below Knaresborough. (See Plate VI. figs. 2. 3. 4. 5. & 6.) Some of the phænomena near Knaresborough may be explained by the false bedding of the sandstone, and the supposed original irregularity of its upper surface. But there are some sections which I think set such an

* For examples of actual sections in which this conglomerate appears, see Plate VI. figs. 1. 2. 3. & 5.

hypothesis at defiance: for the true stratification may be discovered in places where the line of its direction bears no relation whatsoever to the plane which separates the sandstone from the limestone. (See Plate VI. figs. 2. & 3.) The examples to which I have referred probably form merely local exceptions to the more general rule. If, however, future observations should prove them to be more numerous, it will then be necessary to make a slight modification of the classification which is proposed, and to remove the formation here described from the group composed of the higher portions of the new red sandstone series. In that case it must be placed in a class by itself; for on no account can it be admitted into the carboniferous order without violating the best rules of geological arrangement*.

§ 2. *A deposit of Marl-Slate, and of thin-bedded and nearly compact Limestone, &c. &c.*

On passing over the edges of the several deposits already described, and mounting to the lower portions of the terrace of magnesian limestone, it might, after a partial examination, appear a hopeless task to attempt to reduce the several calcareous beds to any natural order. The very same beds at short distances from each other, and sometimes even in the same quarry, are crystalline, earthy, compact, or cellular; perpetually changing their mode of aggregation in such a way as almost to baffle description. In the midst of this confusion there are, however, certain beds which preserve a considerable uniformity of character; and which, though by no means co-extensive with the formation of magnesian limestone, wherever they do appear are generally found in the same portion of it. Such are the beds of marl-slate and thin-bedded compact limestone, which in several parts of the range through the county of Durham, and in some parts of Yorkshire, rest immediately upon the lower red sandstone. In placing them in a separate group, I have not therefore adopted an arbitrary subdivision for the mere purpose of bringing

* In an excellent memoir by M. L. Élie de Beaumont on the secondary formations of the Vosges (which did not appear till after this paper was written), a deposit is described under the name of *grès des Vosges*, which, both in structure and position, agrees very exactly with the lower red sandstone. It deserves remark, that this deposit, like the formation described above, appears in several places to have undergone considerable degradation before the existence of some of the higher groups of the new red sandstone series. "*Dans beaucoup de localités, le dépôt de grès qui, sans aucun doute, fait partie du grès bigarré, paraît reposer à stratification discordante sur le grès des Vosges, et semble n'avoir commencé à se déposer qu'après que la surface de ce dernier avait subi des dégradations considérables.*"—Observations Geologiques sur quelques Terrains Secondaires du Système des Vosges, p. 54—55.

After the new analogies supplied by the details of this paper, it appears at least highly probable that the whole of the *grès des Vosges* is the equivalent of the *lower red sandstone*, and that no part of it (as has been conjectured) is contemporaneous with our magnesian limestone.

our own formations into a nearer accordance with those of the same age in central Germany; but I have followed an arrangement which is borne out by many natural sections. At the same time it must be allowed that this deposit is, with local exceptions, very imperfectly developed; that it often does not admit of any well-defined line of separation from the beds which are superior to it; and that it is probably contemporaneous with some of the lower beds of magnesian limestone which frequently occupy its place without exhibiting the same mineralogical characters.

The group I am describing is seen in a very characteristic form on the side of the Stockton rail-road, at the quarries of Midderidge and East Thickley. In the construction of that work a series of beds was cut through, which presented the following phænomena, commencing with the lowest part of the quarries.

1. Beds of light-coloured siliceous sandstone, worked as a coarse flagstone and also as a building stone. The upper beds alternate with a blue-coloured calcareous shale. At East Thickley they are about thirty feet thick.

2. Yellow-coloured calcareous shale and marl-slate, in thickness about nine feet. Some of these beds are incoherent and sandy; the marl-slate forms a series of indurated bands which divide the more incoherent shale.

3. A series of thin beds with marly partings; the whole about twenty feet thick. The average thickness of the several beds is not more than a few inches; their surfaces are often coated with yellow marl; at their natural partings they are generally covered with dendritical impressions. Not unfrequently in their interior they pass into a nearly compact limestone, the finer specimens of which have a conchoidal fracture, are translucent at the edges, and exhibit a smoke-grey, yellowish, or bluish colour. The separation of these beds can seldom be represented by a plane surface: but on the removal of any of the upper strata, we may generally observe a number of spherical protuberances, which indicate a more or less perfectly concretionary structure. The fracture of the more compact beds seldom gives any indication of this structure; yet when viewed externally and on a considerable scale, they may be said to resemble a number of spheres which have been placed side by side, and afterwards have been compressed and partially melted into each other. Over all the preceding come the ordinary beds of coarse yellow magnesian limestone.

The beds described in the preceding section appear to contain very little magnesia; indeed some of the beds of indurated marl-slate and compact limestone do not exhibit a trace of it. Some of the compact beds are, however, partially cellular, like the magnesian limestone, and have their cells lined with crystals of carbonate of lime, occasionally associated with small but beautiful crystals of sulphuret of lead and sulphuret of zinc. As these metallic sulphurets are found with other crystalline materials in cells which have no communication with the surface of the several strata, they must be nearly contemporaneous with the rocks in which they are imbedded.

The excavations formed for the new Stockton rail-road led to a discovery of great geological interest. In the marl-slate, about two feet above the white sandstone, were found a great many impressions of vegetables and of fish. Of the former, a great many specimens were unfortunately destroyed by the workmen. The only examples which I have seen are now before the Society, and appear to be ferns. Of the fossil fish many good specimens were preserved, and I have seen portions of at least seven species. Among these the genus Palæothrissum of De Blainville is the most abundant; and the two species Palæothrissum magnum and Palæothrissum macrocephalum have been identified by that distinguished naturalist. These two species are extremely abundant in the marl-slate of the Thuringerwald; and it perhaps deserves remark, that in their distortion and mode of preservation they exactly resemble many of the Durham specimens*.

The superior and more compact beds above described also contain fossils; among which are two species of Producta, a Spirifer, and a Terebratula. The Producta antiqua of the mountain limestone occurs, though I believe very rarely, in the two quarries above mentioned.

The zechstein which overlies the marl-slate of Thuringia has been described as containing Gryphites and Terebratulites, and indeed has been named by M. Voigt a gryphite limestone. Had this account been correct, it would certainly have thrown some difficulty in the way of our classification. Fortunately, however, the Gryphæa aculeata of Schlottheim belongs to the genus Producta of English mineral conchology; and the fossils of the zechstein appear to be nearly identical with the corresponding deposit of the British series.

In order to complete the analogy between the deposits which I am describing and the corresponding formations of Thuringia, it may be remarked, that in the county of Durham the marls which separate the bands of marl-slate and the beds of compact limestone are sometimes bituminous. Traces of bitumen have often been found in the compact limestone; and at Somerhouse quarry near Denton, a thin-bedded limestone of the same age with the Midderidge series alternates with thin bands of a black micaceous shale, which is sufficiently bituminous to be regarded as an impure coal. These, and one or two

* See Plates VIII. IX. X. XI. & XII.

similar instances, though perhaps exceptions to the more usual character of the contemporaneous deposits in our country, seem to confirm the conclusion which I have endeavoured to establish.

Following the magnesian escarpment from the rail-road above mentioned towards the north, we frequently lose all traces of the marl-slate and thin-bedded compact limestone. They may, however, exist in many places under the incoherent matter which disguises the lower part of the terrace.

A quarry in the hill above Coundon lays bare the bottom beds of limestone. They are thin and almost slaty, and of a smoke-grey, ash-grey, and blue colour. Some of them are earthy; but others are almost compact, and contain crystalline nodules of sulphate of barytes, with sulphuret of lead and sulphuret of zinc irregularly disseminated through their mass. Their position, texture, mode of bedding, and association with metallic sulphurets, clearly identify them with the compact limestone of East Thickley and Midderidge.

In several parts of the escarpment between the last-mentioned locality and the banks of the Wear, I have found thin beds of impure sandy marl-slate between the magnesian limestone and the lower sandstone. And in the sinkings of the Hetton pits, as also in the wells near Sunderland, the same beds have been found associated with thin layers of blue and nearly compact limestone.

Some of the natural sections on the south bank of the Wear exhibit distinct traces of the marl-slate immediately under the great shapeless beds and masses of magnesian limestone; and there can, I think, be no doubt that the whole quarry at Pallion is very nearly connected with it. For we there find a system of strata which are chiefly composed of thin and nearly compact masses of light ash-grey, and smoke-grey limestone, separated by, and mixed with, various marls and thin beds of yellow marl-slate: and in the lower part of the section are some thicker beds, with various shades of light-grey, ochre-yellow, and blue, which contain very little magnesia. Some of these lower beds are almost compact, and near the bottom of the quarry are of so fine a texture that they were formerly worked for marble. The discovery of a fossil fish in these quarries further tends to identify them with the formation of marl-slate and compact limestone, though their mineral character somewhat differs from its usual type*.

The only part of the escarpment between the Wear and the Tyne which exhibits these inferior beds in a characteristic form, is at West Bolden. We have there a section nearly fifty feet high, which exhibits about thirty feet of thin slaty beds resting on the lower red sandstone, and surmounted by about twenty feet of hard amorphous cellular masses of yellow limestone †. The slaty beds possess an intermediate character between the varieties of marl-slate and compact limestone above described. They are generally of a yellowish brown colour; and they are almost covered with black dendritic impressions. It is difficult to obtain a clear cross fracture from them; for they separate at a number of transverse natural joints, which are also covered with a similar dendritic coating.

To the north of the Tyne, the two outlying masses at Whitley and Cullercoats may perhaps both be referred to the marl-slate and compact limestone. The several beds at the former locality have been already described in the Society's Transactions (First Series, vol. iv. p. 5). Some of

* For some further details respecting the Pallion sections, see a paper by Dr. Clanny, Annals of Philosophy, vol. vi. p. 115, &c.; and Mr. Winch, Geol. Trans. First Series, vol. iv. p. 9.

† See Plate VII. fig. 2.

these beds contain small crystals or crystalline nodules of galena; and at Cullercoats, blende is associated in a similar manner with the beds of limestone*.

Lastly, in the cliff between North-point (about two miles south of the Tyne) and Marsden rocks, there is a fine exhibition of the inferior beds, in the form of a yellowish brown slaty limestone, resembling the corresponding deposit at Pallion and West Bolden, surmounted by light-coloured cellular and brecciated masses belonging to the superior formation†. Near Marsden rocks we may also find many varieties of marl-slate and compact limestone: but in their arrangement, and in their manner of association with the superior beds, they are extremely anomalous, and will be more properly noticed in a subsequent part of this paper.

The appearances of the marl-slate and compact limestone in Nottinghamshire, Derbyshire, and Yorkshire, will require a very short notice. In the two former counties thin-bedded varieties of magnesian limestone much coated with dendritic impressions are found in some places immediately over the coal formation. They occupy, therefore, the exact position of the marl-slate of the county of Durham, and in some respects resemble it. In other respects they, however, differ so much from it, and are so nearly connected with the upper beds of magnesian limestone, that I have not ventured to arrange them in the inferior group. The same remark may be applied to some nearly similar beds, which in various parts of Yorkshire are interposed between the inferior red sandstone and the great amorphous beds of yellow limestone. There are, however, in some parts of that county, beautiful and unequivocal exhibitions of the compact limestone and the marl-slate.

1. In the lower part of the terrace which extends from Kippax towards Aberford, there appears a thin-bedded blue compact limestone alternating with thin layers of marl, and resting upon the lower red sandstone. It contains some obscure impressions and casts of bivalves, among which is the genus Axinus of Sowerby. The lower beds are sandy, and might be mistaken for coarse varieties of lias. The blue beds do not, I believe, contain magnesia; but they are (especially near the top of the group) associated with yellow beds containing that mineral.

2. Beds of nearly the same character occupy the same geological position in the quarries opened in the outlier (above described) north of Seacroft, and in various other places under the magnesian escarpment.

3. In the quarries at Linderick near Ripon, there is also a highly characteristic exhibition of the compact beds. In these quarries which form the bottom of the terrace, the limestone is fetid, nearly compact, thin-bedded, of a dark smoke-grey colour, and alternates with thin beds of marl. The bottom of the formation is unfortunately not exposed.

4. Lastly, the same group is seen in various quarries between Knaresborough and Ripon: for example, at Yew Bank near Burton Leonard, in a perpendicular section nearly forty feet thick;

* I am by no means prepared to deny that the metallic sulphurets may sometimes traverse the beds above described in small strings or veins. I never, however, saw them in that form; but they always appeared to be imbedded in a way which seemed to indicate a contemporaneous origin.

† See Plate VII. fig. 4.

and in the two outliers in the same neighbourhood. In the last-mentioned place the character of the group is considerably modified, and is partially associated with coarser beds of yellow magnesian limestone: it may, however, be described in general terms as a deposit chiefly composed of grey thin-bedded limestone, alternating with thin layers of marl. Most of them are coated over with dendritic impressions; and, with partial exceptions, they contain much less magnesia than the strong coarse yellow beds by which they are surmounted. On the whole, they make an approach to the external character of the well known beds of Brotherton and Ferry Bridge, though placed at the opposite extreme of the magnesian series.

Such are the facts upon which is founded that subdivision of the formation of magnesian limestone which I am endeavouring to establish. The beds here described,—in their mineralogical character, their relative position, their geological relations, and their organic remains,—present so many analogies with the copper-slate and zechstein of central Germany, that it seems impossible not to consider them as all belonging to a common epoch, and as originating in the simultaneous action of similar causes.

§ 2. (A.) *A deposit of variously coloured Marls, containing irregular beds of Shell Limestone without Magnesia.*

When I stated in a former part of this paper, that there was no characteristic exhibition of the inferior red sandstone to the south of Barlborough, I by no means intended to assert that, in the whole range between that place and Nottingham, the magnesian limestone rested immediately on the coal-measures. Not far from Nottingham (for example, at Bilborough and Kimberley) there are some traces of red marl-beds under all the beds of the limestone. Marl-pits are also said to have been dug under the escarpment in several places west of Sutton Ashfield; and some thin beds of a kind of pipe-clay have been found in the same geological position between Barlborough and Clown. These masses of marl and clay would hardly have deserved enumeration, had they not appeared in connection with a much more important deposit, which is laid bare in the hill side under Kirkby Wood-house; and also with a second similar deposit, which ranging for three or four miles under the escarpment in Derbyshire, is exposed in the side of the road under Glapwell, and in the quarries of Palterton and Bolsover. I therefore now proceed briefly to describe the phænomena presented at these several localities.

A rail-road which extends from the Kirkby coal-works towards Mansfield, and cuts through the lower part of the escarpment of the yellow limestone, exposes a series of beds in the following order. 1. A thick bed of shale. 2. Beds of soft light-coloured slaty sandstone. These two form the base of the hill, and belong to the regular coal-measures. 3. Beds of conglomerate and coarse sandstone, six or eight feet thick. They are of a yellowish-red colour, from the prevalence of fragments or concretions of red and yellow ochre. The finer portions resemble many varieties of the lower red sandstone; but the coarser beds contain fragments of sandstone and water-worn fragments of mountain limestone*. 4. Beds of red, grey, and yellowish marls, containing nodular concretions and thin bands of limestone. The whole thickness about fifteen feet. In the lower part, the clay is generally of a red tinge, and the limestone nodules partake of the same colour. In the higher portion, many of the irregular bands of limestone, like the marls in which they are imbedded, are of a greyish colour. Externally they are sandy, and sometimes micaceous; but the centre of the larger concretions commonly exhibits a nearly compact and pure limestone, containing a few obscure traces of bivalve shells. 5. Immediately over the preceding beds are some thin bands of yellowish marls, surmounted by the great deposit of magnesian limestone in the ordinary form in which it is developed in that district.

At Palterton and Bolsover in Derbyshire, the sections through the corresponding deposits exhibit the following succession, beginning as before with the lowest beds. 1. Common coal shale. 2. Soft light-coloured sandy shale with vegetable impressions. The two preceding are members of the coal formation; their junction with the next superior beds is unfortunately not well exposed. 3. Beds of yellowish clay, with some carbonaceous matter apparently derived from vegetable fossils. In it are thin beds of blue limestone, with bivalve shells, and, in a few instances, containing small fragments of carbonized wood. Many of the specimens resemble hard varieties of shelly lias; others are meagre, impure, and sandy. The thickness of this system is about six feet. 4. Red and yellow clay, with beds of blue and red shelly limestone. Some of the varieties of limestone are very impure; other parts are compact or semicrystalline, and in hand specimens might be mistaken for mountain limestone. The thickness of these beds is about nine feet. 5. Over the preceding are the lower beds of the yellow magnesian limestone.

There is obviously a great analogy between the two preceding sections. The conglomerate of Kirkby Wood-house does not, however, appear at Palterton and Bolsover; and the beds of limestone are thicker and much better developed in the latter section than they are in the former. The organic remains appear to be the same in both, and consist almost exclusively of small bivalve shells, which are generally too much imbedded to exhibit specific characters†. To what formation shall we then refer these two deposits? The red marls and conglomerate seem to connect them with the inferior red sandstone; but the beds of limestone seem on the other hand to unite them with the next superior group of marl-slate and compact limestone. To avoid all ambiguity, I have placed them in a group by themselves, an arrangement which can lead to no mistakes, though the subdivision may perhaps be thought too unimportant to deserve so formal a notice.

§ 3. *Great middle deposit of Yellow Magnesian Limestone.*

The deposit I am now about to notice, not only occupies the greatest part

* This is perhaps the only instance in which a conglomerate containing pebbles of mountain limestone is found in association with any of the groups described in this paper. (See Plate V. fig. 1.)

† As these beds of limestone contain no magnesia, they are extensively quarried, and much used in agriculture.

of the western escarpment, but is spread over more than nine-tenths of the area included between the eastern and western boundary of the whole formation. The difficulty of describing it does not arise so much from its great extent as from its complexity of structure; for it presents incomparably more changes in its external character, and in the arrangement of its subordinate parts, than any other secondary formation of the British series. A detailed account of one portion of it might present very few analogies with the details exhibited by another portion, even in a neighbouring district. All, therefore, which I shall attempt in this place will be, to describe some of the most remarkable varieties of rock subordinate to this great system of beds; considering only in a general point of view their relations to each other, and to the deposit of which they form a part.

I. *Arenaceous Dolomite.*—This modification of the rock is of an open arenaceous texture, being made up of a congeries of small irregular crystals, the forms of which cannot always be determined; but they may sometimes be traced to the inverse rhomb.

It forms a considerable portion of the deposit which rests immediately on the coal-measures to the north-west of Nottingham, and alternates with other varieties of magnesian limestone in different parts of Nottinghamshire and Derbyshire. In these districts, its prevailing colours are reddish or yellowish brown; and it is deposited in thin beds, which are sometimes used for flag-stones or coping-stones, but are never sufficiently coherent to make a good building stone. On exposure to fire, it often passes into a bright brick-red colour; and in some rare instances, native specimens may be found in the quarries of this colour*.

To the same variety I would refer various irregular concretionary masses, which near Knaresborough, and in many other parts of Yorkshire, are found subordinately to earthy and pulverulent beds of magnesian limestone. I have not noticed any specimens in the county of Durham which can be classed under this head.

This modification (especially as it is found in Nottinghamshire) is a true dolomite, with a great excess of iron; and, notwithstanding its crystalline texture, is probably in a great measure of mechanical origin. For it is thin-bedded, separated by thin bands of marl and siliceous sand; and in some places a coarse sand coated with green earth enters partially into its composition. Lastly, in some quarries near Bilborough, the separating red marl and sand increase so much in thickness, that the dolomite becomes subordinate to them†. In such instances the carbonate of

* The specimens here described are not easily reduced to a calx. They are, however, associated with beds which are burnt for lime: but it is never of a white colour, being stained with various colours derived from the metallic oxyds of the rock.

† The *lower red sandstone* is not found in the neighbouring districts as a distinct formation: but the localities alluded to above, may be considered as exhibiting an alternation of this sandstone with the lowest beds of yellow limestone. I have only noticed two other decided examples of a similar alternation; one in the escarpment at Glapwell in Derbyshire, the other on the right bank of the Nid immediately above Knaresborough. There are, however, many instances in which the bottom beds of magnesian limestone contain a considerable portion of sand, apparently derived mechanically from the strata on which they rest; and thin bands of variously coloured marls are not unfrequently interposed between the beds in this part of the formation.

lime and magnesia appears to have been mechanically deposited along with the other materials which constitute the system of beds; and if these earthy salts were derived from the destruction of pre-existing dolomites, they would be supplied in that definite proportion which would enable the comminuted particles to reunite and form a simple crystalline rock.

II. *Small-grained Dolomite.*—This variety is also a crystalline dolomite; differing from the preceding in being smaller-grained, and not having the same open arenaceous texture. It exhibits various shades of colour from ochre-yellow to yellowish white, and rarely becomes almost snow-white. When mixed with impurities, or alternating with other modifications of the magnesian limestone, it sometimes is brown, dull brick-red, or bright red. The finest specimens are of a glimmering pearly lustre; and a number of minute black spots (occasionally aggregated in stellated forms) are often irregularly diffused through them. Their fracture is generally uneven, and the fragments into which they break are of irregular form. Beds, or crystalline masses, answering more or less perfectly to the preceding description, are found in various parts of Durham: for example, at Conisclif Castle, Eden Dean, Tunstall Hill, Black Rocks, and other places on the coast; but in all these places they are entirely subordinate to other varieties, and are neither of sufficient regularity nor extent to be used in architecture.

In the same subordinate form this dolomite occurs in various parts of Yorkshire; and in Nottinghamshire and Derbyshire it passes into, and alternates with, the former modification. Its most perfect development may, however, be seen in various ancient quarries, which, in the long range of the formation from Nottingham to Bramham Moor, have been opened in the upper part of the deposit I am attempting to describe. Any thing beyond a short notice of these remarkable quarries would be incompatible with my present object.

1. In the extensive quarries of yellow dolomite which are opened on the south side of Mansfield, the lowest beds are thin, and are separated by thin layers containing greenish sand. Some of these beds are arenaceous, and pass into the variety (No. I. p. 82.) above described; others form an excellent building stone. The upper quarries are composed of irregular beds or tabular masses, some of which are twelve or fourteen feet thick. They are partially tinged with green sand and other impurities, and also contain a few veins and crystalline nodules of sulphate of barytes; but large blocks of nearly pure dolomite may be separated from them. The whole system above described is surmounted by the lower marly beds of the forest sand.

2. On the east side of the glen which descends to Mansfield, is a quarry which lays bare a system of beds, about fifty feet thick, of very extraordinary character. The bottom beds are about twenty in number, and vary from less than one foot to three or four feet in thickness; but the planes of separation are extremely irregular, and not continuous. They are of a dull red colour, and might, without close examination, be mistaken for new red sandstone. The thin beds are much used in building; and the thickest are hewn out into large troughs and cisterns, and in that state are conveyed into all the neighbouring counties. Over the system just described is a

band of clay surmounted by striped slaty ferruginous beds, which gradually pass into a coarse yellow magnesian limestone.

This red dolomitic sandstone rises and falls in long sweeping undulations, and may be traced to a quarry on the side of the Chesterfield road, where it preserves nearly the same colours and external characters, and is worked for the same purposes.

In the whole range of the magnesian limestone I know of no deposit which can be compared with that which is here described; and it is the more remarkable, as it is found in the heart of the formation, and nearly in a line with the finest specimens of crystalline dolomite*.

3. On Bolsover Moor, about two miles east of the village, is a beautiful yellow crystalline limestone, which is extensively quarried for building. Its lustre is pearly, and excepting the colouring matter and the minute black spots which are scattered through it, it contains very little impurity. Some of the beds become so granular as to pass into the preceding modification. (No. I. p. 82.)

4. Among the rocks forming the beautiful ravine called Cusswell Crags, are some fine dolomites; but they are irregularly bedded, are associated with compact, cellular, and earthy varieties, and have not been quarried. There are, however, some beds on the hill to the north-west of the ravine which have been used for building, and, except in colour, resemble those of Bolsover Moor. In passing into a solid state, some of these beds have penetrated each other; so that their separation is not represented by a plane superficies, but by a number of imperfectly crystalline points and protuberances, which give to the surfaces of the blocks an appearance resembling artificial rustic work. These natural surfaces have been occasionally used in ornamental architecture.

5. The neighbouring quarries of Steetley are of considerable extent, and of great antiquity. The rock laid bare is not more than twenty feet thick. It is divided by a number of irregular horizontal partings into beds from one foot to three feet thick; and it is also intersected by a number of irregular transverse seams and fissures. The finest specimens are of a greyish white colour, crystalline, fine-grained, and of a beautiful shining pearly lustre. The top of the quarry is composed of thin soft yellowish beds much stained with the black spots before alluded to †.

6. In the neighbourhood of Roach Abbey are also some very ancient quarries of dolomite of a beautifully greyish white colour. In its mode of bedding, thickness, mineralogical character, and geological position, it is nearly identical with the Steetley rocks above described; but it is more finely grained. Only four or five beds are worked. The strata above them and below them are

* The beds above described are an instance of the extensive operation of mechanical agents during the deposition of the magnesian limestone. Some of the coarsest specimens probably contain as much as 30 per cent of siliceous sand. The Rev. J. Holme examined one of the finest cistern beds, and from 100 grains obtained the following results:

Lime	28.750
Magnesia	11.125
Carbonic acid	34.750
Silica	20.250
Red oxyd of iron and alumina	3.375
Earthy muriates of soda, lime, and magnesia?	0.250
Water and loss	1.500
	100.000

† Many ancient churches, and some monastic buildings, of which the ruins exist in the neighbourhood, were formed of materials derived from these quarries. This stone was also used in the construction of Clumber House, Worksop Manor, and some other noble modern edifices.

of the same greyish white colour, but are of a softer and more earthy texture, and on that account are not used for building.

7. In following the formation from the last-mentioned locality towards the north, there are for nearly thirty miles very few traces of the fine white dolomites. But they reappear at Huddlestone near Sherburn, and on the north-east side of Bramham Moor. At the former place is a quarry about forty feet high, exposing ten or twelve great irregular beds or tabular masses. Some of them have the lustre and texture of the Roach Abbey stone, but in general they are less crystalline; and in one part of the quarry they pass into a compact yellowish white rock, which exhibits the conchoidal fracture and external characters of a perfect Alpine limestone*. In the quarries of Bramham Moor the best beds are yellowish white, very fine-grained, of dull glimmering lustre, and less crystalline than the Huddlestone beds. Many of them are veined and cellular, and pass into common earthy varieties of magnesian limestone. The two last-mentioned quarries have supplied materials for the construction of some of the finest Gothic buildings in our island.

To the north of the river Wharfe, the whole formation of magnesian limestone does not, I believe, afford a single quarry of dolomite which deserves notice from its value as a building stone.

In the description of the two preceding modifications, the term "dolomite" has been used in a somewhat extended sense; for the specimens are certainly not all composed of a definite triple salt, in which one atom of carbonate of lime is chemically united with one atom of magnesia. Even in the crystalline varieties we may often observe a small quantity of uncombined earthy matter and other impurities; and in the more ordinary forms of the deposit, carbonate of lime is most frequently in considerable excess. In some cases, we may in great measure separate the uncombined carbonate of lime by dilute acid, which does not so readily act upon the true dolomitic portion of the rock; and this accounts for the brisk effervescence of certain varieties of magnesian limestone when first plunged in acids. There are also some rare varieties of the rock (when its external character is both earthy and crystalline) in which carbonate of magnesia is in excess. Of twelve specimens of dolomite examined by Tennant, ten were composed of one atom of carbonate of lime, and one atom of carbonate of magnesia, with a small quantity of carbonate of lime in excess. Two were of similar composition, but with a very small quantity of carbonate of magnesia in excess; and the specimen in which this excess was greatest, was derived from the magnesian limestone formation near Doncaster†. We may, however, presume, that in all specimens which are highly crystalline, which effervesce feebly with acids, and are not much mixed with extraneous matter, the two earths are chemically combined, and that the composition of such specimens will be found to agree very nearly with theory. To bring this to the test, I selected from a very large number of specimens of dolomites, derived from various parts of the formation, some beautiful and perfectly crystalline fragments; and after an examination of some of them, which was kindly undertaken by Professor Cumming, the result was what had been anticipated. For example, one of the most crystalline rocks from Roach Abbey was found to be a definite compound of one atom of carbonate of lime, and one atom of carbonate of magnesia, subducting something less than two per cent of oxyd of iron and other impurities ‡.

* From a hundred grains of this compact rock, Mr. Holme obtained the following result:— Lime, 34.75. Magnesia, 16.125. Carbonic acid, 45. Black oxyd of iron and alumina, 1.375. Silica, 1.25. Water and loss, 1.5.

† See Phil. Trans. 1799, p. 314.

‡ The mode of examining the above specimens was as follows:—" Fifty grains were dissolved in nitric acid, dried and redissolved in acetic acid; afterwards being converted into a mixed sulphate and submitted to a red heat, the weight was 67.95 grains. This was lixiviated with a saturated solution of sulphate of lime to separate the magnesia, and left a residue of sulphate of

III. *Compact Magnesian Limestone.*—Under this head are included true compact dolomite, and many varieties of imperfectly compact magnesian limestone. The former is found in Derbyshire and Nottinghamshire, in thin beds associated with, and subordinate to, the crystalline varieties described above. Its fracture is flat, conchoidal, and it is translucent at the edges; but in structure it is very irregular, and often passes by insensible shades into other varieties. A beautiful compact rock found in Huddlestone quarries is also a fine example of this species.

Of the imperfectly compact rock the examples are much more numerous, and are commonly found in rather thin beds alternating with other more earthy masses in different parts of the formation. Some fine thick strata of this variety (which are of grey colour, splintery fracture, and translucent at the edges) are found on the banks of the Worksop canal, and have been extensively used in forming the stone facings of the locks, and in other works of strong masonry.

It may be convenient to bring under this variety the hard thin beds, occasionally of almost porcellaneous texture, and often partially cellular, which in several places, especially in the southern parts of Yorkshire, are found at the bottom of the formation, and are separated from each other by thin bands of marl. Some of these local deposits are (as before stated) probably contemporaneous with the "compact limestone and marl-slate" of the preceding section of this paper. They agree with them in position, and resemble them in their mode of bedding, but differ from them in colour and mineralogical character. For examples of such deposits, I may refer to the lowest beds of the yellow limestone near the village of North Anston, and to the system of beds at the bottom of the outlier above the village of Keswick near the river Wharfe.

To the preceding examples may also be added many of the harder beds of the formation, which as they lose the compact character, pass at one extreme into an earthy texture, and at the other into a granular dolomite. Black oxyd of iron, in the form of dendritic impressions, is constantly found investing the exterior, or penetrating the substance of all the various rocks here described.

IV. *Laminated Structure.*—Rocks of this structure (in which the laminæ are parallel to the planes of stratification, and look like successive layers of deposit) are found abundantly in the county of Durham; especially on the coast, and in some quarries near Sunderland. They replace and pass into the other modifications, but seem to be most developed in the middle and higher parts of the formation. Their colours are dark brown, smoke-grey, and ash-grey; and they are sometimes extremely fetid. They are associated with earthy and pulverulent beds or masses; often exhibit subordinate regular

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lime, which, after being heated red, weighed 35.4 grains; the remainder 32.55 was sulphate of magnesia. Hence it appears, that the carbonate of lime and magnesia in this specimen are respectively 26.2 and 22.75 grains.

"Another portion of the same specimen weighing 50 grains being exposed to a white heat for an hour in a platina crucible, lost 23.5 grains of carbonic acid. Now if it be supposed that this was divided equally between the lime and the magnesia, the result will be 26.85 carbonate of lime, and 22.2 carbonate of magnesia. This accords so nearly with the analysis, that we may conclude the supposition to be true, and that the specimen is a true dolomite."

concretions; and when the laminæ disappear, pass into slaty beds, and sometimes into thick smoke-grey fetid beds of nearly compact structure.

Of these laminæ, some are shining and crystalline, others are dull and earthy. The very thin laminæ of the latter variety, which occur in abundance near Marsden Rocks, are often slightly flexible; and very fine specimens of flexible magnesian limestone with thicker laminæ, occur in a bed near the middle of the cliff.

V. *Earthy Magnesian Limestone.*—This modification does not occur in any striking form to the south of Doncaster; but, in the range of the formation from that place through Yorkshire and Durham, it exists in the greatest abundance. It is in some places hard, coherent, and regularly bedded; in other places it becomes soft as chalk, and stains the fingers; occasionally it loses all the marks of stratification, and passes into great pulverulent masses only held together by the veins and harder concretions which pass irregularly through them*. It will, however, be better to describe this last variety as subordinate to other modifications of the formation, especially those which exhibit a great or small concretionary structure.

So far I have endeavoured to describe those modifications of the formation which make an approach to a simple structure: but whatever may be their mineralogical or economical importance, they are developed upon a much less scale than some of the varieties I am now about to notice.

VI. *Large irregular Concretionary Structure.*—Under this subdivision are included all those parts of the deposit which are composed of great irregular concretions, and in which the subordinate parts exhibit a complex irregular structure. These modifications may often be traced in the separate beds of an escarpment which is distinctly stratified. They are, however, seen in the most impressive form, when, to all appearance, an entire system of beds has been so changed, that the lines of deposit are obliterated, and the whole escarpment shows an amorphous mass of crystalline, compact, cellular, and earthy materials rudely blended together, and apparently passing into each other without order or arrangement. Phænomena like these do not admit of

* The proportion of lime and magnesia in such specimens as these is found to be extremely variable. Two pulverulent varieties (one found near Ripon, and the other near Knaresborough,) proved, however, to be nearly identical in composition. The following analysis is by Mr. Holme.

1. *Earthy variety from Ripon.*		2. *Earthy variety from Knaresborough.*	
Carbonate of lime	71.125	Carbonate of lime	72.000
Carbonate of magnesia	25.625	Carbonate of magnesia	25.500
Red oxyd of iron and alumina	1.750	Red oxyd of iron and alumina	1.000
Silica a trace of, and water	1.500	Silica a trace of, and water	1.500
	100 grs.		100 grs.

accurate and systematic description; but they may be conveniently separated into the four following classes.

1st. Where the lines of stratification are not obliterated, and where earthy and pulverulent masses containing many cellular knotty protuberances are arranged in beds which are nearly parallel to each other. Escarpments answering more or less perfectly to this character may be seen in various parts of Yorkshire, especially in the neighbourhood of Pontefract and Ripon; and under such circumstances, the face of the rock sometimes resembles a gigantic work of ancient masonry decomposing and crumbling into ruin.

2nd. Where the earthy portions are rather more compacted than in the preceding class, and where the harder portions are subordinate, and stand out in great cellular tuberous masses which have no parallelism or regular arrangement. Examples of this structure may be seen in many parts of Yorkshire and Durham; and a fine series of sections illustrating all its modifications are exposed in the precipices on the left bank of the Nid near Knaresborough.

3rd. In this class are included all those modifications of the rock where, on a great scale, the earthy and pulverulent portions become subordinate, and where the knotty protuberances frequently pass into each other. Portions of escarpments possessing this structure often admit of no subdivision, and can be regarded as only one mass of irregular concretionary form. In some places they resemble great irregular beds of brecciated structure thrown unconformably over the stratified rocks which support them; in others, they are rough and cellular, like a great mass of scoria. Frequently they are of a more compact and continuous texture, but interrupted by irregular cells, which vary from a fraction of an inch to two or three feet in diameter. The harder portions of these masses are crystalline, compact, or earthy; and generally of a yellowish brown colour. The intervening spaces are often filled with a pulverulent magnesian earth of an ochre-yellow, or pale-yellow colour. The smaller and more regular cells are (as in most other parts of the formation) generally empty, and coated over with crystals of carbonate of lime.

There is, however, no end to these modifications; nor is it an easy task to convey a correct notion of them by verbal description. They may be studied in the escarpments near the Mill or river Nid below Knaresborough; at Clacks Heugh, and West Bolden on the Wear; in the quarries which are opened in some of the round-topped hills near the western limits of the formation in the county of Durham; in the cliff near North Point in the same county, and in numberless other localities.

4th. In this class the irregular concretionary structure almost disappears, and the whole mass passes into a nearly compact or porcellaneous structure, has a glimmering lustre, is translucent at the edges, and has a fine-grained uneven fracture, here and there passing into splintery. The rock is hard, occasionally giving fire with steel; and is, in some places, brittle, flying under the hammer into small irregular fragments. Having, however, no natural joints, it is not easily broken into larger fragments. In other places it is tough, porcellaneous, and difficult of fracture, and rarely fetid.

It differs from the compact beds above described (No. III. p. 86.)—1st, in having no marks of stratification; 2nd, in exhibiting on its weathered surface irregular nodosities, indicating a concretionary texture; 3rd, in its irregular fracture; 4th, in containing many very minute cells or vacuities which have no tendency to a spheroidal form; and which, though frosted over with minute crystalline points, are not regularly coated with crystallized carbonate of lime like the cells in the more regular beds.

Large irregular masses, answering more or less perfectly to the preceding description, lie scattered upon the crown of the escarpment on both sides of the village of Maltby, and might at first sight be mistaken for enormous boulders; but on examination they are found to be *in situ*, and are the hard indestructible remains of beds which were once continuous, and of which the softer portions have been washed away. Striking appearances of the same kind may be seen on the escarpment near North Anston, and in some other places in the course of its range through the southern parts of Yorkshire.

To this modification may perhaps be conveniently referred some of the varieties of magnesian limestone which appear in the Gill quarries above Sunderland Bridge. In this locality the rock, when considered on a great scale, has not a concretionary structure so evidently exhibited as in some of the preceding examples, and is more interrupted by vacuities containing earthy pulverulent matter. The harder specimens, which are of a smoke-grey colour, answer however very well to the description given above.

The various masses described under this sixth modification of the magnesian limestone, appear to have been regularly deposited with the other parts of the formation. But being composed of an indefinite mixture of carbonate of lime and magnesia, with certain impurities which could not entirely combine into a true dolomite, and being prevented by some internal cause from cohering and forming a solid rock, the particles, after deposition, seem to have undergone great internal movements,—to have run into lumps and masses more or less crystalline, rejecting great portions of earthy residuum,—and in this way to have produced that complexity of structure, and those cells and vacuities which are above described.

This concretionary rock is never a true breccia; and the causes which produced its structure having acted irregularly, it is very seldom bounded by plane surfaces. Hence that false appearance of want of conformity, presented by some of those sections, in which the amorphous masses of yellow limestone are seen to overlie the stratified parts of the formation. (See Plate VII. figs. 2. & 4.)

VII. *Beds, and irregular concretions of Crystalline Limestone, without Magnesia.*—Masses of dolomite of more or less perfectly crystalline texture are, as before stated, found subordinate to the earthy beds of magnesian limestone; but, in some rarer instances, beds, or more properly, irregular concretions of carbonate of lime, seem to have separated themselves from the other parts of the formation, at the time of its passing into a solid state. Of these we have some remarkable examples in a quarry about one mile south of Ripon, where great masses of nearly pure limestone (of a grey, smoke-grey, or cloudy bluish-grey colour, of a porous texture and crystalline structure) are irregularly imbedded among the soft earthy strata of this formation. These masses cannot have been formed by infiltration; and they are too much blended with the other beds (passing insensibly into them, or penetrating their substance in the form of strings or small contemporaneous veins), to be regarded as mere accidents of deposition: they must, therefore, be considered as further examples of that irregular concretionary structure which I have been endeavouring to illustrate. (See Plate VII. fig. 3.)

It may be convenient to mention in this place some masses of crystalline limestone exhibiting beautiful shades of yellow, red, and brownish-red colours, which are found on the east side of Bramham Moor, and in some quarries near Newton Kyme: also some large beds of bright-yellow dendritic crystalline limestone, which appear in the cliff on the left bank of the Nid, about a mile and a half below Knaresborough. In these instances, the composition of the rock does not seem to be due to any separation of parts after deposition. It has the external characters of dolomite, yet it contains only a mere trace of magnesia: it may therefore be regarded as an extreme (and in this part of the formation a very rare) case of magnesian limestone, in which the triple salt has almost disappeared *.

VIII. *Rocks of a brecciated structure, &c.*—The obscure bands of conglomerate which in a few places separate the magnesian limestone from the lower red sandstone, do not, either from their thickness or continuity, deserve any detailed description; and were only mentioned above (p. 74.) because they seemed to have originated in those causes which produced a local want of conformity between the inferior and superior deposits. There are, however, in other places (especially on the coast of Durham) great beds of a coarse brecciated structure, which cannot be passed over without some notice: and they may be properly introduced in this place, because they occupy the same part of the series as the irregular concretionary rocks above described, and sometimes seem to pass into them by gradations which are almost imperceptible.

Commencing an examination of the coast of Durham at North Point, about two miles south of the Tyne, we find a lofty cliff composed of a brown-coloured marl-slate, sometimes coarse and cellular, surmounted by grey-coloured cellular amorphous masses of large irregular concretionary structure. This is the general character of the coast for more than a mile. To the north of Marsden Bay (a place celebrated for the great picturesque masses of insulated rock which have been formed by the irregular encroachment of the sea upon the neighbouring cliff), the whole escarpment is composed of a hard grey cellular rock, with many knotty protuberances. But further south, on entering the bay, the preceding modification is gradually replaced by a system of beds which are partially fetid, are of a yellowish brown or buff colour, of a slaty and finely foliated structure, and which occupy a cliff more than one hundred feet high. The foliations often alternate with soft earthy laminæ, giving the weathered surface of the rock a striped or grooved appearance. These beds in turn exhibit various modifications; some portions contain cells with spheroidal concretions; others lose their foliated texture, and pass into irregular yellow earthy masses, alternating with harder compacted greyish beds †. After some slight undulations

* In the above remarks it is taken for granted, that, in this formation, carbonate of magnesia appears only in chemical combination with carbonate of lime. This is undoubtedly the general fact; but the rule perhaps admits of some exceptions.

† In this part of the coast it is not perhaps possible to determine the true relations of all the beds. Some of the foliated masses may represent the "marl-slate" of the preceding section. (§ 2. p. 75.) The greater portion of them are, however, in a higher position, and belong to the modification described above. (No. IV. p. 86.)

they have, by the action of great disturbing forces, been broken into thousands of angular fragments, which are in no instance water-worn, and are united by a yellow cement not differing in texture from the earthy beds of the neighbouring cliff. In this way the ordinary deposit is, here and there, interrupted by great masses of breccia, in which all traces of stratification vanish.

Proceeding southward, the complications of structure are still more striking; for the foliated, the compacted, and the earthy beds are considerably contorted, and *alternate* with great grey masses of coarse breccia. At the southern extremity of the bay, the preceding masses are replaced by a system of strata in which the brecciated structure is no longer visible, the cliff being composed of foliated, slaty, cellular, and earthy beds, alternating with thick compacted grey beds, which in their weathered surfaces resemble mountain limestone.

Near the last-mentioned point, the finely foliated structure disappears, and the earthy pulverulent beds are less frequent. For two or three miles may be seen in a low cliff a system of slaty beds (of which some parts are yellow, coarse, and cellular; other parts nearly compact, of a smoke-grey colour, occasionally fetid) passing into, and alternating with, irregular masses composed of great and small globular concretions. To the south of Whitburn, the whole cliff is composed of these concretions, varying from a quarter of an inch to a foot and a half in diameter: but, before reaching the banks of the Wear, they are replaced by a regularly bedded yellowish white magnesian limestone of earthy texture.

In a part of the coast between Castle Eden-dean and the sands to the north of Hartlepool, we find the same complications of structure, the same brecciated beds and globular concretions, and the same passages from one modification into another; and, as a natural consequence, the cliff has, by the action of the waters, been worn down into the same kind of grotesque forms and great insulated masses which were before remarked in Marsden bay. Here, however, the earthy structure is more prevalent; and the finely foliated beds above described are represented by a series of fetid beds, generally of a dark brown or smoke-grey colour and slaty texture*. Moreover, the contortions are more violent, and the subordination of the brecciated masses to the other beds is more distinctly exhibited than at Marsden rocks; for not only in the cliff, but also in the great perforated masses which are surrounded by the waters, we find the breccias distinctly surmounted by regular brown, slaty, or foliated beds, associated with yellow, cellular, amorphous, concretionary masses.

These details may convey some notion of the complex and irregular structure of the whole deposit, which can be seen in no place so well as in an extensive coast section†. They also seemed necessary to an explanation of the true relations of the brecciated masses.

It appears then, that these breccias are neither at the bottom nor at the top of the formation of magnesian limestone, but that they are subordinate to it;

* In one or two places, the earthy incoherent masses, when rubbed or struck with a hammer, are as fetid as the regular beds with which they are associated.

† Many of the natural sections in the ravines which are transverse to the formation of magnesian limestone illustrate the same fact. For example, the cliffs on both sides of the Nid near Knaresborough exhibit some fine modifications of magnesian limestone; but the different varieties replace each other with so little regularity, that in many places it is not possible to find the corresponding points of the sections on the opposite sides of the river, though its direction is transverse to the bearing of the strata. A confirmation of this fact may sometimes be seen even on the opposite sides of a narrow cut, made through the beds of the deposit for the passage of the public road.

that the disturbing forces which produced them were violent, mechanical, and local, and in some instances were several times brought into action; and that they were not of long duration; for the fragments of the beds are not water-worn, and appear to have been re-cemented on the spot where they were formed.

How far these mechanical movements which broke up the half-consolidated beds during the epoch of their deposition, were connected with those internal movements of the particles which, on a great scale, produced the irregular concretionary structure, would perhaps be impossible to determine: but both causes seem in some places to have operated together; for, as was before stated, we may find many large masses of an intermediate character which seem to form a passage between a brecciated and a concretionary structure.

IX. *Small concretionary structure.*—Of this there are two modifications: 1st, when the minute grains which enter into the composition of the rock are of ill-defined and of irregular forms: 2nd, when they are better defined, and are spheroidal.

The first modification is infinitely the most abundant. In the whole range of the formation we can hardly find a single quarry or escarpment in which some of the rocks do not exhibit a dull earthy uneven fracture, and a kind of compound structure; being partly made up of minute and imperfectly granular portions, coated over and mixed with earthy matter which is often nearly incoherent. Of this structure there are several varieties which may deserve enumeration, especially as they connect the rock in question with the other modifications of the magnesian limestone.

1st. When the granulated are subordinate to the pulverulent or earthy portions. These rocks have little coherence; often soil the fingers, and pass imperceptibly into masses which are quite pulverulent, like the *asche* of the German geologists.

2nd. When the earthy parts are subordinate to the granulated. These rocks sometimes soil the fingers; but the harder parts cohere, and bear exposure to the weather. They are often regularly bedded; but below Knaresborough there is an escarpment nearly one hundred feet high, composed of this variety, in which there is hardly a trace of stratification. In some places they contain casts and other traces of organic remains.

3rd. When the grains become very minute, and the rock passes into a nearly compact state.

4th. When some of the granulations exhibit a glimmering lustre. The rock then begins to form a passage into the dolomites above described.

5th. When the minute amorphous grains have a dull surface, and irregularly pass into each other, with a very small mixture of earthy matter. This variety, which is the most perfect exhibition of the rock I am here describing, exists in various localities, especially in the southern parts of Yorkshire, where it is met with in some places near the bottom of the formation in thick beds, which have been extensively quarried*. In these beds are also found traces of organic remains.

Second modification, when the grains are of more regular form, and the structure becomes oolitic. Rocks of this structure are on the whole of rare occurrence, though they abound in a few places. I never remarked them (at least in any perfect form) in Nottinghamshire or Derbyshire: but in the range of the formation in the southern parts of Yorkshire, especially between the rivers Don and Went, there are several localities where they are well exhibited. Some of these deserve notice.

1. On the left bank of the Don near Cadeby, is a fine quarry exposing eight or ten hard sound beds (some of which are nearly four feet thick), surmounted by eight feet of hard cellular amorphous masses of yellow limestone. The sound beds are partially oolitic, cut soft in the quarry, harden by exposure, and then ring under the hammer, and externally resemble the Bath freestone. On examination, the grains are found to be less uniform in size, and not so perfectly spherical as they are in the great oolite. Their surfaces, especially when seen through a lens, have generally a glimmering lustre, and when broken they are frequently found empty. Sometimes they exhibit an aggregation in concentric laminæ, in which case the exterior portion is more crystalline than the interior; and as these spherules are occasionally hollow, they have the appearance of having been formed by an aggregation commencing at the surface, and proceeding inwards. In some instances a fracture will pass through the centre of the oolitic grains, and in that way expose on the surface a great number of minute spheroidal cells †. In other instances, the separate grains resist the force of percussion, and the broken surface is studded (as in the great oolite) with an indefinite number of spherical particles.

2. A few miles to the north of the preceding locality (for example, on the road side between Marr and Hickleton) there are, in the very centre of the formation, several quarries exhibiting beds similar in structure to those last described. These beds are, however, darker, coarser, and less coherent; and they contain many beautiful casts of a small turbinated shell. Moreover the oolitic grains are less uniform in size; and they occasionally pass into large pisolitic concretions, which, on fracture, expose a number of concentric laminæ. These laminæ appear in some instances to be hollow at the centre; in other instances they have arranged themselves about the casts of the small univalve above mentioned, and sometimes about a spherical congeries of minute oolitic grains.

3. At Stubbs Hill (on the road from Doncaster to Wakefield) are some coarse cellular red-coloured beds, resting immediately upon the marls of the lower red sandstone. They contain many organic remains, especially the casts of bivalve shells; and through them are disseminated a number of oolitic grains of more uniform size and texture than in the preceding varieties ‡.

* The quarries near the escarpment on both sides of the river Don produce some good building stone, which may be referred to this variety. Conisborough Castle is, if I remember right, built of a stone which is allied to the modification here described.

† One of the varieties above described, consisting of a congeries of hollow oolitic particles, in some places (for example, in the great white quarries to the S.W. of Burton Leonard, near Ripon) graduates into a rock of very singular appearance. In passing into a solid state, the oolitic grains seem to have been completely blended; and the rock has the character of an uniform subcrystalline mass filled with minute spheroidal cells, like the vesicles of a piece of fine pumice.

‡ See Plate IV. Map 3. Sec. 3.

These instances are sufficient for my present purpose; and it may be stated that even in the districts where they occur, they are exceptions to the more usual character of the rock.

In the whole range of the formation through the remaining parts of Yorkshire to the north of the Went, there are very few examples of an approach to a decidedly oolitic structure: but it reappears in some parts of the county of Durham, more particularly in the cliff on the east side of the promontory of Hartlepool, where there are not less than eight or ten beds which are more or less perfectly oolitic. They are associated with, and surmounted by hard, cellular, concretionary, and earthy beds belonging to several of the varieties of magnesian limestone already described*.

These various modifications of *small concretionary structure* derive a great interest from the consideration, that in them are exhibited, on a minute scale, the same peculiarities of aggregation, which, on a great scale, form the most extraordinary features of the deposit I am describing.

X. *Large globular concretionary structure.*—I have never seen a single example of this structure in Derbyshire or Nottinghamshire. But it occurs, though very rarely, in Yorkshire: for example, in the cliffs on the left bank of the Nid below Knaresborough, associated with rocks of earthy and pulverulent texture; also in some quarries in the hills on the west side of the village of Well.

It is seen in its most imposing form on some parts of the coast of Durham, where the whole cliff resembles a great irregular pile of cannon balls: but it is not in those localities that the formation of the large spheroidal concretions can be studied with greatest advantage. Their true history will be best understood where they are associated with other modifications of the limestone.

The following statements are the result of repeated examinations of the quarries of Building Hill, Fulwell Hill, and Southwick Hill, near Sunderland; and of the coast sections, especially near Marsden Rocks and Black Rocks. At all these places are found different modifications of the laminated variety described above (§ 4. No. IV. p. 86.), and it is principally with them that the finest concretionary masses are associated.

1. The finest laminæ are generally of a brown colour and crystalline texture; but the beds of which they are composed are often marked with a number of earthy spots on the transverse surface. Sometimes these earthy marks are disposed with great regularity; and as the matter of which they are composed, not only interrupts the range of the laminæ, but is easily washed out, the weathered surface of the rock has, in such cases, a beautifully honeycombed appearance. This

* This locality has often been noticed as exhibiting the finest specimens of oolite in the whole range of the magnesian limestone. The spherules are, however, partly hollow and of earthy texture; and so much mixed with earthy incoherent matter, that very few of the beds in question would afford a good material for building.

is the first approach to a regular concretionary structure, and appears to have been effected by a separation of parts after deposition; for the harder portions of these honeycombed masses sometimes contain scarcely a trace of carbonate of magnesia, while the earthy portions contain it in considerable quantity.

2. On separating the beds (especially where the transverse fracture exposes the earthy spots above described) in a direction parallel to the planes of deposit, we often find that the laminæ are not continuous, but made up of circular plates irregularly blended with, and running into, each other; the intervals between which are filled with a yellow magnesian earth. These plates sometimes assume a discoidal form, and at first sight might be mistaken for large Nummulites. Here we have a distinct tendency to aggregation about different centres; but the operation being confined to given laminæ, could not develope itself in a vertical direction. The concretions were therefore expanded laterally, and assumed a lenticular or flattened spheroidal form. That these changes took place after the deposition of the rock, is rendered probable by the additional fact, that the laminations of the beds may be often observed to pass (without any deviation) through the various subordinate concretionary masses.

3. At the planes of separation between two of these laminated beds, there is frequently some earthy matter; and the discoidal concretions are still more perfectly developed, and sometimes approach the spherical form. These spheroidal masses impress both the upper and lower surfaces of the beds with which they are in contact; and we may find large concretions in such a position that it is impossible to know to which bed we should refer them, although we may trace through their substance the laminæ and the lines which mark the stratification of the contiguous masses. In such cases (of which I have seen examples near Black Rocks), it seems hardly to admit of doubt, that the concretionary form was superinduced by some internal movement of the particles after deposition. In the preceding instances the rock exhibits at the same time an earthy, a crystalline, a laminated, and a globular structure. The following modifications are still more remarkable.

4. Several of the slaty or laminated beds (especially at the localities near Sunderland) are interrupted by cells of considerable magnitude, which are of very irregular forms, but generally elongated in the direction of stratification. Some of the smaller cells are nearly empty, and are not so much coated with crystallized carbonate of lime as in many instances before mentioned. But in general they are nearly filled with concretionary masses mixed with the yellow magnesian powder. The concretions may be separated into three classes, which will be described in order:—those which are aggregated on the floor and roof of the cells;—those which are aggregated on the sides;—and those which are packed up in the middle of the powder and unattached to the parent rock. On examining the floor and roof of one of these cells after the powder has been washed out, we may find them studded with circular plates or spheroidal concretions resembling the modifications last described; but the process of aggregation being here uninterrupted, gives rise to more complex results. We often find the concretions ascending from the floor, or hanging from the roof in the form of elongated cones; sometimes extended so far as to approach and become interlaced with each other, and nearly to occupy the whole cell; sometimes aggregated from one of the surfaces and extending to the other in the form of irregular cylindrical or conical pillars; and, sometimes, exhibiting all these varieties of form mixed with, and interrupted by, distinct spheroidal concretions, producing a structure too complicated for description.

The surfaces of these concretions are sometimes smooth, in which case the internal structure is imperfectly crystalline. Sometimes they are covered with crystalline points composed of the acute solid angle of the inverse rhomb; in which case the internal structure is crystalline, and each solid angle is the acumination of a distinct bundle of crystalline fibres diverging from a centre.

Some of these masses have been erroneously called stalactitic. They have not the structure of stalactites; for they are not made up of successive layers arranged about the axes of the elongated pendent cones, but on the contrary (where the crystalline structure has not been carried too far) we may find them made up of circular plates piled upon each other, with their planes at right angles to the same imaginary axes; and these plates seem to be the prolongations of the laminæ of the contiguous beds.

The concretions on the sides of the cells are often extremely beautiful, and are generally composed of imperfect spheres or clusters of spheres. They never stand out in elongated forms like those last described, because the laminæ here present their edges to that face of the rock on which the concretions are aggregated. They are generally more crystalline than the preceding class, and the crystalline parts are arranged nearly in the same manner. A fracture through the centre of one of these clusters of spheres often exposes a structure of great beauty. The whole mass is found to be made up internally of a congeries of spheres of various sizes, compressing, interrupting, or penetrating each other; and each sphere is composed of separate bundles of diverging crystals acuminated (wherever the process is complete) by the acute solid angle of the inverse rhomb. Yet even through such masses as these, we may often trace the original lines of laminated or slaty texture: and when they are struck off from the wall to which they are attached, we may see them passing into the rock, partaking of its inequalities, and penetrated by its cells. They have then a singularly complex structure, being at one and the same time crystalline, earthy, cellular, slaty, and globular.

The last set of concretions to be noticed in this place, are found in association with the dolomitic earth occupying the cells, are unattached to the surrounding beds, and are always of a more or less perfectly spheroidal form. Sometimes they are single; but more frequently several spheres are in contact, which by mutually penetrating each other, produce a number of grotesque forms; and occasionally they are grouped in beautiful regular clusters. In general they are less crystalline than the globular masses before described, and they do not exhibit the same kind of laminated structure; but in some instances they are studded with the projecting angles of the inverse rhomb, and on fracture are found, as in the former instances, to be composed of diverging bundles of crystals. The largest of these concretions (which at Fulwell Hill are sometimes more than a foot in diameter) have commonly a smooth surface; and when broken in two, expose a number of thick ill-defined concentric layers, which are either aggregated about an earthy nucleus, or are hollow in the centre*. These layers are of various colours; ash-grey, smoke-grey, yellow, or dark-brown. Towards the centre, the fracture is usually dull and earthy; but towards the circumference, the layers are made up of many curved crystalline plates, and the lustre is shining. In other instances, balls of considerable size have the internal structure here described, while their outer zone is made up of diverging crystalline fibres, with the usual acumination. The transverse fracture in such cases is very beautiful.

These spheroidal concretions are in some places subordinate to the pulverulent matter; in others, they abound so much that they nearly fill the irregular cells; and the ochreous powder

* In such cases the original nucleus has probably been carried off; like the shell which leaves only its cast in the rock, or the crystal which leaves only its impress on a secondary investing pseudomorphous substance. All these seem to be examples, on a small scale, of movements among the particles of solid bodies which are in contact, and of new crystalline arrangements, without the intervention of any previously chemical solution.

appears as an upfilling matter in the intervening spaces. In some rare instances, the earthy matter becomes hard and coherent; and when broken with a hammer, exposes a surface which passes through the centres of the imbedded balls.

In all the different varieties of concretions there are some which, when rubbed, exhale a hepatic odour. This circumstance is, however, accidental or local. Carbonate of lime is their essential constituent*. During the process by which the concretionary structure was effected, this mineral seems to have separated itself almost entirely from the dolomitic earth, which is rejected, into the ochreous powder.

So far I have considered these various concretions in association with the regular beds of the formation; and the details seem to indicate that the several forms have been superinduced upon masses which were originally stratified. We have only to suppose that the same causes acted upon a more extended scale, and we may imagine that the structure of whole systems of beds was obliterated, and that they gradually passed into great piles of spherical concretions like those which appear on the coast of Durham.

A very complex modification of the concretionary form still remains to be noticed.

5. In the quarries near Sunderland (for example, at Fulwell Hill), there are some strong thick beds, in the greater part of which there is not a trace either of laminated, earthy, or globular structure. Here and there we may, however, observe in them a kind of honeycombed appearance, in which the small cells are not arranged in horizontal lines in the manner before alluded to, but in concentric circles. These cells (which were originally filled with pulverulent matter) are the intervals between small irregular discoidal concretions, having a concentric arrangement about a hard spherical nucleus, which is commonly made up of an obscure congeries of spheres. In this way are found, in the heart of the most solid strata, a number of spherical concretions (sometimes nearly a foot in diameter, and having little appearance of a crystalline texture), each being formed by the juxta-position of an indefinite number of small irregular discoidal concretions.

As these small discoidal concretions not only touch but pass into each other, they give each of the large spheres, especially on a fractured surface, the appearance of being made up of irregular, wavy, concentric laminæ. The same bed which in one end of a quarry is homogeneous, in the other is almost made of these singular concretions: and it deserves remark, that the concentric rings of the different centres do not intersect each other. The several compound spheres commenced their aggregation at their respective centres; expanded themselves till they came in contact, and then mutually compressed, but did not penetrate each other †. Blocks composed of these concretions, when struck with a heavy hammer, separate at a number of natural joints, and fall into many irregular solids bounded by trapezoidal faces. When the separation is complete, each solid contains within itself the elements of a distinct concretion; and the trapezoidal

* Carbonate of lime is, I believe, found in considerable excess in most of the beds containing the concretionary masses above described. The carbonate of magnesia, or more properly the combined carbonate of lime and magnesia, is only a subordinate part.

† See Plate V. fig. 4.

joints are formed by the compressed surfaces of the contiguous compound spheres*. Large masses of stone, exhibiting on their weathered surfaces the indications of the structure here described, have occasionally been used for building.

Such are the principal modifications of the central deposit of magnesian limestone. In local descriptions many further details might be wanting: but what has been done may be sufficient to convey a correct notion of the general character and relations of the great system of beds I have been considering.

Before leaving the subject, it seems natural to inquire what limits we can assign to the effects of crystalline forces acting upon large masses. If they have produced such striking effects upon a secondary, mechanical deposit, may they not have produced, in a similar way, still more important modifications in the more ancient and more crystalline stratified rocks? An answer to this question seems essential to a solution of some of the difficulties presented by the ancient zones of schistose rocks which surround the lowest unstratified protuberances of the earth.

Thickness of the deposit.—To the average thickness of this division of the formation, it is difficult even to make an approximation; as it not only rests upon an uneven, unconformable surface, but appears also to have been deposited with much irregularity. Thus at Eldon, Ferry Hill, and Thickley, the limestone, covering the coal-strata near the escarpment, is about fifty feet thick: but at Cowndon, the same portion of the limestone covering has lately been proved to the depth of more than 120 feet. The aggregate thickness of the beds in some parts of Durham and Yorkshire must be very considerable. The bore-hole at Hart, though descending to the depth of 312 feet, neither commenced in the highest beds nor descended to the lowest†. Perhaps five hundred feet might be taken as an approximation to the maximum thickness.

Organic remains and conclusions.—In the preceding details the organic remains which occur in this part of the deposit have been hardly noticed;

* The following section, from a part of the quarry of Fulwell Hill, may convey some notion of the complex nature of the deposit, and of the manner in which the spherical concretions are grouped with the other portions of the rock.

1. At the top of the quarry irregular, cellular beds of dark-grey and brown limestone, with some globular concretions, especially near the lines of stratification: thickness = 10 feet. 2. Under the preceding, a bed six or eight feet thick, chiefly composed of globular concretions imbedded in ochreous magnesian earth. 3. Thinly laminated beds much mixed with earthy matter, and containing a few spherical concretions: = 4 feet. 4. Earthy cellular beds, with hard, grey, irregular concretions, = 3 feet. 5. Hard, dark brown beds, partly laminated and earthy, = 8 feet. 6. Thin, yellowish grey, slaty beds, = 10 feet.

In a section from another part of the quarry the details would not be the same, because the different varieties of the rock constantly replace each other.

† Geol. Trans. First Series, vol. iv. p. 8.

because, however important in other respects, they produce very little effect upon the mineralogical character of the different systems of beds which have been described.

There are very few traces of them in Nottinghamshire and Derbyshire. In some parts of Yorkshire (e. g. the escarpments on both sides of the Don, Stubbs Hill, Wentbridge Hill, and the hills to the north-east of Masham, &c. &c.) they are found in considerable abundance, but in a rather obscure form, generally among the lower and more coherent beds of the deposit; while in other parts of the county we may follow the same beds through districts of many miles in extent, without seeing the impress of any organized being.

Many organic remains may also be seen on the weathered surfaces of the rocks on the coast of Durham (e. g. the south end of Black rocks, Tynemouth cliff, &c. &c.); but incomparably the most interesting specimens are found in some shelly coralline masses which occupy the central portion of the deposit in the same county.

The most northern point at which I have seen them (although they probably extend still further), is Humbleton quarry, a well known locality on the Durham road, about two miles from Sunderland. There, they occupy the top of the escarpment, resting upon a set of thin brown cellular beds. Here and there, they are tinged with ochreous stains; but their prevailing colours are light grey or yellowish white. Their texture is in part earthy and rubbly; other parts are hard, subcrystalline, and porous, but not cellular; more rarely they pass into beautiful, hard, crystalline masses, like the coral rag of the middle oolite.

With all these varieties of structure, and with local modifications, they may be followed into Tunstal Hill; and thence, ranging nearly south, they pass over the hills between Dalton-le-Dale and Easington. Their further range is disguised by diluvium.

In this way have shelly beds been traced six or eight miles in the direction of their range through the very heart of the formation, and they may be prolonged considerably further. As they contain a fine suite of organic remains, (*e. g.* corals, encrinital stems, casts of univalves, and several species of the genera Producta, Arca, Terebratula, and Spirifer, &c. &c.), they throw a most important light upon the natural history of the formation to which they are subordinate: and it is chiefly by their help that we arrive at the following important conclusion; viz. that the magnesian limestone, notwithstanding its unconformable position, is, in zoological characters, more nearly allied to the carboniferous order than to the calcareous formations which are superior to the new red sandstone.

From what has been here stated, combined with many obscure indications of organic remains in other parts of the formation, it is probable that marine shells existed in great abundance during the whole time that the magnesian limestone was deposited; and that they have in a great measure disappeared, because they did not find in many portions of it a matrix proper for their preservation. In the pulverulent beds they could not undergo petrifaction or form casts, and would, therefore, almost of necessity, be absorbed and carried off*. Again, the great internal movements which took place while many of the strata were passing into a solid state, must have been unfavourable to the process of petrifaction, and may have destroyed the imbedded shells and corals. Under such circumstances they could not form casts: they would, therefore, probably disappear altogether; for they very rarely, under the most favourable circumstances, are seen in the form of perfect petrifactions exhibiting the shelly covering. In this manner we may perhaps account for the non-appearance of organic remains in many extensive parts of the deposit, compatibly with the hypothesis which has been just stated.

If the marl-slate and compact limestone of a preceding section (§ 2.) has been properly identified with the *kupfer schiefer* and *zechstein*, it follows that the great deposit of yellow limestone last described must be the equivalent of a part of the upper system of calcareous strata in the Thuringerwald. The descriptions of this upper system, given at length by Freiesleben and abridged by D'Aubuisson†, fully bear out the conclusion. We there meet with most of the modifications which have been already enumerated; the same cellular strata (*rauchwacke*); the same foliated and fetid beds (*stinkstein*), associated with, and passing into, masses which are pulverulent (*asche*); the same contemporaneous breccias; the same small concretionary structure rarely passing into oolitic; the same confusion of chemical and mechanical structure; the same concretions of carbonate of lime; and the same frequent passages of one modification into another. So that three-fourths of the descriptions given in the abridgement of D'Aubuisson might be applied, almost word for word, to the corresponding parts of the English series.

There are at the same time, as might be expected, some points of difference. In England the concretionary structure seems to be more perfectly developed than in Germany. On the contrary, the great masses of rock salt which in Thuringia are subordinate to the calcareous beds, have no adequate representatives in our magnesian limestone‡. The alternating gypseous beds of Thuringia may perhaps be represented, though under a modified form, by the deposit which I now proceed to describe.

* In the same way the organic spoils have probably disappeared from many of the incoherent portions of the formations (such as the Woburn sands) under the chalk. A curious instance of the gradual absorption of certain organic remains in a recent deposit, is given by Mr. Lyell in a preceding part of the Geol. Trans. (See Second Series, vol. ii. p. 87, &c. &c.)

† *Traité de Géognosie*, vol. ii. p. 344.

‡ I had been informed by the Rev. J. Holme, that in analysing various dolomites from this formation, he had found traces of muriate of lime; but I was not aware that any trace of muriate of soda had ever been discovered. He has, however, since examined some large specimens which I procured from the red beds near Mansfield, and has obtained beautiful cubes of muriate of soda from them. The Thuringerwald salt is therefore not altogether without its representative in the English series. For an analysis of one of the red beds alluded to, see p. 84, note.

§ 4. *Lower Red Marl and Gypsum.*

The existence of this deposit in the higher part of the dolomitic series had been known in Yorkshire many years before the appearance of any of our geological maps. Mr. Smith was, however, the first to give the proper importance to it, by determining its exact relations, by tracing its range, and limiting its extent. In the neighbourhood of Doncaster and Ferry Bridge there are several ancient pits from which the beds of plaster rock have at different times been extracted: and they have been found in so many wells, works of drainage, and other artificial excavations, opened on the line of range, that there can be little doubt of their continuity from the confines of Nottinghamshire to the south bank of the Wharfe near Tadcaster.

The bottom beds of this deposit are not visible in any section with which I am acquainted; but they have been reached by wells sunk in the neighbourhood of Ferry Bridge, and are said to be composed of yellowish marls, making a passage into the inferior beds of yellow limestone. The central beds are generally composed of red and variegated unctuous marls and gypsum, not distinguishable from the upper gypseous marls of the new red sandstone. The highest part of the series is sometimes represented by a stiff blue clay; but perhaps more frequently by beds of red, grey, greenish, or yellowish marls, rather meagre to the touch, and containing a little fibrous gypsum.

A correct notion of the nature of this deposit will be conveyed by the following sections.

1. *Plaster-pit Hill near Ferry Bridge.*

	Feet.
1. Various beds of gypseous marl resting on the yellow limestone which crops-out on the west side of the quarry. Thickness not exposed	—
2. Blue, red, and variegated marl with much fibrous gypsum	15
3. An irregular bed of red marl, with strings and nodules of gypsum	6
4. Hard chocolate-brown and reddish brown marl, with eight or ten thin beds of fibrous gypsum	18
5. Red and blue marl beds contorted and passing into the diluvial covering	8

The whole deposit must, in this locality, be of very unusual thickness, perhaps not less than one hundred feet; for there appears to be a considerable thickness of marls, not seen in the section, which are interposed between the red and blue bed (No. 5.), and the superior limestone. There are some fissures in this quarry which contain fine crystals of transparent selenite.

2. *Section exposed by the cut for the Canal below Knottingley.*

	Feet.	Inches.
1. Red marl and fibrous gypsum at the bottom of the section. The whole thickness not exposed: the part visible about	6	0
2. Impure yellowish clay	1	0

	Feet.	Inches.
3. Yellow indurated marl	0	4
4. Stiff blue clay	2	6
5. Meagre calcareous yellowish marl	1	0
6. Impure earthy limestone	3	0

Over the preceding came the regular beds of the superior limestone.

3. *Quarries behind the village of Askerne.*

	Feet.	Inches.
1. Unctuous, red marl and fibrous gypsum. The upper part only is exposed, and the thickness is unknown	—	—
2. Meagre, blue and red clay	2	0
3. Striped, red and yellow sandy beds	3	0
4. Red marl mixed with incoherent, yellow sand	3	0
5. Grey, impure, sandy limestone marked with dendritic impressions	0	4

Over the preceding came the regular beds of the upper limestone.

All these sections are in the ascending order; and the two last only represent the highest part of the deposit.

Range and Extent, &c.—These gypseous marls, on the average probably not more than thirty feet thick, are very well laid down by Mr. Smith: they are, however, extended too far to the south; and there are one or two slight errors which I have endeavoured to correct in the accompanying maps*. It is indeed often impossible to determine the range of these beds otherwise than by connecting in imagination the several points where the plaster rock has been excavated. In other places they occupy the base of a low escarpment formed by the upper limestone, and may under such circumstances be laid down with much more precision.

The first indication of them in any decided form, is at the base of an obscure escarpment under the village of Letwell in Yorkshire. To the south of this place they thin off, and probably disappear; at least there are no denudations which offer any proof of their continuity in that direction †.

Of their range towards the north it is not intended to offer many details; but the following list of localities in which the gypseous marls have been excavated, may at least serve the purpose of verification: 1. The bottom of the hill, half a mile west of Old-coats on the Firbeck road. 2. In the mill-dam under Limestone Hill, three-quarters of a mile west of Tickhill. 3. Brick-pits

* See Plate IV. Nos. 2. 3. and 4.

† It may perhaps be proper to notice in this place a thick mass of red marl and sand, which appears on the banks of the Worksop canal (about a mile and a half east of the escarpment of magnesian limestone), and ranges towards the south. When I first saw it, I considered it as a prolongation of the red gypseous marls described in the text. On examination, however, it not only was found unconnected with them, but appeared to be in a lower part of the series. If it be really imbedded in the formation, it must be regarded as a local deposit subordinate to the yellow limestone, and may perhaps be brought into comparison with the anomalous red sandy beds of Mansfield. It may, however, be an outlying mass of the upper red sandstone brought in by a local depression of the dolomitic beds.

west of Wadworth*. 4. In wells at Loversal, Balby, and various places near the Don. 5. A pit near the south-west end of Cusworth Park. 6. In wells near Red House. 7. West side of Campsmount and Clay-flats. 8. The west side of the village of Askern, where the marls are brought up by a fault. 9. The south end of Norton. 10. On both sides of the Went below Little Smeaton. 11. Pits on the west side of the road near Grove Hall. 12. Great canal under Knottingley. 13. Rail-roads from the Air to the limeworks of Fairburn, &c. 14. Plaster-pit Hill, &c.

From the last-mentioned place, the gypseous marls range across the north road nearly four miles from Ferry Bridge, and are continued in a very obscure form, and apparently interrupted by some great faults, to the south-west side of Sherburn, where they have been proved in wells. In this part of the range they seem gradually to thin off; and at the village of Towton, they are, if I mistake not, represented by a bed of stiff blue clay not more than two feet thick. There are some obscure indications of them in association with outlying masses of the upper limestone at Dalton lane, and one or two other places north of Bramham; but they have not, I believe, been discovered in any part of the formation of magnesian limestone to the north of the Wharfe.

§ 5. *Upper thin-bedded Limestone, sometimes without Magnesia.*

The gypseous marls last described are surmounted throughout their range by a grey thin-bedded limestone, which forms the highest tier of the dolomitic series resting on the back of the other parts of the formation, and dipping (generally at a very low angle) into the plain of the new red sandstone. The thin-bedded structure is universal, not unusually passing into a structure which is slaty and sometimes foliated. Between these beds, and even between the foliations, there is generally interposed a very thin plate of bluish grey or greenish grey marl; and when these marls become so thick as to assume the character of beds (which is, however, rarely the case), they have then generally a tinge of red or purple. When seen in a quarry or natural section, the thinner beds have an irregular shattered appearance: and when one of them is struck with a hammer, it generally falls into pieces at a number of natural joints, which are coated over with beautiful, black, dendritic or stellated impressions.

The deposit is traversed by a great many nearly perpendicular fissures or small faults, on the opposite sides of which the beds have seldom the same exact inclination. From the appearance of the large denudations near Ferry Bridge, as well as in other places, it would seem that the system here described had been partially broken up after its deposition; and that the disturbing forces not being able to raise the incoherent beds into continuous undulations, had snapped them asunder at all the points of greatest flexure†.

* See Plate IV. No. 4.

† To the remark in the text there are one or two striking exceptions; but they apply to the greater dislocations, which are not noticed in this place. See Plate IV. sec. 1., and Plate VII. fig. 6. (Wadworth and Knottingley.)

The mineralogical character of these beds is much more constant than in the lower parts of the formation: there are, however, many variations of structure, some of which must be enumerated. In some quarries (for example, at Carlton near Worksop) the separate beds cannot be distinguished by colour or composition from the inferior deposit of yellow limestone. They are not unfrequently cellular; and we may, here and there, find traces of a concretionary and globular structure. Such forms are, however, imperfectly developed; partly perhaps in consequence of the separating marls, which keep the thin beds distinct from each other, and prevent any modification of structure from operating on the whole mass.

The prevailing colour of the series is grey, varying from ash-grey to dark smoke-grey; and the several shades are not unusually exhibited in stripes or cloudy spots; and among beds possessing such colours we may find portions of a red, brown, or bluish tinge. It also deserves remark, that the colours of the rock are much affected by the thin bands of marl, which not merely coat over the surface, but partially penetrate the component strata. In quarries, however, exhibiting the most ordinary structure and colour, we may occasionally find beds of hard, bright yellow, subcrystalline dolomite.

Some of the thin beds have a dull, earthy fracture, and must be regarded as varieties of marl-slate. In general they are considerably indurated, and gradually pass into hard and nearly compact limestone. Of the harder varieties which have a dull surface, some are porous and almost granular; some nearly compact, with a rather uneven fracture; others perfectly compact, with a beautifully smooth conchoidal fracture; the several modifications being mixed together, replacing each other, or alternating in thin stripes.

Associated with the preceding, and without any visible order, are other beds which are nearly compact without the smooth conchoidal fracture, and which, when examined with a lens, show a glimmering lustre. These pass through many shades into a hard, small-grained, crystalline rock. All the specimens, which are both granular and crystalline, are, I believe, dolomites: but of the other varieties, some do, and some do not, contain magnesia, the composition in this respect being apparently dependent upon circumstances merely accidental or local.

As some of the harder beds in this deposit form a good material for the road, and as those parts of it which contain little magnesia are burnt and extensively used in agriculture, large quarries have been opened in it (nearly along the line of the great North-road) which exhibit in great perfection all its modifications. One or two of these localities may be briefly noticed.

1st. *Brotherton, near Ferry Bridge.*—In the rail-roads and quarries of this place, the beds are exposed in the following order, beginning with the lowest.

	Feet.
1. Red marl and gypsum, surmounted by a few feet of blue clay	—
2. Soft, yellow, earthy limestone, which effervesces feebly with acids	3
3. An irregular bed or congeries of thin beds, imperfectly concretionary, partly earthy, and partly compact, very difficult of fracture, of various shades of colour, with a blue tinge near the centre	3
4. Thin, greyish beds, with layers of bluish or ash-coloured marls	6
5. A bed similar to No. 3	1
6. Many thin, shattery beds with the separating marls; of these beds some are porous or cellular; some are compact; the structure is variable. The colours (sometimes exhibited in cloudy spots, and sometimes in stripes,) are grey, yellowish grey, or brown	20

At the top are some very thin beds resembling marl-slate.

2nd. *Knottingley.*—In the cut for the canal below the village, the bottom earthy beds (No. 2.) of the preceding section were laid bare. Near the centre of the system there were some remarkable contortions, which had brought up the lower gypseous marls; and in the highest portion of the same section were some thick, cellular and concretionary fetid beds, of a dark, smoke-grey and bluish grey colour, and entirely unlike all the other parts of the series. This locality is also interesting from its exhibiting the junction of the top beds of the deposit with the upper red marl; but the contortions of these beds make the phænomena less instructive than might have been anticipated*. At the two last-mentioned localities none of the strata contain much magnesia, and the greater part of them do not exhibit a trace of it; yet in other quarries in the same neighbourhood, and in the same geological position, magnesia is an essential constituent of the rock†.

3rd. *Limestone-Hill on the west side of Tickhill.*—The beds are in the following order, beginning with the lowest.

	Feet.	Inches.
1. A grey, close-grained dolomite, hard and translucent at the edges, lustre glimmering, fracture uneven, and fragments irregular	1	0
2. Very thin, irregular beds; some nearly compact and glimmering; others dull and earthy; colours grey, smoke-grey, and yellowish-grey; separated by many natural joints coated with dendritic impressions, and parted by very thin seams of light-coloured bluish or yellowish marls	3	6
3. A hard, irregular bed of dolomite; concretionary; cellular; of various shades of colour, and coated over with dendritic impressions; glimmering; part nearly compact and porcellaneous, part granular and porous	1	0
4. Thin, shattered beds like No. 2.	3	0

* See Plate VII. fig. 6.

† Subordinate to the above deposit are occasionally found some thin beds which contain a larger proportion of magnesian earth than any other part of the whole series. From a specimen derived from a quarry south of Robin Hood's Well, Mr. Holme obtained the following result.

Carbonate of lime	29.75
Carbonate of magnesia	60.25
Alumina and red oxyd of iron	7.75
Silica	1.25
Water	1.00
	100 grains.

	Feet.	Inches.
5. A hard, yellowish brown dolomite, in texture like No. 1., but here and there passing into an earthy form	1	0
6. Very thin beds with partings of marl; irregularly slaty or foliated; general characters like those described under No. 2.	8	0

It is seen in the preceding section how the regular dolomites alternate with the peculiar, thin beds of this part of the series. Some of the thin beds, however, effervesce feebly with acids, and contain a small quantity of magnesia.

The alternations are still more remarkable in the quarries near Old-coats a few miles further to the south. We there meet with all the modifications of structure which have been just described: the thin beds are in some rare instances studded over with minute globular concretions; and one nearly compact bed contains a great many small specks of galena. Before reaching Carlton this deposit becomes so changed, that it is not easily distinguished from the lower portions of the magnesian series.

4th. *Askerne.*—At this place there is a very fine section of the upper limestone. Many portions of these quarries are magnesian; but we meet with no yellow, crystalline dolomites like those of Tickhill. Some of the beds are of a reddish colour, and are almost irreducible in the kilns. The workmen have learned to separate those portions which burn to a cold lime from the more caustic magnesian beds with which they alternate.

These sections, together with the general notices which precede them, are, I hope, sufficient for the description of this highest member of the dolomitic series.

Range—Outliers—Probable Extension of the Deposit towards the North, &c.

These upper beds first appear on the west side of the village of Carlton near Worksop; but in following them towards the north their relations, for two or three miles, are rather obscure. Before reaching the village of Old-coats, they put on a very characteristic form; and to the west of that place they are bounded by a regular escarpment resting upon the lower gypseous marls. From the neighbourhood of this place they may, with very limited exceptions, be easily traced to the banks of the Wharfe. Their western boundary in this long range is determined by the gypseous marls above described; and their eastern boundary has already been sketched out in the former part of this paper*. The escarpment seems to die away in the alluvial plain of the Wharfe near Grimstone, and the upper limestone sinks below the surface: but a small patch (which may, perhaps, be considered as an outlier) appears some miles further up the river, occupies the right bank for a few hundred yards near Paper-mill Bar, and seems to range in a very obscure form towards the right bank of the Bramham river.

There are three small outliers of this upper limestone: one forming the cap of the low ridge immediately south-west of Ferry Bridge; another about two hundred yards from the great North road, close to the cross road leading off to Kirk Smeaton; and a third near the south-west corner of Wetherby Grange Park; and there may be more small patches of the same kind which have escaped notice.

As this limestone is certainly prolonged beyond the limits of the lower gypseous marls, it becomes a question of some importance how far we can trace it in the range of the formation to the north of the Wharfe. In a general point of view the whole dolomitic series may be described as a complex for-

* See page 51.

mation, the highest and lowest divisions of which are more compact and thin-bedded than the great central mass, and generally contain a less proportion of magnesia. There are some parts of Yorkshire north of the Wharfe where the highest portions of the magnesian limestone have this compact and thin-bedded character; yet in the absence of the lower red marl, it is difficult to find their exact relations. In some instances they are probably contemporaneous with the deposit here described, and they may at least be conveniently classed with it.

In this view of the subject, I would refer to this upper system a thin-bedded, light-coloured, magnesian limestone of Copgrave and Goldisborough; also a similarly bedded, yellowish brown and dark smoke-grey limestone, which appears in several places on the back of the formation near the villages of Well, Snape, and Watlass*.

Between Nosterfield and Well, there is a system of beds in the position above described (ranging about N.N.W. and S.S.E., in length about a mile, and in breadth about a quarter of a mile), and of so very peculiar a character as to require a more detailed notice. As they dip about S.E. at a considerable angle, the most northern quarry on the range lays bare the lowest beds, and shows that they rest immediately upon the yellow limestone, without the intervention of any red marl.

First Section.—From Welsea quarry, a quarter of a mile south of Well, beginning with the lowest beds visible and ascending.

	Feet.	Inches.
1. Hard, yellow, magnesian limestone	1	0
2. Several thin beds of ditto	1	0
3. Fine, yellow dolomite, like the dolomites of the carboniferous limestone	0	6
4. A system of beds of very deep smoke-grey, and dark greyish blue colour	30	0

The greatest part of the system (No. 4.) is composed of incoherent, shattered beds resembling a highly calcareous, indurated shale; but there are a few beds, each about a foot thick, of closer texture, some of which are fetid, and cannot be distinguished from carboniferous limestone. One of these beds, near the top, is traversed by many compressed cylindrical stems about one inch and a half in diameter, but without any external markings to indicate their origin.

Second Section, in the ascending order.—From a quarry (called Seven-acre) further on the dip of the beds.

	Feet.
1. Strong, yellow, cellular, magnesian limestone forming the base of the quarry	—
2. Thin, shattered beds of a brownish blue colour, and with thin seams of marl	12
3. Earthy, yellowish beds	3 or 4
4. Dark brown and black shale highly calcareous and semi-indurated	1

* Among the thin beds of Watlass quarry are some which exhibit traces of globular concretions like those of Fulwell Hill; and some of the bands of marl are dark and carbonaceous.

	Feet.	Inches.
5. Yellow, rubbly limestone much mixed with earthy impurities, and containing a considerable portion of galena	0	5 or 6
6. Dark shale passing into limestone	1	6
7. Yellow, magnesian limestone, with a few carbonaceous stains	3	0

No. 5. of this section is unquestionably a *bed;* and the galena is not a waterworn, mechanical deposit, but is apparently contemporaneous. It is found in lumps of considerable size, and penetrates the hardest portions of the rubbly limestone. In the year 1823 some profit was made by excavating it, but the works have been since deserted. Some of the beds have the character of mountain limestone; and the resemblance is rendered more complete by the innumerable petrifactions of the Producta calva which appear in the dark bluish limestone. In the same beds are rarely found some traces of corals like those of Humbleton quarry near Sunderland.

There is a third section still further on the dip of the beds, which exposes a higher portion of this series. The whole face of the quarry is composed of thin very dark beds, penetrated by white contemporaneous veins, and very nearly resembling transition limestone. In this, as well as in the two preceding sections, all the dark compact beds are, I believe, without magnesia*.

Some of the highest portions of the magnesian limestone in the county of Durham (for example, the beds of Fulwell Hill, the beds on the coast south of Marsden Bay, and some of the beds south of Black Rocks), seem to be very nearly related to the part of the series which I have been describing. They are, however, so intimately blended with the other modifications of the formation, that I found it impossible, in description, to separate them from the general mass of the yellow limestone.

Such are the principal facts connected with the range and extent of this deposit. In that unequivocal part of it which rests upon the lower red marl, there are, in general, but rare traces of organic remains at Cold Hill to the east of Aberford: in a few other places they are, however, abundant, though in an obscure form.

Its thickness is of course variable, and cannot in any case be easily ascertained; for, with the exception of the section below Knottingley (and even there it is disguised by a dislocation), there is not a single spot which exposes the junction of the top beds with the upper sandstone and marl†. Perhaps eighty feet may be assumed as its maximum thickness in the southern parts of Yorkshire.

§ 6. *Deposits immediately superior to the Magnesian Limestone.*

The deposits which succeed the magnesian limestone are of enormous thickness and extent, and form the subsoil of what may be called the great central plain of England. They are, as is well known, principally composed

* Lime which is burnt from the best parts of these quarries may be spread over the land at the rate of six chaldrons the acre; but of the lime derived from the magnesian beds, not more than two chaldrons can be used with advantage. A larger quantity would produce sterility.

† See Plate VII. fig. 6.

of red sand, sandstone, and marl; and they are of such complex and irregular structure, that it is not, I believe, possible to separate them into any natural divisions which, in their range through the whole island, preserve a constant relation to each other. There is, however, in that part of the system which rests immediately on the back of the magnesian limestone series above described, an approximate order which requires a short notice.

In Nottinghamshire the yellow limestone is surmounted (as has been already stated) by a thick formation of sand and sandstone, which ranges nearly due north through the forest lands of the county into the southern plains of Yorkshire, occupying on the average a breadth of eight or ten miles; but to the north of Doncaster it disappears under the alluvial and diluvial plains which are spread out between the banks of the Don, the Air, the Wharfe, and the Ouse. The soil resting upon it, is chiefly composed of a light yellowish sand; but all the deep sections of the undisturbed beds, exhibit a reddish colour. This sandstone is generally coarse,—often nearly incoherent; passes here and there into a fine conglomerate; contains many small rounded pieces of quartz, and (judging from the appearance of the diluvium associated with it) appears also to contain many rounded pebbles of ancient quartz rock. Immediately over the preceding sandstone is a deposit of bright red-coloured gypseous marls, which form the subsoil of the eastern clay lands of Nottinghamshire. The escarpment of these beds is seen in a well-defined chain of low hills which crosses the great North road above Markham Moor. They gradually sink down into the great plain which is drained by the Trent; and a few miles to the east of that river they are surmounted by the lias.

These two great divisions of the new red sandstone (which, when taken in association with the deposits already described, may be called the *upper red sandstone*, and the *upper red marl and gypsum*), appear also to exist in the county of Durham, as far as we can judge from the denudations on the banks of the Tees, and from the coast section between Hartlepool and the mouth of the same river. The magnesian limestone, notwithstanding the immense accumulations of diluvium, is evidently surmounted by a zone of strata chiefly composed of red sandstone; and the red sandstone is, in the direction of the dip, succeeded by an extensive deposit of red gypseous marls, which are seen in several open sections not far from the mouth of the Tees.

Whether the same great divisions are prolonged through Yorkshire cannot be determined; as many parts of the county do not offer a single natural or artificial section which throws light upon the general arrangement of the formation.

In Ripon Park there are extensive gypsum pits; and gypseous red marls have been cut through near the village of Monkton, not far from the eastern boundary of the yellow limestone. The upper limestone in the canal below Brotherton is also immediately surmounted by red marl*. These facts may seem opposed to the order above described; but they admit of explanation. The deposits of gypsum near Ripon may belong to the lower red marl and gypsum, or they may be subordinate to the lower part of the upper red sandstone. The red marl of the Knottingley section can hardly be considered as anomalous; for red marl (generally in the form of a thin band, and sometimes swelling out to a considerable thickness) is regularly interposed between the thin-bedded limestone and the upper red sandstone†. Any further details connected with these deposits would be foreign to the objects of this paper.

Such are the seven great natural divisions of the new red sandstone series. A general summary of their relations to corresponding formations on the continent will be given among the concluding observations of the next Chapter.

CHAPTER III.—*Detailed Sections.—Faults and Dislocations.—Minerals and Mineral Springs.—Organic Remains.—General Conclusion.*

THE following sections exhibit in detail the relations of some of the lower beds of the group described in the preceding Chapter.

No. 1.—Micklebring‡, near Doncaster. The series is derived from the old reddle pits, and from the coal works, and in the descending order§.

	Feet.	Inches.
1. Lower beds of the great yellow limestone: between the beds, blue and yellowish blue argillaceous seams. These form the top of the escarpment	—	—
2. White and yellow marl	1	6
3. Yellow, incoherent, rubbly limestone	4	0

* See Plate IV. No. 1. and Plate VII. fig. 6.

† In the greater part of Nottinghamshire the order is as follows:—1st. Yellow limestone.—2nd. A thin bed of red marl.—3rd. Forest sand or upper red sandstone.

Near Worksop the bed of red marl becomes of considerable thickness; and a little further to the north it is subdivided, and its place is occupied by three distinct deposits. The order then becomes as follows:—1. Yellow limestone.—2. Lower red marl and gypsum.—3. Upper limestone.—4. Thin band of red marl.—5. Forest sand. This thin band of red marl, though generally too insignificant to be counted, may in some places swell out into importance, and give rise to appearances like those at Knottingley.

‡ See p. 57. and p. 68.

§ Large quantities of reddle were formerly raised from these pits and exported to Holland. The works are now almost deserted.

	Feet.	Inches.
4. Reddle (earthy red oxyd of iron), texture fissile	0	5
5. Red and yellow clay	2	0
6. Reddle	0	4
7. Red and yellow clay	2	0
8. Reddle	0	9
9. A thick irregular bed. Highest part, blue clay; middle part, blue clay, alternating with gritstone bind; lower part, strong blue slate clay. Thickness about	40	0
10. Coal, impure and pyritous	1	5
11. Fire clay, used in the potteries, followed by the regular Yorkshire coal-measures	—	—

In this section there is no trace of the marl-slate. The beds from No. 4. to No. 8. inclusive (and perhaps also the upper part of No. 9.), represent the inferior red sandstone. On the south-west side of the hill, these beds are replaced by a coarse and micaceous sandstone, exhibiting many irregular lines of cleavage not parallel to the planes of stratification.

No. 2.—Section, in descending order, derived from the great cut for the road at Wentbridge Hill.

	Feet.	Inches.
1. Under the soil, a mass of earthy, rubbly, yellow limestone	2	0
2. Six beds of soft, coarse, cellular, yellow limestone	12	0
3. Cellular beds, each about one foot thick, yellowish grey, hard and splintery	6	0
4. A coarse, irregular bed, with many casts of shells	5	0
5. Coarse, soft, cellular bed	2	0
6. Various thin, cellular beds, hard and porcellaneous, with a few casts of fossil shells	3	6
7. Yellow sand	0	3
8. Irregular bed of soft sandstone; brown, with bands of purple and yellow.	5	0
9. Violet-coloured slate-clay, thinning off in both directions	3	0
10. Soft, micaceous, reddish brown sandstone, with subordinate lenticular masses of slate-clay and concretions of oxyd of iron	10	0
11. Micaceous, sandy, slate-clay of various colours, purple, blue, brown, and red, containing some bands of yellow sandstone; also of grey sandstone, with particles of green earth	30	0

All the beds below No. 6. form a part of the lower red sandstone, the whole thickness of which is not exposed.

No. 3.—Section from a denudation on Bramham Moor*.

	Feet.	Inches.
1. Under the soil four beds of hard, yellow, cellular limestone	4	0
2. Magnesian conglomerate, containing pebbles of grit, with a magnesian cement	1	0
3. Yellow magnesian marl	0	4
4. Semiindurated sand, separated into tabular masses not parallel to the strata	3	0
5. Coarse, grey sandstone, with white quartz pebbles	8	0
6. Micaceous, slaty sandstone, with false bedding like No. 4.	3	0
7. Coarse sandstone, lower part not exposed	8	0

* See p. 73.

In this section, Nos. 4. 5. 6. & 7. are undoubtedly the representatives of the upper part of the lower red sandstone, and they are unconformable to the overlying beds*.

No. 4.—Section from left bank of the Nid above Knaresborough Castle.

	Feet.	Inches.
1. A precipice of yellow limestone. Upper part composed of hard, cellular, concretionary beds: middle part soft, earthy, and cavernous; the cells of large size and very irregular forms. The lowest portion is soft and earthy, mixed with harder concretionary portions standing out in relief	70	0
2. Incoherent, magnesian earth	1	0
3. A conglomerate of yellow marl, with concretions of yellow limestone and fragments of red sandstone	1	0
4. Slaty, red, micaceous sandstone and red marl	1	0
5. Light and variegated slaty sandstone, with fissile portions not parallel to the beds	3	0
6. Strong, grey sandstone, with red streaks and concretions of earthy red oxyd of iron. Lowest portion concealed	12	0

The beds below No. 3. are a part of the lower red sandstone; and the stratification is so obscure, that it is not easy to determine whether they are or are not parallel to the yellow limestone.

No. 5.—Sections of the Hetton, Ellemore, and Eppleton Pits near Houghton-le-Spring in Durham, taken in 1826†.

1. *Hetton Pit.*

	Feet.	Inches.
1. Sand and gravel	15	0
2. Limestone marl	18	0
3. Yellow limestone, with much water	95	6
4. Blue limestone, a kind of ragstone, and here and there of slaty texture	44	2
5. Blue metal (slate clay)	5	2
6. Red rotten sandstone	4	4
7. White and grey metal	1	11
8. Strong, brown limestone and whin	8	8
9. Blue and grey metal	32	3
10. Coal	1	4

The pit descends through the *high* and *low main* to the *Hutton seam*, which is nearly nine hundred feet below the surface. In this section, No. 4. (and perhaps also a part of No. 3.) represents the marl-slate. No. 6. and a part of No. 5. appear to represent the lower red sandstone in a degraded form.

2. *Ellemore Pit*, about a mile S.W. by S. from the former.

	Feet.	Inches.
1. Soil, and strong blue clay	49	0
2. Limestone marl	1	6
3. Yellow limestone	60	0

* See Plate VI. fig. 2.

† For these important sections I was indebted to the superintendant of the Great Hetton coal works. See Plate V. fig. 3.; and p. 74.

	Feet.	Inches.
4. Yellow slaty limestone	2	0
5. Limestone in thin blue beds	4	0
6. Yellow clay	0	6
7. Blue metal	0	9
8. Yellow, indurated sand, with much water	62	10
9. Yellow and grey post	6	6
10. Blue metal	16	0
11. Impure coal, &c. &c. The *high main* is about 66 fathoms below the yellow sand, No. 8.	2	4

In this section the marl-slate is represented by Nos. 4. 5. & 6. No. 8. is the common form of the lower red sandstone in this county.

3. *Eppleton Pit*, about three-quarters of a mile N.E. of the old Hetton Pit.

	Feet.	Inches.
1. Soil and clay	24	0
2. Limestone like Nos. 3. 4. & 5. of the previous section	54	0
3. Soft, half-indurated yellow sand, lower part quick and full of water	126	0
4. Grey metal, &c. &c. The *high main* expected at about 80 fathoms		

The quick sand contains hard concretionary portions cemented with carbonate of lime.

No. 6.—Section derived from the borings near Nunstainton*.

	Feet.
1. Alluvial matter, principally strong clay, about	40
2. Coarse, cellular, yellow limestone, (part of it described as approaching the conglomerate form).	150
3. Thin-bedded, hard, and compact limestone	90
4. Various beds chiefly composed of shale, containing some thin beds of a red claystone	60
5. Coal, a good workable bed	

This section is remarkable from its locality, being derived from a place two or three miles within the escarpment of the limestone. The greatest part of No. 3. (and perhaps also a part of No. 4.) represents the compact limestone and marl-slate. As the lower sand is not mentioned, it is probably either absent or represented in an obscure form, as in the Hetton section.

I think it unnecessary to accumulate any more details respecting the transverse sections through the other parts of the deposits described in the preceding chapter. There are, however, one or two places where the order has been interrupted by great faults and dislocations, which require a short notice.

Great faults or dislocations, &c.—The most southern of these, which seems to require notice, traverses the upper part of the series a few miles to the south of Doncaster, ranging from the banks of the Don down the valley which separates Wadworth from Loversall. It has produced a great *upcast* to the N.E., in consequence of which the lower gypseous marls are repeated, as is proved by the wells sunk through the upper limestone at Loversall. On the south side of the valley near Wadworth, the broken edges of the limestone beds are much contorted†.

* See p. 60, note.

† See Plate IV. No. 4. and Section 1.

The whole country between Robin Hood's Well and Wentbridge, is intersected by great dislocations, which have altered the position of the beds, and modified the whole surface of the country*. 1st. A great north and south fault, producing an enormous upcast to the east, brings in the lower gypsum behind the village of Askerne†. 2nd. A great east and west fault crosses the North road, ranges on the south side of Upton Beacon, and throws the plateau of North Elmsall below its natural level. 3rd. A similar fault crosses the road at the Robin Hood House, and throws the upper beds, with an inverted dip, below the level of the yellow limestone. 4th. A similar break (and perhaps a prolongation of the preceding) appears at Stubbs Hill, at which place there is also a second break producing a downcast in the opposite direction‡.

A considerable dislocation, ranging east and west near Sherburn, has brought up the yellow limestone of Huddlestone quarry, &c. to the level of the higher series§. There are also several indications of extensive dislocations among the beds appearing in the banks of the rivers which traverse the formation. For example, on the banks of the Nid, in the escarpment below Maltby; on the banks of the rivulet below South Anston, &c. &c. In some of these instances it seems probable that the direction of the transverse valleys has been in a great measure determined by the direction of certain lines of fault which were formed anterior to their excavation; for denuding currents would act more readily upon the broken edges than upon the solid beds of secondary deposits; and faults would therefore prepare the way for future valleys.

Lastly, there are some very remarkable contortions and breaks of the strata on the coast of Durham, between Black Rocks and Hartlepool; but they are perhaps on too small a scale to be mentioned in this place; and an adequate notion of them cannot easily be conveyed by verbal description.

Minerals found in the several deposits subordinate to the Magnesian Limestone.—Mineral Springs.

I. ORES OF IRON.—1. *Hydrate of iron* appears to form the colouring matter of many of the yellow beds of limestone; also of many of the beds of marl and sandstone,—more rarely in nodular concretions. 2. *Red oxyd of iron*, less generally diffused than the preceding, forms the greater part of the colouring matter of the lower gypseous marls, also of many of the red beds in other parts of the series; rarely seen as a hæmatite; in that form associated with sulphate of barytes, and traversing the yellow limestone of Bramham Moor in thin veins. 3. *Black oxyd*, constantly associated with the various beds of No. 3. and No. 5. in the form of black spots, generally stellated, and of dendritic impressions; rarely forms the colouring matter of considerable masses. 4. *Iron pyrites*, rare, found in marls subordinate to No. 3. under Burton Leonard; also near

* Plate IV. No. 3.

† Plate IV. Section 2.

‡ Plate IV. Section 3.

§ Plate IV. No. 2.

Bolsover; probably exists in a state of minute subdivision in some earthy beds, which are liable to effloresce.

II. *Green carbonate of copper.*—Very rare; a few fibrous veins about a tenth of an inch thick, in a limestone near Newton Kyme; in the same form at Farnham near Knaresborough*.

III. *Sulphuret of zinc.*—In small crystals imbedded in calcspar, contained in the hollows of the marl-slate at Midderidge; in the same form at Cowndon, with sulphate of barytes†; found also by Mr. Winch nearly in the same form, and in the same part of the series, at Cullercoats.

IV. *Sulphuret of lead.*—Found in several places, but generally in very small quantities, in two small strings traversing a white limestone under the mill dam south end of Mansfield; said also to occur in the same form on the coast of Durham; also at Whitley near Cullercoats; in small single crystals imbedded in the rock under Knaresborough; in the same form in the upper limestone at Oldcoats near Tickhill; in a similar form, and associated with sulphuret of zinc and sulphate of barytes, at Midderidge and Cowndon; in large crystals and crystalline nodules subordinate to a small earthy bed at Nosterfield‡.

V. *Carbonate of lime.*—Rarely in thin fibrous beds, like those which alternate with the Purbeck limestone; frequently in large stalactitic masses occupying crevices and the sides of small caverns, e. g. at Farnham near Knaresborough, and in quarries in the outlier west of Collingham§; in contemporaneous veins; in crystals lining the cells of the regular beds.—N.B. When these beds are magnesian, the crystals lining the cells generally exhibit the inverse rhomb, rarely the equiaxe. But in the marl-slate, and other parts of the formation where the magnesia disappears, the crystals lining the cells lose the rhombic form, and generally exhibit modifications of the dog-tooth. In all the preceding instances, the crystals above described are free from magnesia. There are, however, some rare instances of pearl spar subordinate to the formation.

VI. *Sulphate of barytes.*—A very abundant mineral in many parts of the formation. In crystalline nodules and veins in the freestone beds of Mansfield and Huddlestone, &c.: in veins of fibrous texture traversing beds of indurated marl, at Pleasley near Mansfield; in contemporaneous lamellar concretions, and also in veins in various parts of Bramham Moor. In small tabular crystals, with carbonate of lime, in the cavities of the cellular beds of the same district; also massive and earthy in many similar localities; in kidney-shaped masses imbedded in marl, alternating with magnesian limestone in the outlier west of Collingham. In many parts of the county of Durham, though not in the same abundance, it occurs in most of the preceding forms.

VII. *Sulphate of strontian.*—A much more rare mineral, found of a fibrous and lamellar structure traversing small veins in the yellow limestone near the left bank of the Nid above Knaresborough; said also to be found nearly in the same form in some quarries north of Hartlepool; in pale blue tabular crystals, associated with carbonate of lime in quarries south of Ripon, &c.

VIII. *Sulphate of lime.*—Though abounding in the lower red marl‖, it is very rare in the other

* Traces of green carbonate of copper have, in a few instances, been left by the water which springs from the magnesian limestone. In consequence probably of these appearances at Farnham, considerable works were, about sixty years since, opened in the yellow limestone immediately behind the village; but they were soon after deserted.

† See p. 77, 78. ‡ See p. 108.

§ Some of the large specimens from this locality are beautifully translucent and fibrous; and among the successive layers of deposit exhibit curious traces of aggregation round different centres.

‖ No. 4. of the general section, p. 64. See also p. 101.

subdivisions of the formation. In crystals and large crystalline nodules, with red marl under the yellow limestone, on the right bank of the Nid above Knaresborough; very rarely, and in very small crystals, in the marl beds in other parts of the series.

9. *Sulphate of magnesia.*—This salt effloresces in great abundance upon some earthy beds of yellow limestone near the village of Bramham. It has been found by Professor Cumming and Mr. Holme to contain a trace of muriate of magnesia*. Mr. Holme also found traces of muriate of lime and muriate of magnesia in analysing specimens of magnesian limestone from Mansfield.

10. *Muriate of soda* diffused (though in extremely minute quantities) through some of the red beds near Mansfield †.

11. *Quartz.*—This mineral in a crystalline form is very rare, notwithstanding the abundance of siliceous matter which is mechanically mixed with the magnesian limestone. It is found lining the cavities of some hard cherty beds in the escarpment west of Watlass. Siliceous nodules occur, though very rarely, in some of the yellow limestone beds in the southern parts of Yorkshire.

12. *Mineral springs.*—1. Thorp Arch Spa rises in the lower part of the yellow limestone on the right bank of the Wharfe. It is fetid, from sulphuretted hydrogen, and tastes of sulphate of magnesia; but it has not, I believe, been analysed. 2. An extremely fetid mineral water springs from the yellow limestone beds below the high-water-mark, near the southern extremity of Hartlepool cliff. 3. Askerne Spa water rises through the upper thin-bedded limestone, but it is secreted by the lower gypseous marls which are brought up behind the village by a fault ‡. A fetid spring is said also to rise from the same beds near the village of Wadworth.

Organic Remains.

Fossil Fish.

An account has already been given of the discovery of the ichthyolites of Midderidge and East Thickley §. Some of them appear to have been destroyed before their value was understood. Others were fortunately preserved, but dispersed into so many hands, that it was only through the kindness of several gentlemen in the county of Durham (among whom I am bound particularly to mention Lord Barrington, the Rev. T. Austin, the Rev. S. Gamlin, Messrs. E. Pease and H. F. Smith of Darlington, and T. Randyll, Esq. of Stockton,) that I became acquainted with the prevailing characters of these fossils. Some other fine specimens (for an examination of which I am indebted to H. Blanshard, Esq. of London, and Henry Witham, Esq. of Edinburgh), have enabled

* Fifty grains of the salt scraped from the Bramham limestone were examined by Professor Cumming, and gave the following result:—Sulphate of magnesia, 47.40. Muriate of magnesia, with a trace of iron, 0.15. An insoluble residue 2.45, was probably derived from the scrapings of the magnesian limestone.

† See p. 100, note. Since this paper was written, a trace of rock salt has been also discovered in the formation near Pontefract, by Mr. Phillips. (Annals of Philosophy, December 1828.)

‡ For an analysis of this water, and an account of the structure of the neighbouring country, see an Essay by Mr. Brewerton. Knaresborough Spa, which springs on the east side of the Harrowgate road, is not added to the above list; because it rises from ground which is covered with diluvium, and is probably out of the limits of the lower sandstone. (See Plate IV. Sec. 2.)

§ See Chap. ii. § 2. p. 77.

me to complete the series, and to procure figures, more or less perfect, of perhaps all the species which have yet been discovered.

It was evident from the first, that many of these fossils, notwithstanding their mutilated condition, very nearly resembled the celebrated fish of the copper-slate of Germany. By far the greatest number came unequivocally under the genus Palæothrissum, being of the order Malacopterygii abdominales, having a forked tail, the rays proceeding exclusively from the lower border, the upper lobe being longer than the lower, and covered with scales, and having one dorsal fin between the anal and the ventral. It might be added, that all the species possessing the above characters appear to have had strong hard scales, which were partly tessellated and partly imbricated, and arranged in oblique rows; in which respect they make some approach to Esox osseus.

As there were, however, considerable difficulties in making out the specific characters of these fossils, some of the earliest specimens were submitted to the examination of M. de Blainville; and that celebrated naturalist, as was before stated, identified two of them with the species *Palæothrissum magnum* and *Palæothrissum macrocephalum*, which he had himself previously established from the ichthyolites of Mansfeld*.

The following plates of fossil fish found in the marl-slate of Midderidge and East Thickley, are as nearly as possible of the natural size, and will it is hoped convey as correct a notion of the several species as their state of preservation allows.

1. *Palæothrissum magnum*†.—This specimen shows the position of the fins; also the arrangement and form of the scales, some of which, on the fore part of the body, exhibit a kind of imperfect articulation, as is represented on a magnified scale under the Plate. The character of the tail is well seen; but it is mutilated. When perfect, it is nearly of the same shape as in the next species.

2. *Palæothrissum macrocephalum*.—This (like the former species) is very abundant. It has many characters in common with the *P. magnum;* differing, however, greatly from that species in its size, and in the form of its head. The individual here figured is a large specimen‡.

3. *Palæothrissum elegans*.—This is a much more rare species than the preceding. The head is smaller; and the upper and lower portions of the forked tail are much more nearly equal§.

4. Another species||, in the form of the tail, the position of the fins, and the arrangement of the

* The genus Palæothrissum was formed by M. de Blainville out of several species of fish which he had found exclusively in the *copper-slate*. "*Il a pour caractère essentiel: d'être abdominal, malacopterygien, de n'avoir qu'une seule nageoire supérieure située avant l'anale, entre les pelviennes et elle, et surtout d'avoir la queue bifurquée, et le lobe supérieur ordinairement beaucoup plus long que l'inférieur, et couvert d'écailles dans toute sa moitié supérieure.*" See the article on *Ichthyolites, Nouveau Dictionnaire d'Histoire Naturelle*, vol. xxviii.

† Plate VIII. fig. 1. ‡ Plate IX. fig. 2. § Plate IX. fig. 1. || Plate VIII. fig. 2.

scales, appears to agree with the genus Palæothrissum; but it differs from all the described species in its form and size, as well as in the singular decoration of its scales. As the fore part is wanting, it is perhaps better to consider it as belonging to an unascertained genus. For purposes of comparison it is, however, not without its use; as fragments of the same species have, I believe, been found in the copper-slate.

5. A fifth species* has also some characters in common with those already described. It is far too imperfect to be ascertained; but it is hoped that it may hereafter be compared with better specimens of the species, and for this purpose it is figured. The small side figures show the scales magnified.

6. Another specimen† differs entirely from all the former, but it is far too imperfect to be referred to any known species or genus. It may hereafter serve the purpose of comparison.

7. The operculum of a large fish‡. From its size, it seems to belong to a species distinct from any of those which have been figured.

8. To this list may be added the fossil fish found at Pallion, and described by Dr. Clanny and Mr. Winch§. The specimen is preserved in the museum of Sunderland, and has been referred to the genus Chætodon: but this cannot be considered as well ascertained till a more elaborate figure of the fossil has been published.

Another specimen||, discovered during the passage of this paper through the press, is probably of the same species with the fish above mentioned from Pallion. It has enabled us to restore the anal fin; and in the structure of the tail it agrees with the other species.

It was found in the marl-slate near East Thickley.

Fossil Shells.

Univalves.—These are much more rare than bivalves. An instance has, however, been noticed¶ where they occur in great abundance; and they are occasionally found in the shelly beds of yellow limestone in the county of Durham, and in the blue shelly beds near Bolsover, &c. &c.

1. *Turbo* (?).—Beautiful small casts of a deeply striated shell, apparently of this genus, occur in the pisolitic yellow limestone between Marr and Hickleton.

2. Casts of a small smooth shell, apparently of the same genus, are rarely found among the fragments of bivalves in the blue limestone of Palterton and Bolsover, in the lower beds of yellow limestone near Conisborough, &c. &c.**

3. *Pleurotomaria* (?).—Beautiful but imperfect casts of univalves, which Mr. Sowerby refers to this genus, were found among the shelly and coralline masses of Humbleton quarry. One of these exhibits five whorls, and is about 1¼ inch in length.

4. *Ammonites*.—A cast of one of the chambers of a small Ammonite was found among the Humbleton fossils††.

5. *Serpula* or *Dentalium* (?).—Traces of small obscure bodies, belonging to one or both of these genera, occur in some shelly beds on the Durham coast south of Black Rocks. Also in the upper beds at Cold Hill near Aberford.

* Plate X. † Plate XI. ‡ Plate IX. fig. 3.

§ See p. 78, note. || Plate XII. fig. 1. ¶ See p. 110.

** This is probably the same species with the following:—Turbo (?) Spires 4, smooth, length under ¼ of an inch; Hawthorn Hive. (M.S. Catalogue of fossils by Mr. J. Phillips of York.)

†† To this list may be added five species of Melaniæ (?) less than half an inch long, with eight whorls; Hawthorn Hive. (M.S. Catalogue by Mr. J. Phillips.)

BIVALVES.

1. *Producta antiquata*, Min. Con. t. 317. fig. 1. 5. 6.—This fossil (so common in the mountain limestone) occurs rarely in the compact limestone over the marl-slate at Midderidge*.

P. calva, α. β. Min. Con. t. 560. fig. 2—6.—Occurs abundantly at Humbleton, in the compact beds of Midderidge; in the dark beds near Nosterfield, &c. &c. †

P. horrida, Min. Con. t. 319. fig. 1.—Humbleton; Whitley quarry; Northumberland; yellow limestone, Derbyshire.

P. spinosa, Min. Con. t. 69. fig. 2.—Humbleton quarries, &c.

A species of Producta, probably differing from all the preceding, was found by Mr. Phillips near Ferry-Bridge ‡.

2. *Spirifer undulatus*, Min. Con. t. 562. fig. 1.—Compact limestone, Midderidge, and Humbleton, &c.

To the preceding list must be added two, or perhaps more, species of small shells of the genus Spirifer, chiefly derived from Humbleton and Tunstal Hill. One (*S. multiplicatus*) has many plaits in front, and shows the internal structure peculiar to the genus. Another (*S. minutus*) is very minute, but is well characterized. Two or three other species of small shells are doubtful, and may perhaps belong to the genus Terebratula.

3. *Terebratula*.—Shells of this genus (generally of a small size) occur in many parts of the formation, particularly at Tunstal Hill and Humbleton. Of these there appear to be not less than five or six distinct species. Some are smooth; others plaited or ribbed. Some are flat; others spheroidal. Some are broad; others oblong. A beautiful, small, smooth species forms nearly the whole mass of some rocks near Dalton-le-Dale.

4. *Axinus obscurus*, Min. Con. t. 314.—Many casts of this species occur at Wentbridge Hill in the lower beds of yellow limestone, and in the same part of the series at Garforth cliff. It is found in a much more perfect form in the lower beds of Stubbs Hill. Casts of this genus are found also south of Black Rocks, on the Durham coast.

5. *Arca tumida*, Min. Con. t. 474. fig. 3.—Tunstal Hill and Humbleton.

6. *Cucullæa sulcata* (S. N.), generally very imperfect, and in casts; which, however, sometimes show the nature of the hinge: transverse dimension about $1\frac{1}{2}$ inch; on one specimen a small part of the shell is preserved, which is deeply striated. Humbleton, &c.

7. *Avicula gryphæoides* (S. N.).—This small species (which in external character resembles a gryphite), abounds at Humbleton. The convex valve has many very small slightly tuberculated ribs. The other valve is discoid and nearly smooth.

There are some imperfect specimens of another striated species which resembles a Gervillia.

8. *Ostrea*.—Casts of a small flat species occur at Whitley quarry, Northumberland.

9. *Astarte* (?).—Casts of a beautiful shell about half an inch in length, marked with concentric striæ, and apparently of this genus, abound in some of the beds of Whitley quarry.

10. *Modiola acuminata* (S. N.).—A very small species found in very great abundance in some shelly beds south of Black Rocks, Durham. A larger species, length half an inch, occurs in the upper thin-bedded limestone at Cold Hill, a few miles east of Aberford. Casts of another very small species of Modiola, in form much less acuminated than the preceding, occur at Humbleton. Found also by Mr. Phillips at Hawthorn Hive.

* See p. 77. † See p. 108. ‡ See Annals of Philosophy, Dec. 1828.

11. *Mytilus squamosus* (S. N.), ovate, acuminate, the laminæ of the shell having the appearance of scales; length more than an inch. In considerable abundance near Ferry Bridge, but generally in the form of casts.

12. *Pecten.*—1. (S. N.) smooth, half an inch in diameter. Abounds at Humbleton, &c.

2. (S. N.) convex, circular, marked with striæ, slightly tuberculated; about the same size as the preceding. Humbleton.

3. To this list Mr. Phillips has added a circular fluted species two inches and a quarter in diameter.

13. *Plagiostoma* (?)—Casts of a very small beautifully striated shell, apparently of this genus, occur at Humbleton.

14. *Venus* (?)—Casts of a gibbous shell three-quarters of an inch in diameter, resembling this genus, are found at Humbleton*.

Crinoidea.

Portions of the columns of one or two species belonging to this family are found in great abundance in the quarries near Humbleton; they also occur in the cliffs of Tynemouth. These fossils are rarely, if ever, found in the range of the formation to the south of the Tees. Some specimens from Humbleton and Tynemouth have been examined by Mr. Miller, and are referred to the *Cyathocrinites planus*†.

Coralline Bodies.

Two retepores‡, mixed with casts and fragments of other coralline masses, abound in the shelly magnesian limestone of Humbleton and other parts of Durham§. The specific names *flustracea* and *virgulacea* are adopted from the MS. Catalogue of Mr. Phillips of York; and the figure of the *Retepora virgulacea*‖ is taken from a specimen kindly lent by that gentleman. Traces of two other corallines¶ occur also at Humbleton.

Vegetable Fossils.

The specimens to be enumerated under this head have been already noticed.

1. Obscure impressions of two species of Fern from the marl-slate of Midderidge**.

2. Carbonaceous matter obviously derived from vegetable fossils; from the marl and blue shelly limestone beds of Palterton and Bolsover††.

3. Long cylindrical stems (probably of vegetable origin) traversing the top beds of the first section near Nosterfield‡‡.

* In the specimens derived from some of the places above mentioned, especially Humbleton quarry, there are more genera and species than have been enumerated, but they are too imperfect for description. Large additions might undoubtedly be made to the list by a more careful examination of these localities.

† Nat. Hist. *Crinoidea*, p. 85.

‡ Plate XII. fig. 6. 8.

§ These coralline fossils are very rare in all parts of the formation south of the Tees. I found a single specimen of the *Retepora flustracea* in the beds of blue limestone at Nosterfield, near Tanfield.

‖ Plate XII. fig. 6. ¶ Plate XII. fig. 5. 7. ** See p. 77. †† See p. 81. ‡‡ See p. 107.

Conclusion.

1. Considering the new red sandstone series as one great complex formation, we are enabled, after the details given in the two preceding chapters, to separate it into the following natural divisions. 1. Lower red sandstone. 2. Marl-slate and compact limestone; or 2 *a*. Compact and shelly limestone, and variegated marls. 3. Yellow magnesian limestone. 4. Lower red marl and gypsum. 5. Upper thin-bedded limestone. 6. Upper red sandstone. 7. Upper red marl and gypsum.

In the whole range of this great system of deposits, through an extent of nearly two hundred miles, these divisions, wherever they occur, are in a constant order: but there are very few transverse sections of the country where the whole of them are exhibited together.

It further appears from the details of the previous chapter, that No. 1. is the equivalent of the *rothe-todte-liegende;* No. 2. of the *kupfer-schiefer* and *zechstein;* and that Nos. 3. 4. and 5. are the equivalents of the *rauchwacké,* gypsum, *asche, stinkstein,* &c. &c. of the Thuringerwald. In the same part of Germany, the deposits immediately superior to those last enumerated are, *bunter sandstein, muschelkalkstein, keuper* (composed of variegated marls, (*marnes irisées*), sandstone, rock-salt, &c.), and *lias*. Nos. 6. and 7. are, therefore, both in position and mineralogical character, the exact representatives of the *bunter sandstein* and *keuper;* the *muschelkalk* not having yet been discovered in our geological series*. Such a coincidence in the subdivisions of two distant mechanical deposits, even on the supposition of their being strictly contemporaneous, is truly astonishing. It has not been assumed hypothetically, but is the fair result of the facts which are recorded in this paper.

2. The previous statements seem to show, that the system of the new red sandstone could not have been produced by any sudden and transitory agency, but must have been the result of causes of very extensive operation, and long continuance; a conclusion which is confirmed by the peculiar groups of organic remains which exist in certain portions of the deposit.

3. Notwithstanding the entire break which, in many parts of England, exists

* English geologists in their first attempts to compare our secondary formations with those of the continent, identified the *muschelkalk* with the lias: but the opinion has been since generally abandoned. Continental geologists have also been at issue on the nature of the deposit immediately superior to the *muschelkalk*. Since the publication of many excellent details connected with this subject by MM. Oyenhaussen and Dechen, confirmed as they have been by the subsequent observations of MM. de Beaumont and Dufrénoy in various parts of France, the question now appears to be nearly set at rest, and the succession of the lower secondary formations to be established in the order stated in the text.

between the coal-measures and the superior deposits; in some parts of Yorkshire there is no such want of continuity, and the lower red sandstone seems to form a connecting link between the carboniferous order and the group of the new red sandstone. Moreover, the fossils of the magnesian limestone have little resemblance to the fossils of the lias and the oolites, but have several genera and species in common with those of the mountain limestone.

4. The new red sandstone series in the south-western coal districts admits of three natural divisions; viz. dolomitic conglomerate, red sandstone, and red or variegated gypseous marls, which are immediately surmounted by the lias*. It therefore follows, that of the seven subdivisions above established, the five lowest are, in the south-western parts of England, represented by the dolomitic conglomerate. Hence these dolomitic conglomerates, and the contemporaneous conglomerates in the valleys of Somersetshire and Devonshire, are not merely the equivalents of the *rothe-todte-liegende*, as has been sometimes assumed, but are in the place of a great part of the Thuringerwald system.

5. The preceding conclusion seems to be perfectly secure; but we may, if I mistake not, advance a step further. The lower red sandstone (or *rothe-todte-liegende*) is best developed in those extensive tracts of Yorkshire where the overlying deposits are very nearly, if not exactly, conformable to the coal formation, and appears to thin off in those places where the coal-measures are most dislocated: moreover, it is under such circumstances that it exhibits in mineral structure a gradation between carboniferous gritstone and new red sandstone. Now, there is an absolute disruption between every part of the dolomitic conglomerates and the coal-measures in the west of England; nor do these conglomerates contain any extensive beds which bear the least resemblance to the lower red sandstone: but they are nearly identical with some masses which in the north of England are subordinate to the yellow limestone†. We may therefore conclude, that the overlying conglomerates in the west of England do not represent the *rothe-todte-liegende*, and that they are therefore in strictness the equivalents of some of the higher subdivisions of the Thuringerwald system‡.

6. The history of the dolomitic conglomerate in the west of England certainly throws great light upon the origin of the series of deposits above

* See Geol. Trans. Second Series, vol. i. Part I. p. 290. † See Plate VI. figs. 2. 3. & 5.

‡ The conglomerates overlying the coal-measures near Bristol, and the conglomerates associated with the transition rocks of Devonshire and Somersetshire, necessarily differ in mineralogical character, but are, I believe, regarded by all geologists as contemporaneous. The conclusion of the text applies, therefore, to them all.

A most unreasonable importance has been given to the conglomerate of Heavitree, because it described*. There can be no doubt that the magnesian limestone has been chiefly produced by mechanical agents; and I have endeavoured to show that the most crystalline portions of it have gained their present structure from internal movements after the regular deposition of the formation. It is therefore probable, that a part of the magnesian earth has been derived from the breaking up of the dolomitic beds in the neighbouring chain of mountain limestone. The much greater proportion of dolomitic earth existing in the derivative deposit admits also of explanation. The waters which filter through the magnesian beds, constantly take up and bear away with them a small portion of carbonate of lime, but reject the dolomite. Thus the stalactitic matter deposited by the streams which have their source in the magnesian beds, does not contain magnesia. May not the waters of the ocean, during a long succession of ages in which they were grinding down the carboniferous chains and depositing the overlying beds on their flanks, have, in the same manner, continued to take up and bear away a portion of carbonate of lime, and on that account have left a larger proportion of dolomitic earth in the residuum than existed in the parent formation?

Granting all the weight to this mechanical hypothesis which it deserves, we must at the same time allow that there are some important facts of which it offers no adequate explanation. In the middle of Yorkshire the magnesian limestone is at a great distance from the calcareous portions of the older rocks, and, I believe, contains more magnesia than could have been obtained from the nearest chain of mountain limestone, though the whole of it had been broken up for the supply. Again, on this theory, no part of the dolomitic series ought to contain more magnesia than enters into the composition of the definite triple salt. But there are some instances of beds in this series which are by no means of crystalline texture, and contain not less than sixty per cent of carbonate of magnesia †.

happens to contain certain fragments of trap and porphyry. These appearances are the exception and not the rule; on which account I think that the Heavitree conglomerate should never be given as the type of one of the English formations. It forms a rare variety, and nothing more.

In Germany, trap rocks are extensively associated with formations of the same age with those described above. The great importance which is given to them in determining the epoch of certain deposits can, however, only be regarded as a lingering remnant of that false theory which considered trap rocks of the same origin with regular secondary strata. In England, with certain exceptions, trap rocks are *not* associated with deposits of the age described in the text. Here there is a broad line of distinction, and one which might have been expected *à priori:* and, if it prove any thing, it proves that trap rocks cannot much assist us in identifying the regular deposits of distant regions of the earth, and ought never to be used among the prominent types of comparison.

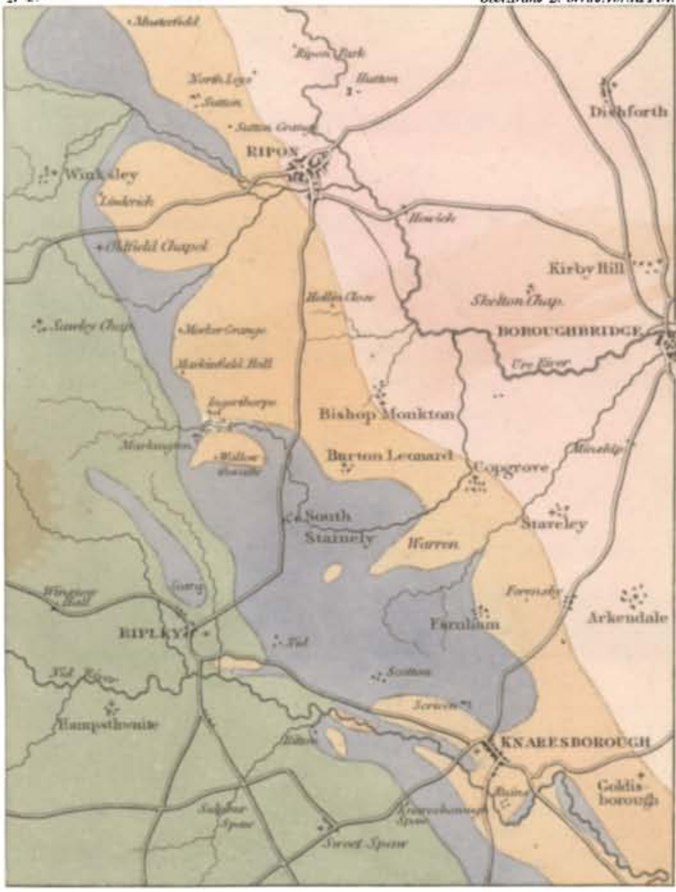
* For some beautiful observations on this subject, see Geol. Trans. Second Series, vol. i. p. 291, &c.

† See p. 105, note.

During that great epoch of destruction which in the European basin produced the complex deposit of new red sandstone, it is at least certain, as an ultimate fact, that the waters of the ocean had the power of separating great masses of magnesian earth, and arranging them in successive beds. The operation may have commenced mechanically, and have been carried on in conformity to that great principle by which (on a great scale as well as on a small,—in beds as well as in distinct concretions), like things aggregate with like, until, by an operation at once chemical and mechanical, the complex structure of the whole formation was perfected. At all events, the facts stated in this paper depend upon direct evidence, and are not in any way invalidated by our ignorance of the causes which produced them.

No. 3.

No. 1.



No. 4.

1 SECTION IN THE DIRECTION OF THE LINE, AB. (MAP No. 4.)

2 SECTION IN THE DIRECTION OF THE LINE, C. D. (MAP No. 3.)

3 POSITION OF THE STRATA ON STUBBS HILL, (MAP No. 3.)

No. 2

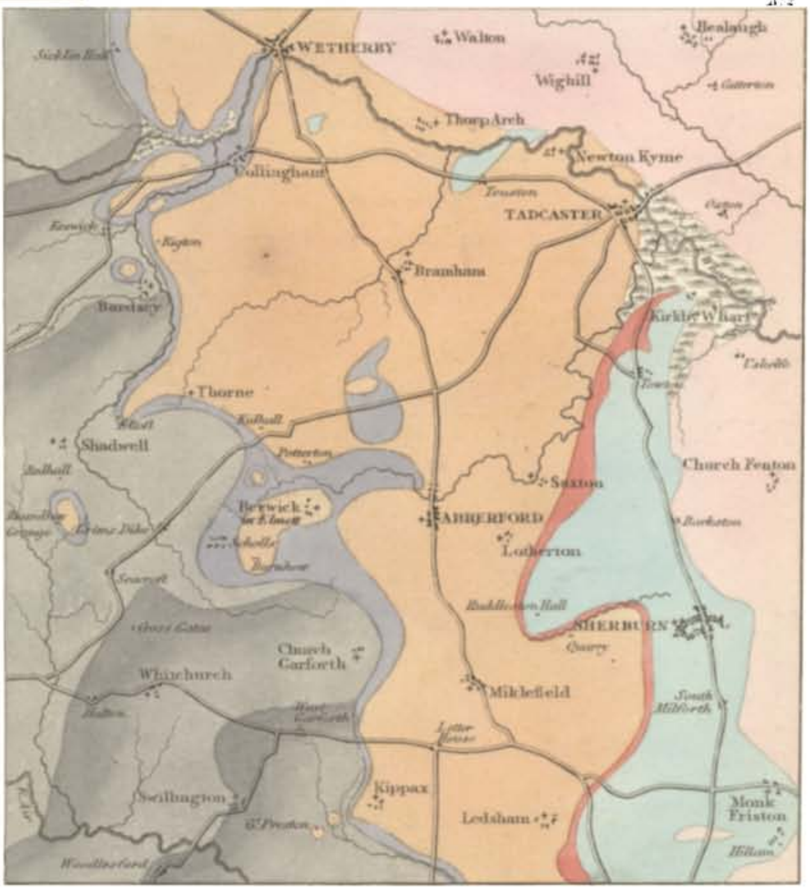


Fig. 1.

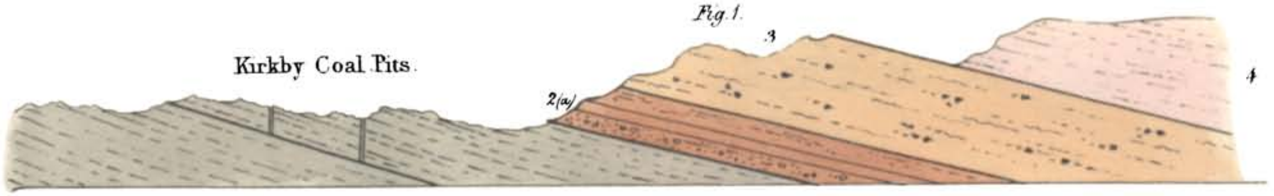


Fig. 2.

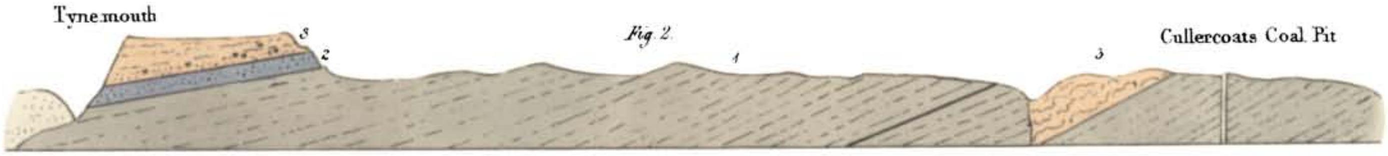
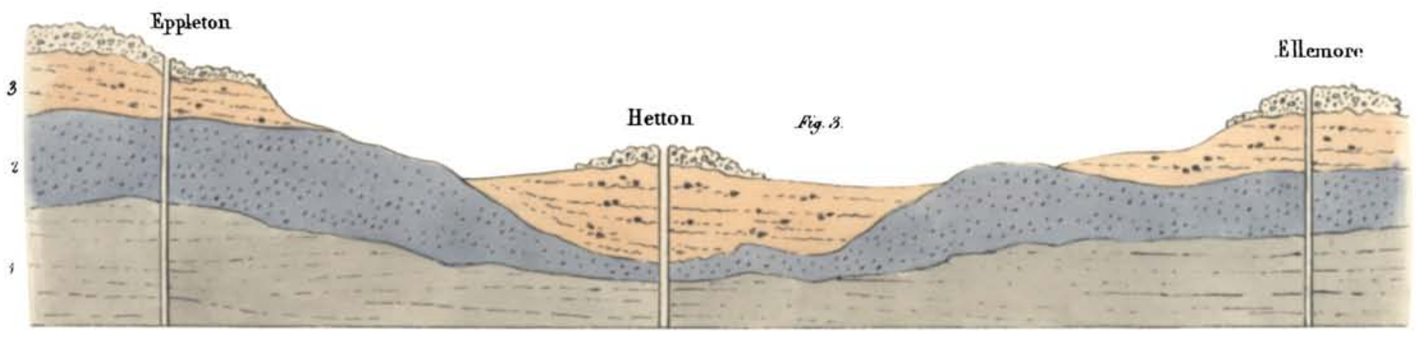


Fig. 3.



1 Coal Measures.

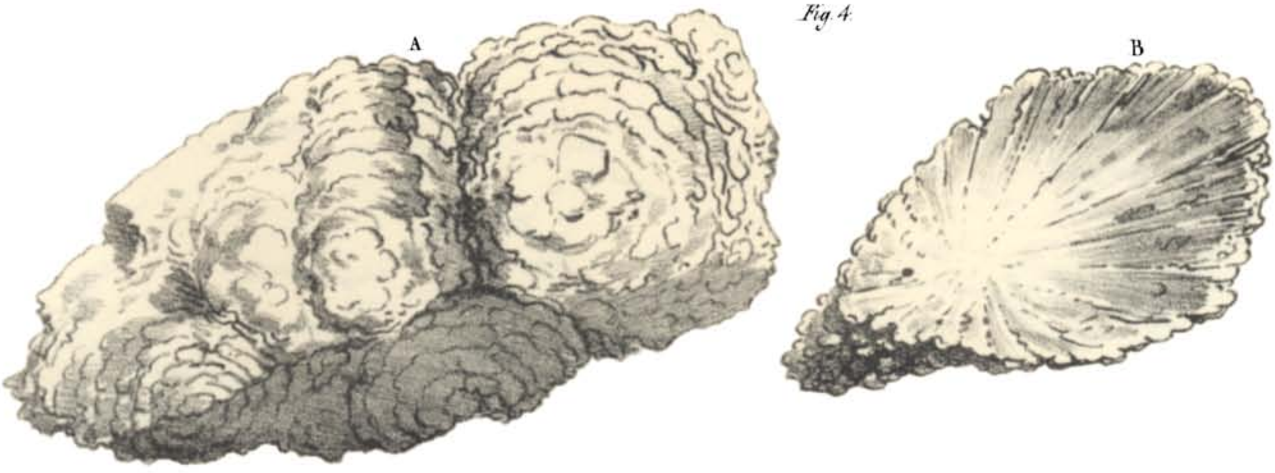
2 Lower red Sandstone.

2 (a) Conglomerate variegated marl & compact Limestone

3 Magnesian Limestone.

4 Upper red sandstone.

Fig. 4.



A. Sedgwick del. G. Scharf lithog.

Printed by C. Hullmandel.

Branham Moor.

Fig. 1.

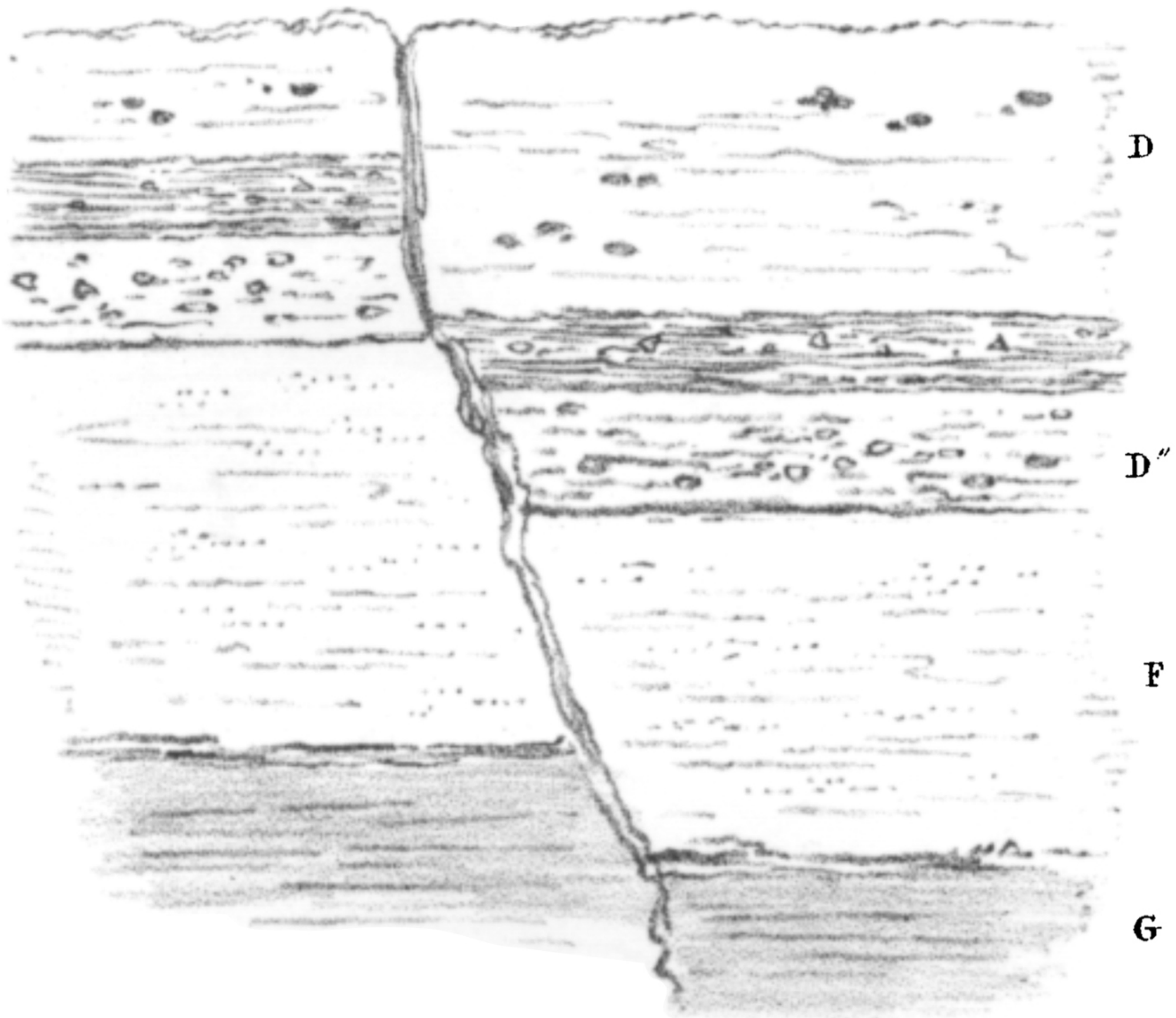
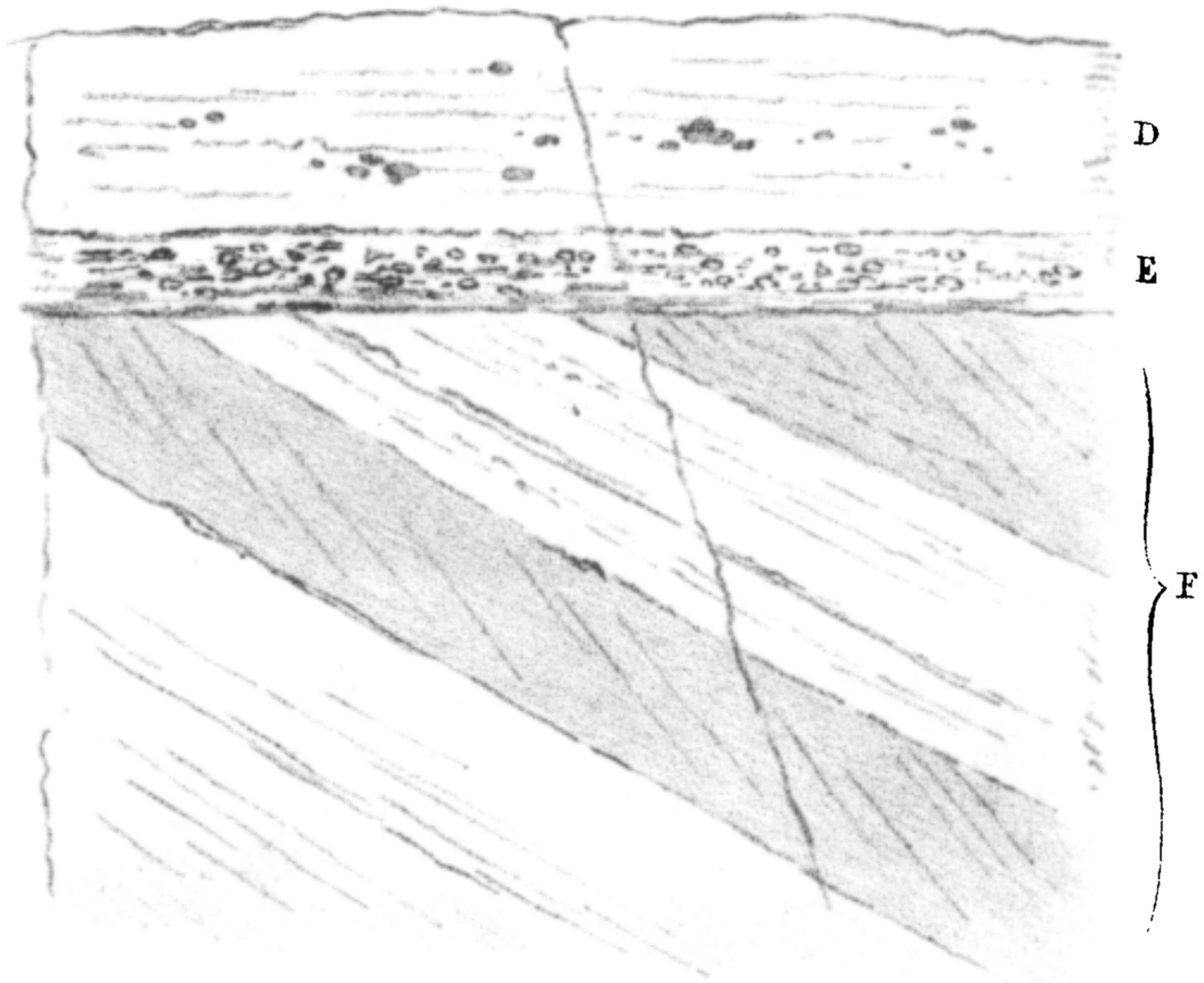


Fig. 2.



Branham Moor

Fig. 4.

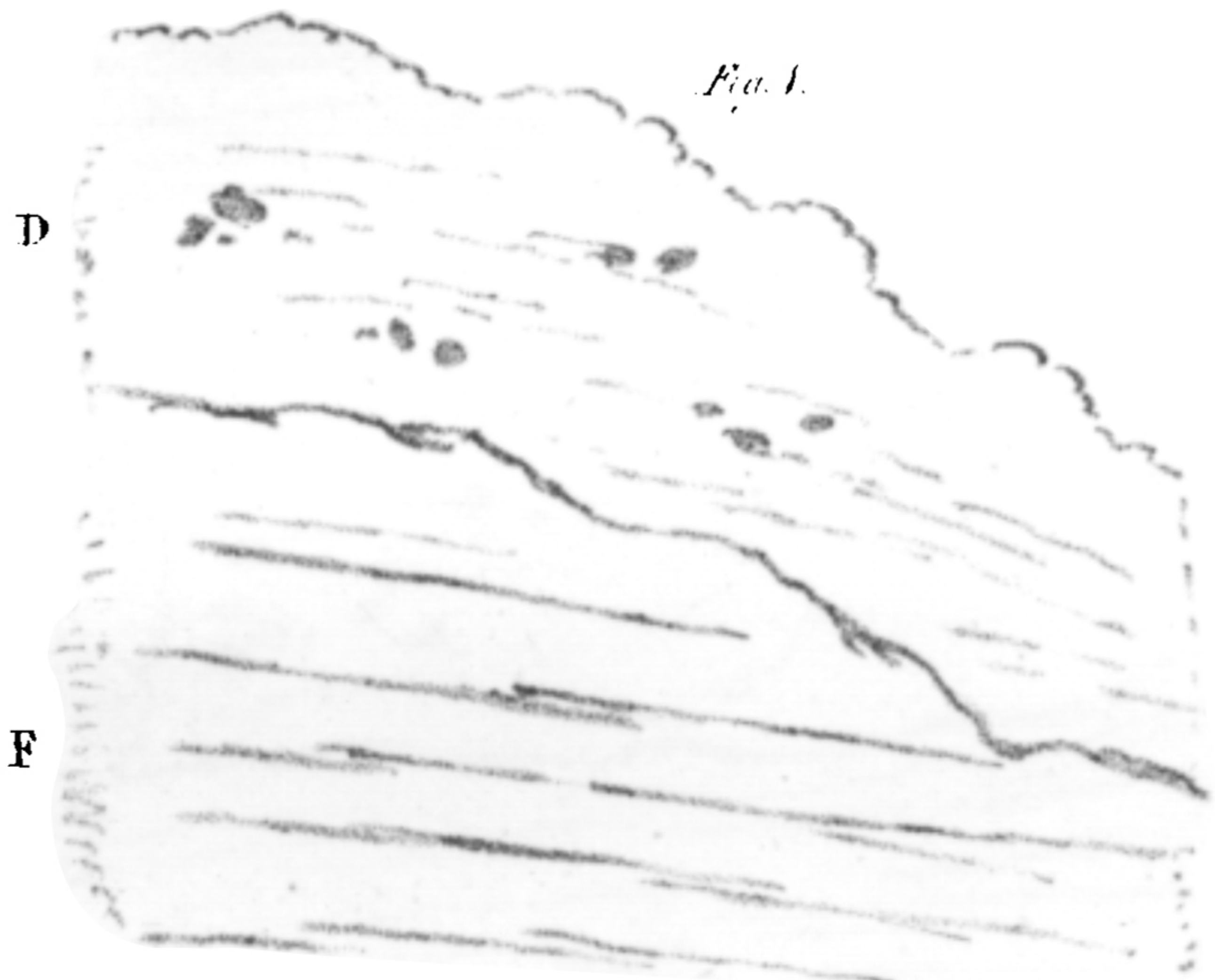


Fig. 3.

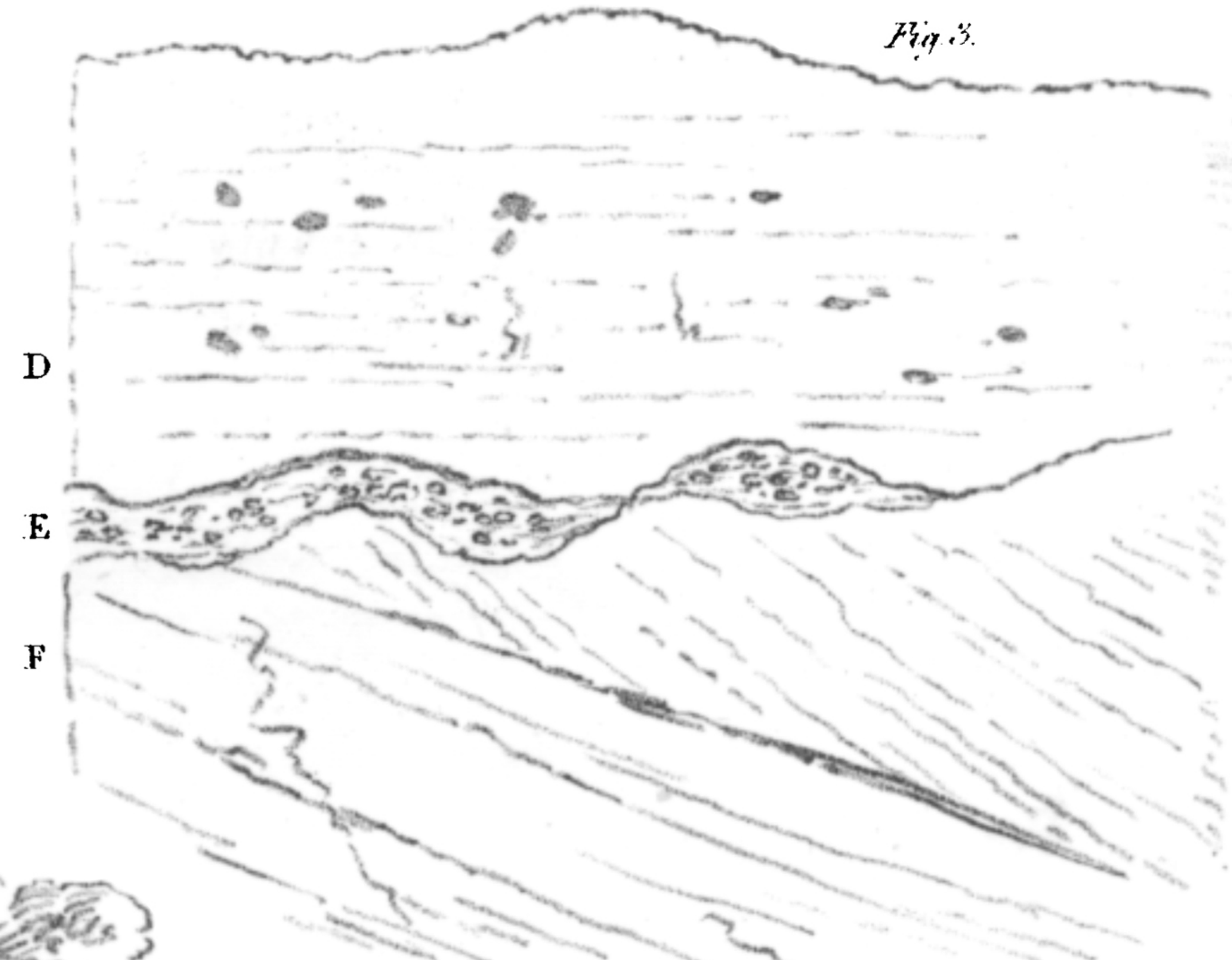


Fig. 6.

Fig. 5.

A Sedgwick del. G. Scharf lithog.

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A. *Gravel.* B. *Red Marl.* C. *Upper Slaty Limestone.* D. *Cellular Magnesian Limestone.* D'. *Marl Slate.* D''. *Brecciated Magnesian Limestone.* E. *Conglomerate.* F. *Lower red & yellow Sandstone.* G. *Coal Measures.*

Fig. 1.

Fig. 2.

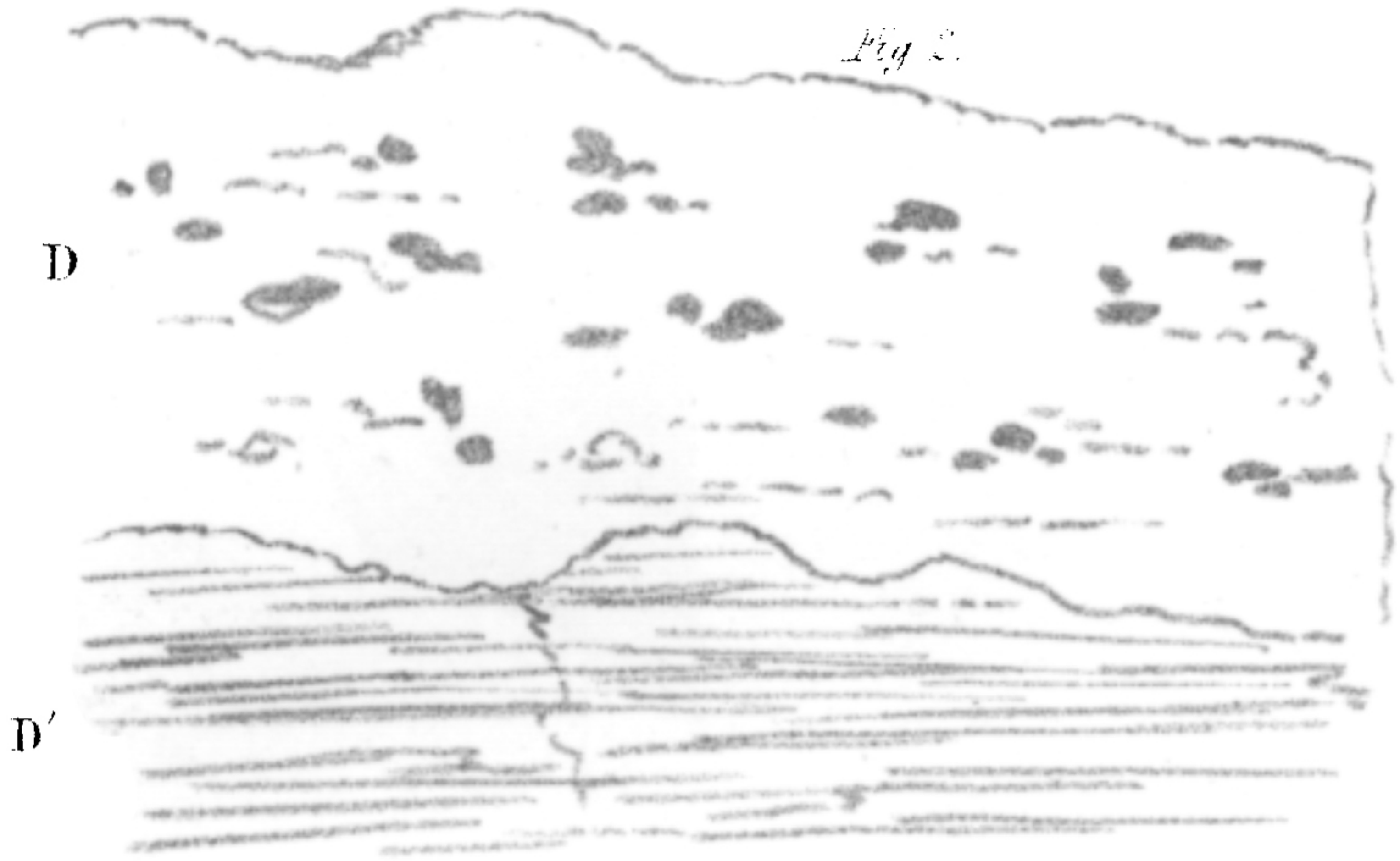


Fig. 3.

Fig. 4.

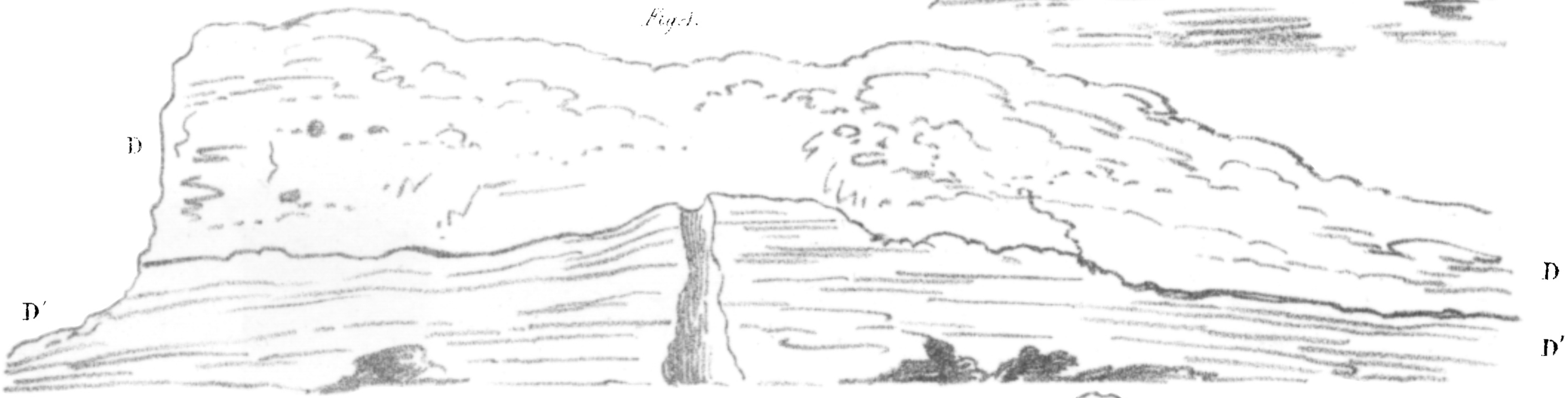
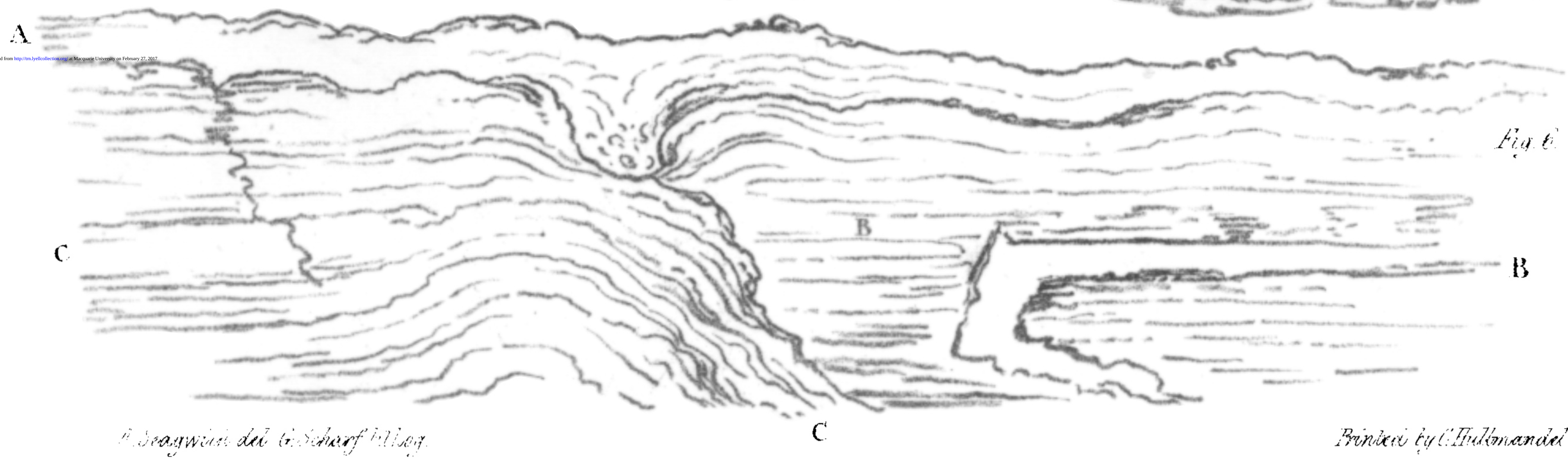


Fig. 5.

Fig. 6.



A. Sedgwick del. G. Scharf lith.

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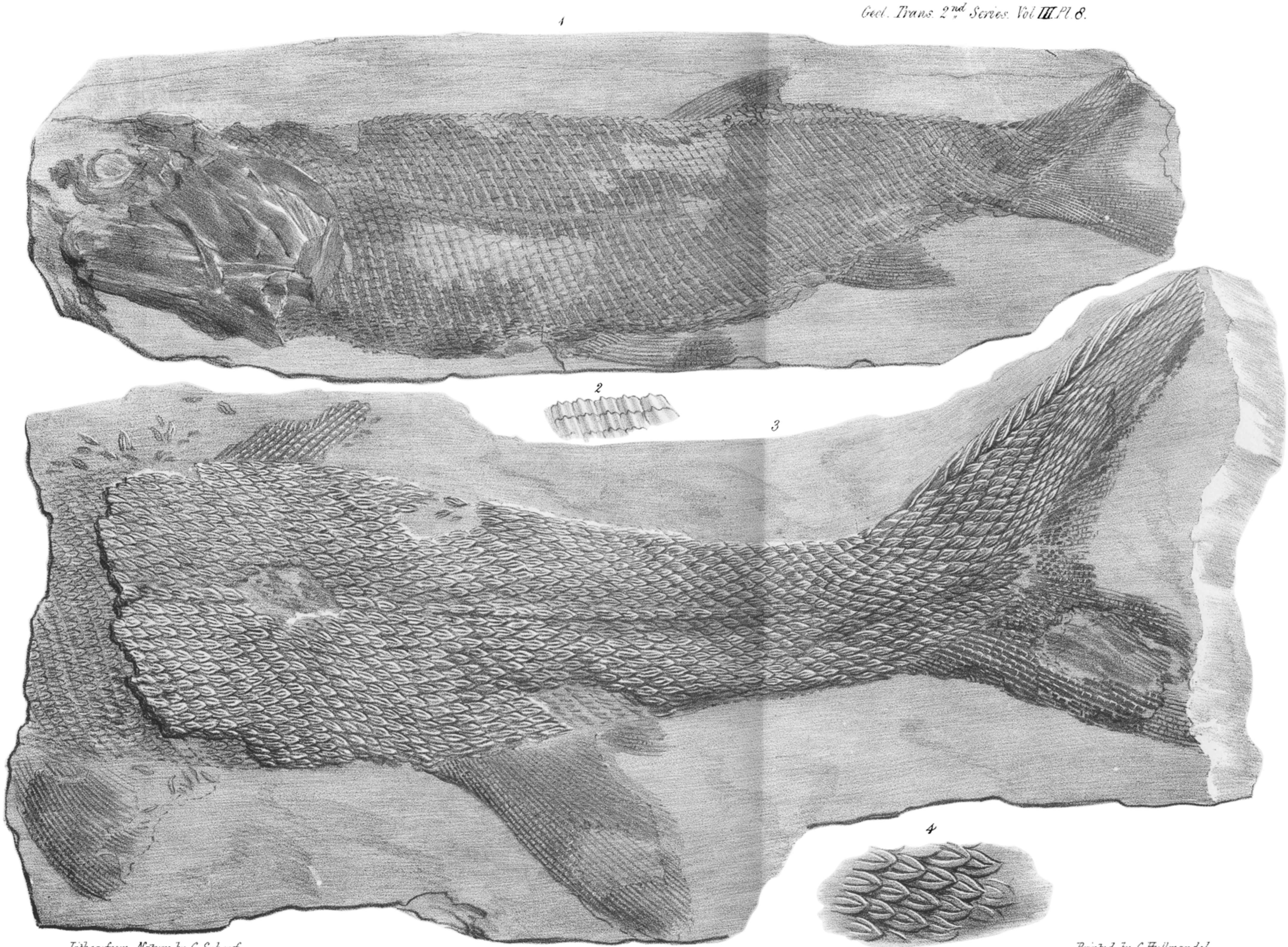

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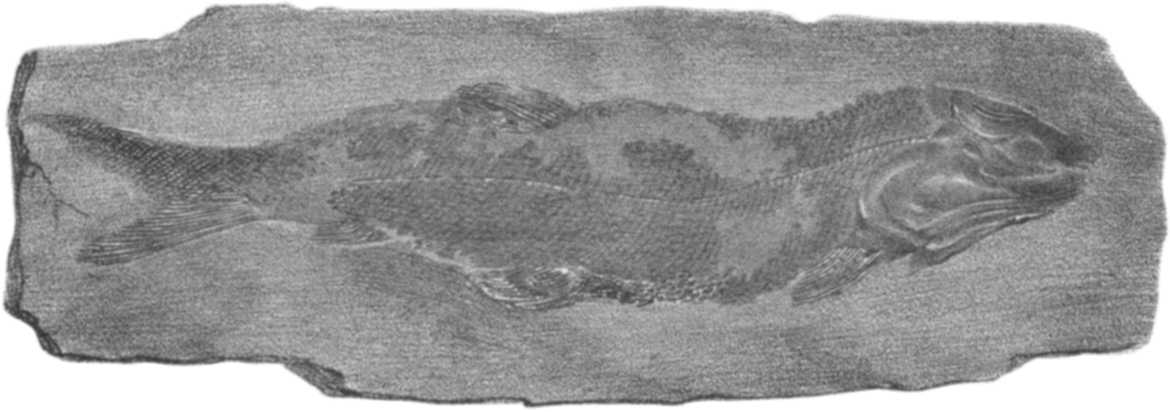

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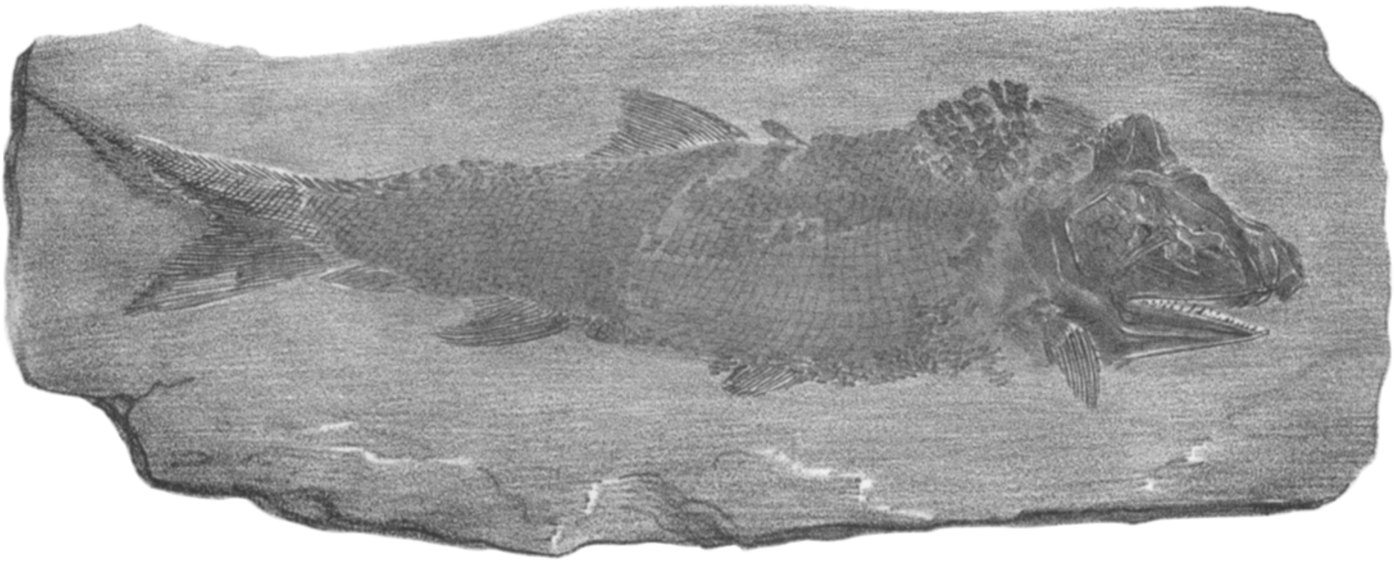

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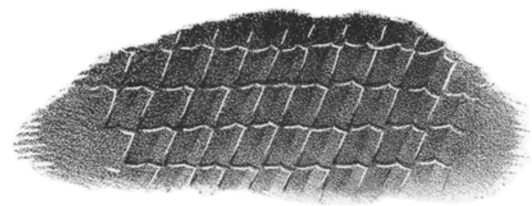

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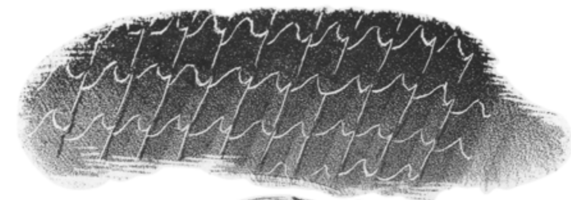

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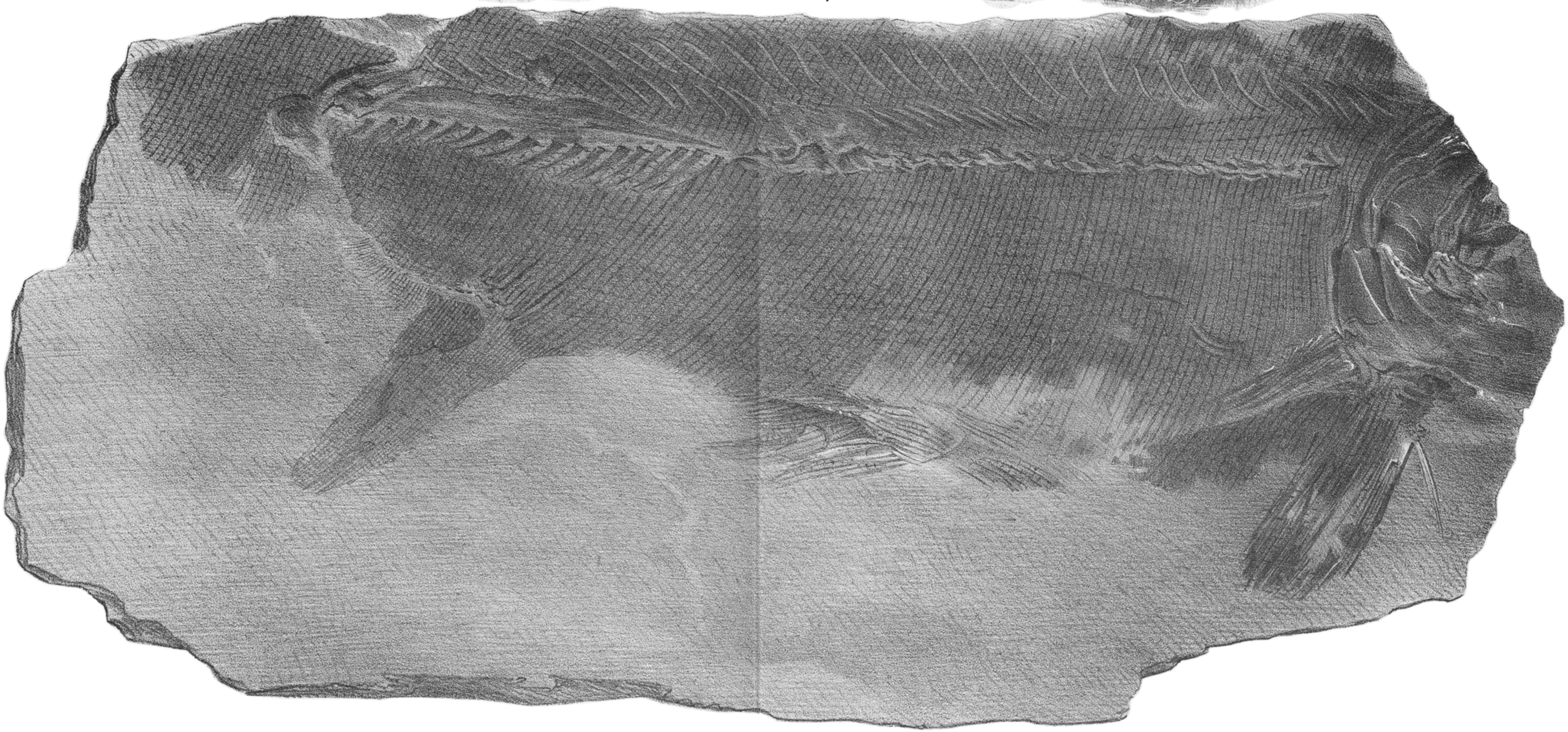

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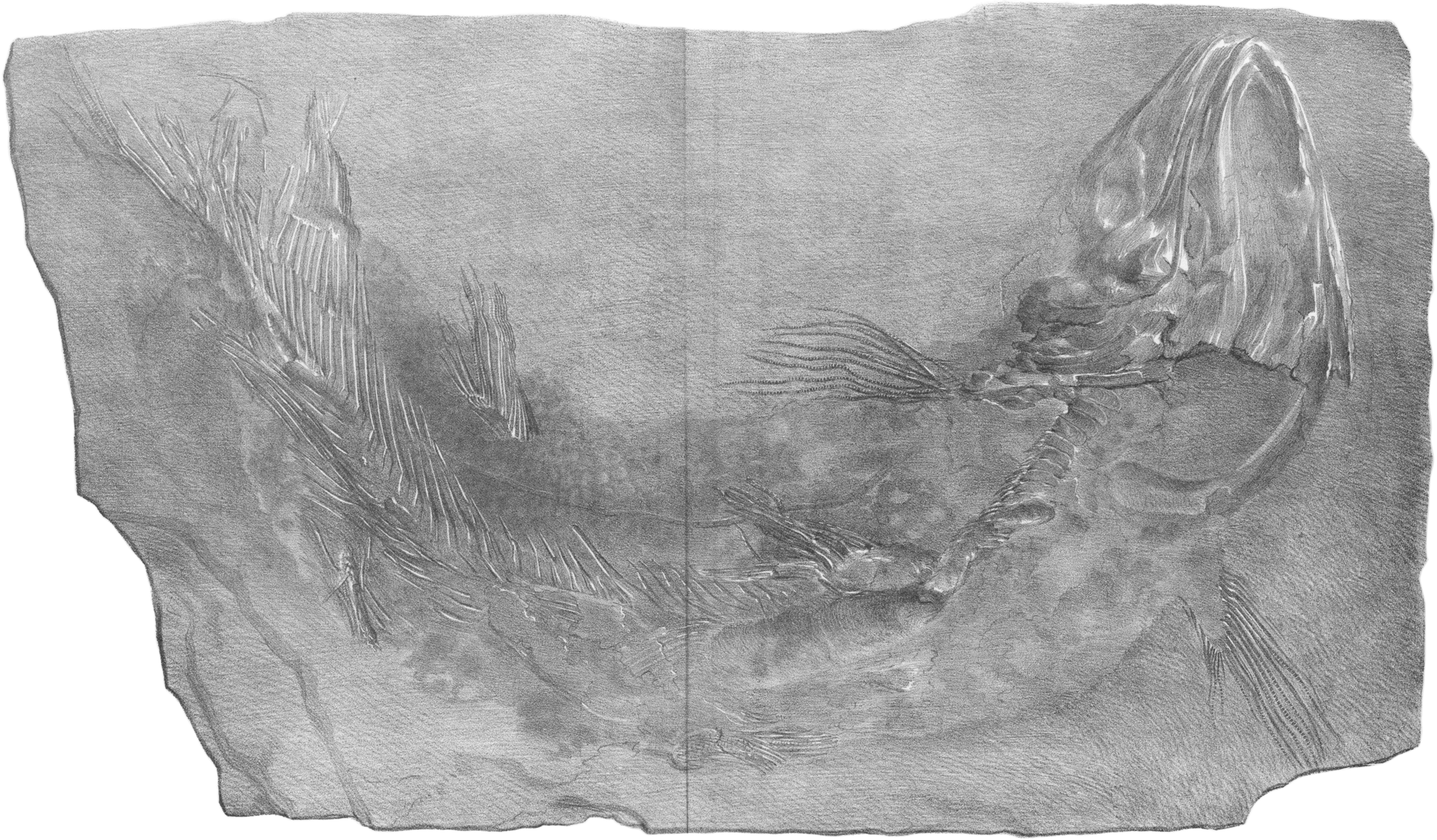

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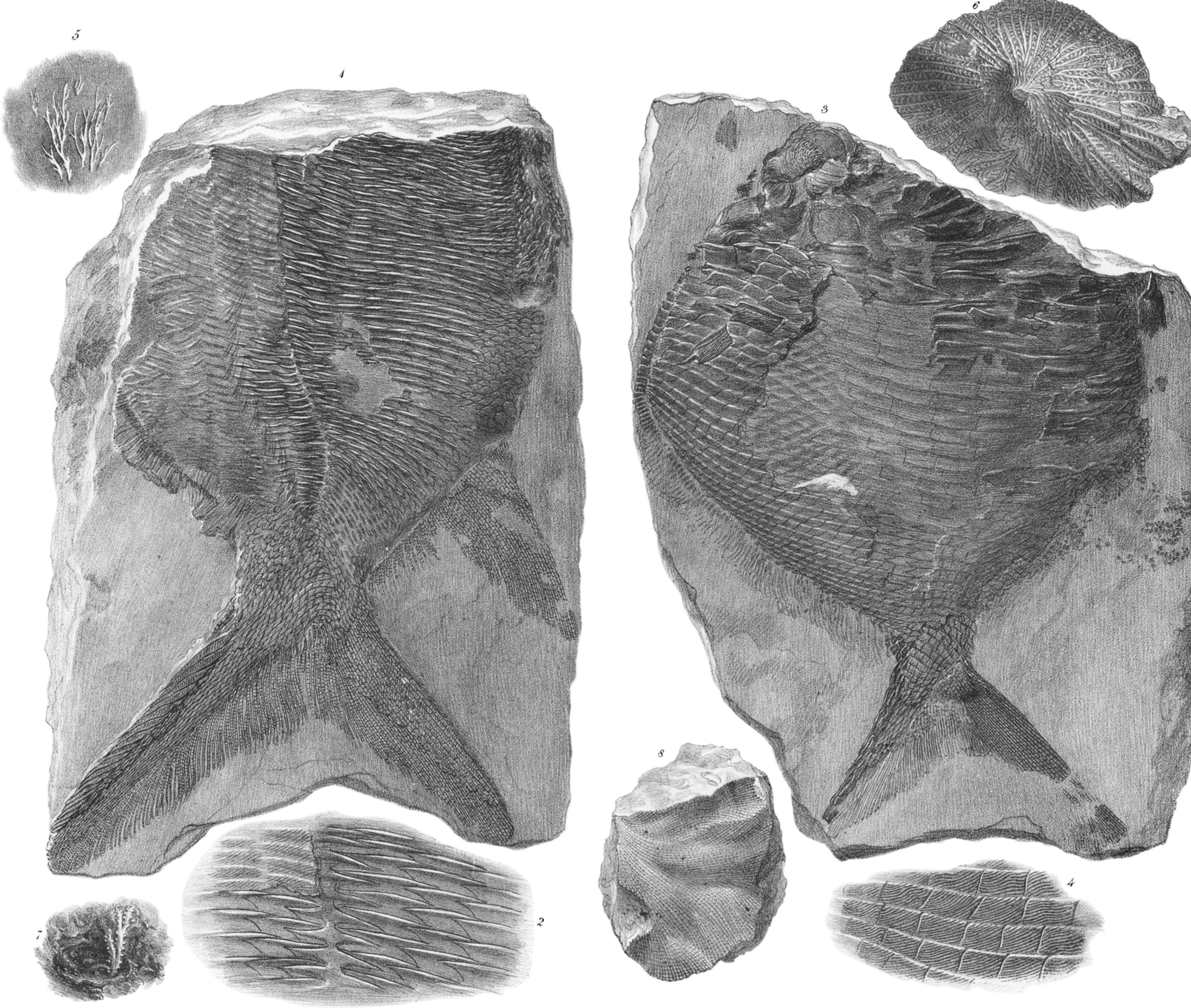

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