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Quod si cui mortalium cordi et curæ sit, non tantum inventis hærere, atque iis uti, sed ad ulteriora penetrare; atque non disputando adversarium, sed opere naturam vincere; denique non belle et probabiliter opinari, sed certo et ostensive scire; tales, tanquam veri scientiarum filii, nobis (si videbitur) se adjungant.

Novum Organum, Præfatio.

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ADDENDA AND CORRIGENDA.

Page.	*Line.*	*for*	*read*
30	27	living shale	living shell
44	22	Dark	Park
53	32	Plate I.	Plate IV.
60, note *	1	seen	won
63	16	eastern edge	western edge
68	10	more	mere
71, note * last line	..	Plate VII. fig. 3	Plate VII. fig. 1
.. ..	..	Plate V. fig. 1	Plate V. fig. 3
88	27	Mill or River	Mill on the River
108	24	remains at Cold Hill	remains. At Cold Hill
...	25	Aberford: in a few	Aberford and in a few
110	20	and in the descending	and is in the descending
110, note ¶		p. 110	p. 93
..., note ††	1	five species of Melaniæ	a species of Melania
129	27	Forhabres	Fochabres
134, note	2	medicinal	economical and medicinal
135	26	Gornigo	Gernigo
141	2	bed	beds
157	2	country. They are	country they are
303	6	primary or transition	primary and transition
305	24	primary or transition	primary and transition
312	4	of a large	of large
312	20	By the expressions here used, the authors do not intend to convey the idea of any general analogy between the fossils of the rock in question, and those of the mountain limestone.	
388	13	—— *scalaria?*	Scalaria?
394	25	Graub-kalk	Grob-kalk
403, note.		In addition to M. Constant Prévost	also M. P. Partsch
413	18	The eastern extremity of the chain, &c. In limitation of the assertion in this paragraph, we may state that the younger tertiary conglomerates and Leitha-kalk of Wöllersdorf are considerably inclined. We believe, however, that the cases of this kind are exceptions which do not affect the general rule.	
424	24	formation of the same age	nearly of the same age
424, note	2 *from bottom,*	Cullompton	Cullumpton

1.—*On a Group of Slate Rocks ranging E.S.E. between the rivers Lune and Wharfe, from near Kirby Lonsdale to near Malham; and on the attendant Phænomena.*

By JOHN PHILLIPS, F.G.S.

HON. MEM. OF THE YORKSHIRE, LEEDS, AND HULL PHILOSOPHICAL SOCIETIES.

[Read December 21st, 1827; and January 4th, 1828.]

General Remarks.

THOUGH the secondary rocks which form a crescent around the Cumbrian Lake district are in general arranged with much regularity, geologists are aware that in consequence of dislocations of some strata and unconformed positions of others, the beds do not always appear at the surface in the order of their consecutive deposition.

The great fault under Cross Fell, investigated by Dr. Buckland, and the double range of limestone scars which stretch to the west and north from under Wild Boar Fell, would have been much less difficult of explanation but for the unconformed deposit of red marl and sandstone in the vale of Eden, upon the depressed range of limestone.

In some parts around the Lake mountains, the obscuration of certain secondary rocks may be ascribed wholly to the over-extension of new red sandstone; as from Egremont to Low Furness, where this rock is brought into contact with granite and slate, to the exclusion of coal-measures, limestone, and old red sandstone;—and sometimes, without any considerable deposit of unconformed rocks, great interruptions in the lines of strata are caused by sudden variations of dip, or remarkable dislocations.

A full account of the variations which are produced by the causes abovementioned, on the direction and appearance of the secondary rocks round the Lake district, would be highly serviceable to the cause of inductive geology.

The observations in the present communication are restricted as much as possible to the illustration of the phænomena connected with a group of rocks, aberrant from the slate district of Westmoreland, and extending in a singular manner about fifteen miles towards the east, under the limestone and gritstone summits of Gragreth, Ingleborough, and Penygent. The tract in question, situated between the celebrated valleys of Lune and Wharfe, and containing some of the finest mountains, caves, and scars in Yorkshire, has long been frequented by the lovers of romantic scenery; and appearances of another kind have probably led many geologists to visit it; but no publication has at all unfolded the peculiar arrangement of its rocks.

It cannot be doubted that many persons have noticed the appearances of dislocation which this country presents in several directions. Whoever enters Settle from the south, and goes along the road by Giggleswick Scar, must be struck by the sudden rising of the northern wall of limestone above the ranges of millstone grit on the south. No one reaches Ingleton without feeling surprised at the rapid declination of the limestone near that place, contrasted with the level brow and expanded base of Ingleborough.

On further examination it will be found that the junctions are unusually numerous and interesting between the slate and mountain limestone; and examples are frequent of the formation of conglomerate in the lower beds of mountain limestone, in places where the old red sandstone is deficient.

Slate Series of the Lakes.

The slate formation is perhaps more developed in the Lake district than in any other part of the island. To describe the numerous and interesting variations which are here presented, would lead to investigations foreign to the object of this paper; but a short statement of the great divisions of the series will be found necessary to a right understanding of the particular portion to which the aberrant group hereafter to be noticed belongs.

A short examination is sufficient to show that the slate rocks of the Lake district are really grouped in three divisions, lying on one another in a certain order; and though many variations occur in each, the character of the component rocks is sufficiently distinct*.

The slate of the lower division is dark, soft, nearly homogeneous, extremely fissile, and so generally contorted as to be seldom fit for roofing. In Skiddaw and Bowscale Fell much chiastolite is imbedded in it. Between Skiddaw and Saddleback so much hornblende is admitted into its lower part as to change the rock to hornblende slate, beneath which is fine-grained gneiss resting

* This arrangement of the Slate rocks of Cumberland will be found precisely in accordance with the general views first established by Mr. Jonathan Otley of Keswick, and published with a geological map of the district, in the Lonsdale Magazine, and in his "Guide to the English Lakes." The opinions of this excellent observer on the stratification of his native district have been freely communicated to all inquirers; and more distinguished geologists than myself have found, in the results of careful and repeated examinations, most satisfactory proofs of their accuracy and importance.

on granite. This series ranges by Saddleback, Skiddaw, Grisdale Pike and Dent Hill, and is seen on the margins of Bassenthwate, Derwent, Buttermere, and Crummock waters, forming smooth insulated mountains down which the streams run in straight lines. Dipping at a moderate angle to the east or south-east, under the argillaceous red rock of Barrow and St. John's Vale, it is overlaid by the second or middle division of slate rocks, which are very different in texture and general appearance, and occupy a very dissimilar tract of country.

Close inspection shows nearly all the rocks of this second series to be granular aggregates, with an argillaceous basis of greenish colour, and considerable but various hardness. Often mottled with different colours, some appear as if filled with fragments like a breccia; and others, variegated with nodules of calcareous spar, green earth, and differently coloured quartz or calcedony, have been mistaken for amygdaloid. Greenstone and other "overlying" rocks are rather plentiful in the country occupied by this range of slate, as in the Walk and Castle Crag at Keswick, and on the margins of Wythburn Lake. Quarries abound in the course of this division of slate, which includes the grand mountain ranges of Helvellyn, Langdale Pikes, and Scaw Fell, and the lakes Ulswater, Grasmere, and Ennerdale.

South of this craggy chain is the line of more recently deposited calcareous slate, or transition limestone, well known to geologists, which ranges across the heads of Windermere and Coniston water to Broughton. It is the lowest rock in the country which has yielded organic remains; amongst which the following are least rare.—Caryophyllia, Millepora, Spirifer, Producta, Orbicula.

The rocks which inclose and cover it are of a dark colour, without fragments or nodules, often micaceous, and in a few places productive of organic remains. They are the third and most recent series of slates in this country, and are often seen covered immediately by carboniferous limestone. As this is the series to which the slate rocks belong, the illustration of which is the principal object of the present paper, a more particular account of them will be found useful.

In hardness these rocks greatly surpass those of the lowest series, and, in consequence, give to the hills which they form a more angular and knotted outline, and a more bare and rugged surface: but in these respects they yield to the middle series, which exhibits the grandest precipices and most alpine forms in the district. Only in Hougill Fells does their altitude exceed two thousand feet, and it is mostly under one thousand; so that the whole tract which they occupy is overlooked in one direction from the mountain of the middle range of slate, and in the other from the high summits of the carboniferous formation.

These rocks are traversed by many joints meeting at acute and obtuse angles, thus producing rhomboidal blocks. This structure prevails in all the varieties, and is to be seen in every stream, the waterfalls of which derive peculiar features from the circumstance; and on all the hill sides, which in consequence show long smooth faces of angular rocks. It is this part of the district which most forcibly impresses the idea of slate being a crystallized rock capable of having its angles precisely determined.

Among several variations in the composition and structure of these more recent slate rocks, two appear predominant; the highly fissile nearly homogeneous variety with little appearance of mica, and the granular sorts, some of which split with micaceous surfaces, while others contain disseminated mica. These micaceous rocks alternate frequently in vertical or inclined layers; and the coarse kind incapable of cleavage, with less mica than usual, is observed to alternate under the name of "galliard," with the homogeneous variety which alone is worked for slate.

Organic remains, rather sparingly distributed, occur in the finer-grained micaceous rocks, in several places about Kendal and Kirby Lonsdale. In the neighbourhood of the latter place Mr. W. Smith and myself (1823) discovered

Near Kestwick—Orthoceras, Patella, Trigonia, Plagiostoma, Pecten, Gryphæa.

At Beckfoot—Turritella, Melania? Terebratula, and unascertainable bivalves.

Similar shells occur at Jenkin Crags and other places near Kendal.

In diluvium at Biggins—Unio, Spirifer, Terebratula.

Rocks which cover the Slate Series.

The slate rocks are in this country usually succeeded by incumbent beds of mountain limestone; but in a few situations, chiefly in the valleys of considerable streams, large beds of old red conglomerate intervene, having a dip conformed to that of the limestone.

Such beds are seen in abundance at the foot of Ulswater, at Dacre Castle, on the river Lowther and some of its branch streams near Bampton, on the Rother about Sedbergh, on the Mint near Kendal, and the Lune about Kirby Lonsdale. Apparently in the same geological relations red marl and sandstone were observed by Mr. W. Smith and myself near Ulverston in 1822. This conglomerate seldom follows the limestone where that rock ascends to higher ground; so that in Underbarrow Scar near Kendal, and under Wildboar Fell near Sedbergh, the slate is covered by limestone.

Above the great scars of limestone lies the series of carboniferous rocks, of which the lower portion is characterized by the presence of the conglomerated sandstone called millstone grit. This rock forms the highest edge around many of the summits between Ingleborough and Cross Fell; but in lower ground, as on the south of Ingleton, it is covered by the upper carboniferous rocks or true coal measures.

The most recent of the rocks known in this country is the new red sandstone, whose unconformed beds sweep round the N.E., N., and S.W. sides of the Lake district, and as we shall find are not absolutely wanting in the tract whose investigation is the object of this communication.

General Description.

The country of which I now propose to trace a geological description extends in an easterly direction from the valley of the Lune almost to that of the Wharfe, and lies principally on the north side of the road from Kirby Lonsdale by Ingleton, Settle, Malham, and Grassington. Along the middle of it, from Casterton Fells near Kirby Lonsdale, to a few miles east of the Ribble, ranges an almost continuous line of argillaceous rocks, mostly fissile, occasionally quarried for slate, tombstones, and flags. It is bounded on the north by the wide, elevated strata of limestone which support the carboniferous summits of Gragreth, Whernside, Ingleborough, and Penygent; and on the south, (except at Kirby Lonsdale, where old red sandstone intervenes,) by narrower and lower surfaces of the same limestone, which are succeeded still further south by millstone grit and coal-measures, occupying for the most part low ground.

Including the rivers Lune and Wharfe, no less than nine streams running from north to south cross this district, and expose in a very satisfactory manner the order of relative position, with the actual declinations and visible or inferred dislocations, of the rocks. Of these streams, the Wharfe, which rises in the limestone series, continues in it across the line of the district in question; the Lune, which gathers its first waters partly from the limestone and partly from the slate, divides slate rocks of different kinds, then crosses old red sandstone and mountain limestone, and passes to the sea through millstone grit. The remaining seven streams, Leck Beck, Kingsdale, and Chapel le Dale waters, Clapham Beck, Wharf Beck, the Ribble, and Stainforth Beck, all originate in mountain limestone and millstone grit: then, in their rapid descent, they cut through these rocks and expose the subjacent slate, from which they all, except Leck Beck, pass off to the incumbent limestone on the south, and afterwards run in millstone grit and coal-measures.

If to these advantages be added the fine mural precipices which encircle Ingleborough and Penygent, and it be considered that the country is for the most part in pasture, open and little concealed by woods, it will probably be admitted that unusual facilities are afforded for geological investigation.

The plan of description of this district which I have adopted is to notice in succession the phænomena presented by each of the streams as it crosses the line of country, and to introduce in their place the appearances on the mountain sides.

Lunesdale.

The river Lune, having collected its waters from the slate tract of Langdale Fells and Shap Fells and the limestone surfaces about Orton, runs through a deep glen by Hougill Fells, and exposes the rhomboidal rocks which constitute the upper division of Westmoreland slates. At Crook of Lune the slate is procured in large tables, whose cleavage planes decline steeply to the south, and have the "bate" grain or false cleavage dipping to the north.

The Rother, which flows into the Lune below Sedbergh, draws likewise its supplies from both slate and limestone; but its main channel is in slate till the neighbourhood of Sedbergh, where it divides rocks of red conglomerate very similar to those which the Lune, after running some miles further in slate, crosses above Kirby Lonsdale.

The stream which flows by the village of Barbon into the Lune originates on the margin of Dentdale, and runs along nearly the line of parting between limestone and slate, till, where the slate of Casterton Fells fronts that of Barbon Beacon, the limestone turns off to High Crag and Gragreth. Along most of this line the limestone, where near the slate, is strangely dislocated, and not unfrequently appears quite vertical, though in the carboniferous hills above on the east, the beds are nearly horizontal.

Leaving these beds the water divides a slate range for about two miles, and exhibits some pretty cascades; but suddenly, on the western side of it, encounters a line of dislocated limestone ranging toward the south, at Barbon Chapel. Below this the channel is excavated in beds of old red conglomerate almost down to Beckfoot.

The Lune, after receiving Barbon Beck, flows between rocks of micaceous slate which present a very interesting occurrence of organic fossils.

We remark on the face of the rock here a single decomposing line, parallel to the micaceous partings or cleavage, but intersected by vertical joints in two directions, meeting at angles of 64° to 74°. This is a layer of shells converted to calcareous spar or exposed in the state of casts. A spiral elongated shell having the general appearance of a Turritella is the most abundant; with it occur small striated Terebratulæ, a larger and shorter spiral shell resembling in contour some species of Melania, and an unascertainable bivalve.

Almost immediately beyond this place, the slate is succeeded by the red conglomerate, whose large horizontal beds filled with large and small pebbles alternate with layers of red and white clay. Henceforward the old red rock, continuing its course down the Lune, appears to underlie the limestone in Casterton woods, as well as at Kirby Lonsdale. At this latter place, examination develops some curious facts.

The pebbles of various size which are here accumulated in immense abundance, and cemented in vast irregular beds by red clay, red sand, and calcareous spar, are chiefly slate and quartz: but I found in addition single specimens of both blue and red (transition?) limestone containing a few crinoidal and coralline fragments, hornstone, and calcareous spar, all rounded.

The pebbles are but feebly cemented in the red clay and sand, and may be easily separated by a blow of the hammer, leaving a smooth concave impression; but where calcareous spar, as about Kirby Lonsdale and Barbon, fills up the cavities, the mass is more coherent.

The slate pebbles are mostly of the granular micaceous variety which abounds in the neighbouring hills, but some specimens may be thought to have been transported from the range of the middle slate. Micaceous iron ore has been found in the quartz. No granite, sienite, porphyry, or greenstone,—rocks which occur in considerable plenty in the central parts of the Lake district,—have yet been observed in this conglomerate; so that it appears to be a deposit caused by a very limited current, which was perhaps confined to what is now the track of the Lune.

This will appear the more probable on viewing the great number of boulder-stones which are found in the diluvial banks of the Lune; for, among these accumulations of a wide-spreading flood, are the granite of Shap Fells, the porphyry of High Borrowbridge, and various hornstones, with limestone, grit-stones, and slate from the neighbouring hills.

The joints which cross the beds of this rock, as may be seen in the Red Scar near Kirby Lonsdale, are scarcely more regular, nor are the few dislocations in it much more distinct, than those in pebbly diluvium. But the beds are crossed by veins of calcareous spar, and these often pass through the pebbles in the same way as the fissures split the fragments in the conglomerate at Oban (Argyleshire).

These beds dip to the south at a moderate angle, and are succeeded, but without the actual contact being visible, by the limestone strata, which also dip to the south at a much greater angle.

The lower portion of limestone is exposed in the channel and on both sides of the stream, for about three hundred yards, at a dip of about 1 in 4 to the south, apparently without any argillaceous partings. Some red beds appear toward the bottom. It is not here very productive of organic fossils, though some beds are full of crinoidal remains; and one fossil, very unusual in this rock, a large nautilus, allied to *N. intermedius*, was discovered in a quarry near Kirby Lonsdale with Bellerophon, Cirrus, Melania, Producta, Spirifer, Terebratula, some heliciform shells, &c.

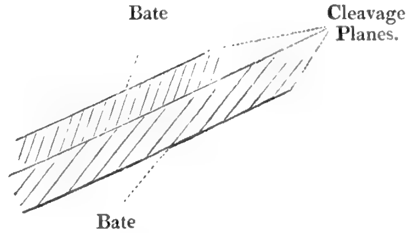
In the river above the bridge, veins of calcareous spar divide the rock, and yield a little fibrous green carbonate of copper.

It is succeeded on the south by some argillaceous strata of considerable but unascertained thickness, and these again are covered by beds of crinoidal limestone and sandstone, of which, probably, a greater quantity would have appeared further south, but for the immense deposit of alluvial and diluvial matter which in that direction hides all the stratification.

Westward, these thick limestone rocks rise by Biggins and Hutton Roof to Farlton Knot, and are overlaid toward Sellet Hall and Whittington by limestone, shale, coal, and sandstone of different kinds, which would occupy much space in description;—eastward, they are seen only in the river banks, being immediately afterwards enveloped in the mass of gravel, which never once allows their reappearance nearer than the neighbourhood of Ingleton.

Leck Beck.

The stream which flows by the village of Leck, and crosses the Ingleton road at about three miles from Kirby Lonsdale, rises among the limestones and shales of Gragreth and Green Crag. It speedily crosses the range of lower limestones which appear in scars on its sides, as at Easgill Kirk, and sinks into the slate series beneath, of which it denudes both the granular and homogeneous varieties. The most interesting appearances of the latter kind are where the stream approaches the inclosed lands. Here a course of fissile rocks, which might perhaps be quarried for slate, crosses the stream in about an E. and W. direction. Besides the numerous parallel edges of cleavage planes on its surface, many other straight joints are made evident by the action of the stream. Two sets of these, crossing one another at angles of 68° and 112°, intersect the cleavage planes at 44° to 47°, and there is a set of distant parallel lines which cross the cleavage at 90°.



At this place some particular parts of the slate much resemble that of Horton, hereafter to be noticed, but exhibit the unusual fact of the laminæ of "bate," varying their direction in contiguous tables of slate.

In one table the "bate" and cleavage meet at angles of 64° and 116°, but in the contiguous table at 25° and 155°.

This appearance is seldom to be distinctly observed except on stones which by long exposure to the weather have had their fissures opened.

After crossing slate rocks for about half a mile further, the river divides beds of red sandstone without any pebbles; beyond which so much gravel, derived from the neighbouring hills, fills the valley, as to conceal the subjacent strata for half a mile, when a grit rock appears full of pebbles. One hundred yards lower is the place where an unsuccessful trial for coal was made by boring. The principal rock discovered in this attempt was a blue argillaceous stone, provincially called "Soapstone," and thought to be similar to a stone of the same name in the Coal-field at Black Burton. Lower down and till the stream joins the Lune, its banks are composed of pebbles.

The smaller streams which intervene between Leck Beck and Kingsdale arise from the northern edge of limestone, and traverse in their southward course, before arriving at the Settle road, a tract which may probably be formed on slate rocks; but the abundance of gravel prevents the exposure of these as well as the southern range of limestone, of which no trace appears before arriving at Kingsdale. But at West House, on the line of the road, a curious rock with a southward dip is occasionally exposed in digging the foundations of houses, which resembles in composition the brecciated beds alternating with new red sandstone at Kirby Stephen and Stenkrith Bridge.

This stone is a fine-grained light-coloured red sand, containing a variety of imbedded fragments, more or less rounded, apparently, according to the degree of their hardness. Limestone fragments of gray and red colour are the most numerous, the largest and the most angular: ironstone in small pieces and in different states of decomposition is plentiful, and a few pebbles (granular slate?) of more sandy substance make up the mass, in whose interstices calcareous spar ramifies as in the old red conglomerate of Kirby Lonsdale. No fossils have been found in it except what the included limestone fragments contain. It is locally called "red limestone," and is occasionally used in building, for which its large thin beds are well adapted. It is unknown, except about West House, where it occupies a considerable surface of red soil.

Kingsdale. (See Section A, Plate I.)

Has its origin in the limestone and shale series between the ranges of Gragreth and Whernside. Having passed between the distant limestone scars in which Yordas Cave is situated, the water of Kingsdale flows by a winding channel among very romantic cliffs of the lower part of this rock. This scene, which reminds a spectator of Derbyshire, is terminated by a very fine waterfall, of perhaps forty feet in height, over the lowest beds of limestone resting on slate, so that, at half the height of the precipice, is seen the junction of these two rocks.

The contrast of horizontally bedded limestone and vertically jointed slate is remarkable, and gives a peculiar character to this interesting spot. The limestone beds higher in the rock are commonly distinguished by a tendency to split vertically into subcolumnar forms; but the thick beds which rest upon the slate show few vertical joints, and are marked by horizontal weather slits, indicating the more laminar structure of the stone.

Climbing to the junction, I found the lowest limestone bed filled for about two feet nearest the bottom with large rolled pebbles of slate, and above these with abundance of smaller pebbles of quartz and slate. This unequivocal conglomeratic condition of the limestone continues for about twenty feet in height, the pebbles diminishing upwards, though irregularly, both in size and number*.

The slate rocks thus exposed have their cleavage planes directed nearly S.E. They continue, and are seen down the stream in large rhomboidal masses, covered by heath, and ornamented by frequent waterfalls, and give to this part of Kingsdale the appearance of some Cumberland valley in miniature.

Beneath the pebbly limestone which ranges in level beds, slate is seen at intervals, principally on the west side of the valley, for a quarter of a mile toward the south, where it attains the height of 150 feet above the water, and has been quarried for the purpose of roofing.

Immediately beyond, the scene changes, the slate sinks suddenly, and limestone fills all the valley to the south; the place of this alteration is marked by a strange confusion and dislocation indicating a great fault, which has depressed, apparently with a sudden reverse of dip, the beds on the south. This confusion may be well examined on the west side, but on the east gravel hides the appearances of stratification.

The line of dislocation appears to be directed more toward the south than the cleavage planes of the slate, and follows a straight part of the stream, in consequence of which the depressed range of limestone appears further upon the west than on the east side of Kingsdale.

Between the nearest points of the slate and limestone in the stream dipping

* See Section B, Plate I.

southward, is about thirty yards: but, in this interval, occurs a series of vertical beds of limestone, and between them and the great calcareous mass on the south is a quantity of argillaceous stone with abundance of calcareous spar in the joints, which at first I supposed to be shale; but, as in only a few cases, any shale lies between the limestone and the slate, and then only in small quantity, it is probably contorted slate. Its specific gravity when dry is 2·73 + after escape of the included air 2·75 +.

Further down the stream, limestone beds continually succeed one another, with a dip to the south, and the series suddenly terminates at Ingleton, and is soon followed in lower ground by the coal measures at Black Burton.

The slate is seen crossing the hill between Kingsdale and Chapel le Dale.

Chapel le Dale. (See Section C, Plate I.)

The water of this valley has its sources in the shale and gritstone series above the great scar limestones, which form the floor of Ingleborough and Whernside. Between these two mountains this limestone is exposed in vast bleached and weather-worn surfaces, which terminate in level ranges of precipices on each side of Chapel le Dale. This character of the valley prevails till within a mile of the village of Ingleton, when slate rocks appear beneath the limestone.

The vertical cleavage planes of these rocks range pretty exactly S.E., and are crossed by frequent nearly vertical joints ranging N. and S., and by oblique joints dipping N.E. The stone is mostly of a fine green colour within, though often purple on the surfaces; but a hard, granular, not fissile variety, called "galliard," sometimes intervenes in elongated nodules and bands parallel to the planes of cleavage. There is in some places a more frequent alternation of the finer and coarser varieties; and certain planes of cleavage are covered by cubical crystals of iron pyrites imbedded on some of the square sides in a parallel coating of some fibrous zeolitic mineral, which occasionally softens by exposure into nacreous laminæ. In some layers of slate very minute polyhedral crystals of pyrites are disseminated, and sometimes this mineral is found beautifully arborescent between two adjacent planes of slate. It seldom crosses the laminæ of slate as calcareous spar and quartz are seen to do. The latter mineral is most abundant in the "galliard." These appearances are most conveniently seen in the slate quarries, which are worked on both sides of the stream.

Below these quarries, gravel obscures the stratification on the west side for about one hundred yards, beyond which the southern range of limestone is seen at the edge of the water, and rises confusedly northward into the hill above. On the east side also gravel occurs for about the same distance, but the stream setting against this side, has exposed at the foot of the bank for about sixty yards a curious scene of dislocated slate, with two remarkable dykes of greenstone, beyond which the southern range of limestone appears near the water's edge, and is seen on both sides of the valley, dipping to the south at high angles down to the village of Ingleton.

The slate rocks crossing over toward Clapham Dale are exposed under the limestone scars of Ingleborough, of which the lower beds are so exactly similar to the conglomerate variety noticed in Kingsdale, as to require no additional description.

The higher range of limestone scars lying on the north of the course of the slate rocks, continues along the breast of Ingleborough, and reaches the sides of Clapham Dale; but the slate rocks, and the southern range of limestone, are concealed nearly from Ingleton to Newby by an abundant deposit of diluvium.

Clapham Dale. (See Section D, Plate I.)

The valley which descends by Clapham originates from the north in a number of dry branches, which expand within the vast surface of bare limestone between Ingleborough and Penygent. These unite into a dry and almost channel-less dale, excavated between cliffs of limestone overgrown with hazel, thorn, sorbus, and ash. Following this for a quarter of a mile, we find a full stream flowing from the right bank out of a broad depressed cavern, with sand and pebbles on its furrowed floor. For a few hundred yards lower, the bed of the stream is filled with large boulders of grit and limestone, but the sides of the valley are limestone. The water, afterwards, flows for one-third of a mile over nearly horizontal beds of limestone, which are covered in the contiguous banks by cliffs of the same rock fifty feet high.

Below this interesting part of the valley the slate rocks appear in the stream for about two hundred yards, with laminæ directed to the east, forming little pools and cascades among overgrowing wood. Further on, the beds of limestone succeed, having a dip to the south, and continue to the village of Clapham.

From Clapham Dale the northern limestone resting on slate ranges in high scars round the head of the valley of Wharfe, while the southern portion rises into Clapham-Lodge Hill, and shows its returning edges above Austwick. Whether the slate rocks are continued superficially across the whole of the intermediate ground from one valley to the other, does not appear very certain; but on approaching the valley of Wharfe they are found covered by the northern limestone, whose lower beds are filled with pebbles of slate, the largest lying at the bottom.

At this place I observed a very interesting occurrence of large slate blocks scattered as well on the higher limestone scars of the north, as on the lower ranges of the same rock on the south. We see the slate *in situ* covered by the limestone edge, on the top of which, 50 to 100 feet above, we find the huge transported blocks of slate in great abundance; further on the scars, to an elevation of 150 feet, the blocks are still numerous, and they may be seen by ascending one ledge after another almost to the top of the Fell, 500 feet above their original position. They appear to have been driven up at a particular place by a current toward the north, and afterwards carried along the surface of limestone in a narrow track toward the summit of the Fell. The contrast is very interesting between these rough angular masses of slate, and the smoothed rain and time-worn limestone which supports them.

Valley of Wharfe.

The northern branch of the valley of Wharfe expands in its upper part into a wide dale based on slate rocks, and encircled by high scars of limestone. These are in several places undulated, so that the slate is exhibited at very different heights on the opposite sides of the valley. In front, at the upper extremity, the granular variety of slate rises to the height of 100 feet; at the same height it appears on the east side, but is nearly level with the base of the valley on the west. Lower down, where the opposite scars are more level, slate fills the whole wide valley, ascends both hill-sides, and is seen touching the limestone in several fine natural sections. One of these on the eastern side*, not easily reached over a slope of loose stones 100 feet high, exhibits the slate in distinct laminæ of cleavage directed E.S.E. and dipping 45° S.S.W. Pretty regular joints cross it with a dip N. 70°. It is cut off by a level top, on which rest beds of limestone, filled, for about 8 or 10 feet, with very large boulders of slate crossed by the same fissures which divide the calcareous paste. In one of these pebbly beds I found a noble mass of Astræa lithostrotion.

Ribblesdale. (See Section F, Plate I.)

The slate rocks are seen ranging with a level top under the precipices of Moughton Fell, till, beyond the village of Horton, the limestone descending to the river marks their northern boundary. Their southern range is on a lower level, under the calcareous summits of Feizer to the Ribble near Little Stain-

* See Section E, Plate I.

forth, so that this river runs for about four miles across the direction of the slate rocks. This great expansion of surface has been favourable to the establishment of slate quarries, of which several may be inspected near the S.E. angle of Moughton Fell. The whole length of this scar fronting the Ribble deserves particular examination.

In a little stream nearly west of the village of Horton the slate is covered by a series of beds which I did not find elsewhere. Immediately on the slate, rests a layer of fragmented quartz and slate in a calcareous paste. Above, are four feet of shale with a hard contained bed: next a bed 18 inches thick, of fragmented quartz and slate, with pyrites: then 2 feet of lumpy shale: 3 feet of lumpy limestone: 5 feet of broad laminated shale, which throws out the water; and 25 feet of limestone in the low scar above. The cleavage planes of the slate here range E.S.E. and dip 70° S.

Following the edge of the scar toward the south, a series of planes dipping 40° S. makes the slate appear stratified. Several variations happen in the direction of their dip, between this place and the great slate quarry further south, where the tables dip S.W. Here the greater portion of the flags now dug is obtained; but, as no junction appears of the slate and incumbent limestone, the older quarries beyond are more interesting. In the first of these the laminæ range E.S.E. dip S.W. 45°, and are crossed by long smooth vertical joints ranging S. and N., as well as by lesser ones ranging E.S.E. and dipping 30° N.E., and by others ranging E. and dipping 45° N. Soft greenish layers occur between the tables. Beyond, is a still older quarry under the limestone scar, where the laminæ dip 80° S.W.; and, in the lower ground, are two others, where the planes of cleavage dipping N.E. 75° are crossed by long smooth vertical N. and S. joints; as well as by others dipping S.W. 60°, which become so numerous as to exhibit a false cleavage. Hard nodules, often septariate and containing calcareous spar, lie in the planes of slate at the lower quarry. Once I thought an Orthoceras was distinguishable in one of these nodules.

East of the Ribble, junctions of slate and limestone are scarcely any where to be seen; and the country is much less favourable to minute examination than that previously described. But the slate is seen in many places with cleavage planes ranging nearly S.E.; and other characters may be investigated in streams and fields, especially near the farm of Neil's Ings.

The northern range of limestone keeps its high level at the base of Penygent and Fountain's Fell, and forms the curious scars known by the name of "Flat Rocks." The southern range of limestone crossing the Ribble appears at the village of Great Stainforth, at the level of the river, with a northward declination. South of this village it rises on each side of the river at a moderate angle to the summits of Settle Rocks and Giggleswick Scar, but no slate is exposed beneath them.

A small portion of limestone crosses the stream at Great Stainforth; but the principal part is on the south side of its eastern branch, and goes on to unite with the northern range in the bare white rocks of Malham Moors. Here then is the termination of this range of slate, which has been shown to extend without any ascertained interruption nearly in a straight course E.S.E. 15 miles beyond the general line of its outbreak.

The phænomena by which it is accompanied are of a very interesting description. The numerous streams and bold precipices which diversify the country, reveal nearly all the peculiarities of its formation. Those who visit this tract will remark the general fact, that from the first appearance of this slate between two parallel bands of secondary rocks to its final concealment under their reunited surface, the southernmost border is greatly depressed beneath the analogous rocks on the northern side. On further investigation it is discovered, that, while the northern carboniferous rocks lie nearly level on their elevated floor of slate, the southern portion declines from these rocks at a high angle; and in Chapel le Dale and Kingsdale we find this great dip accompanied by a great dislocation and confusion of strata.

An examination of these points is a clue to the relative positions of the rocks in other situations; for though, as at Stainforth, other dislocations and unexpected reverses of declination occur, we are always struck by the evident depression of the southern border of the slate. The extent of this depression in Kingsdale certainly exceeds 150 feet, and in Chapel le Dale probably equals 400 feet. The appearances at Stainforth indicate about an equal difference of level there, between the northern and southern calcareous boundaries of the slate; and I think the dislocation still continues to be traceable across the wide surface of Malham Moors in the line of the Tarn. The only greenstone dykes which I remarked in this country are seen in Chapel le Dale, at the place where the dislocation and confusion of strata appear, and their direction is in the line of the fault.

The lower beds of the northern range of limestone resting on slate are commonly filled with pebbles of slate and quartz. Generally very large boulders of slate lie at the bottom, and the higher beds contain less and fewer pebbles till the character of conglomerate finally vanishes in common limestone. The pebbly beds may be known at a distance by their horizontal laminæ and weather-slits, which contrast decidedly with the vertical fissures of the equal-grained rocks above.

This occurrence of pebbles in the lower beds of the mountain limestone is not confined to the district in question. I have collected such specimens at Underbarrow Scar near Kendal, and at Winder Moor near Ulswater, in neither of which places is any old red conglomerate known to separate the limestone and slate, though it occurs in lower ground in the neighbourhood of both localities.

On the Stratification of Slate.

Few subjects are involved in greater difficulty than the question of the stratification of slate. We see this rock divisible into layers, and sometimes observe these layers alternately of finer and coarser texture,—appearances which in shale would be deemed very satisfactory evidence of the laminæ of deposition; but the generally vertical direction of the layers or planes of cleavage, and the numerous geometrically intersecting joints, leave much doubt in the case of slate.

This difficulty is not lessened by the fact, that, in many kinds of slate, there are really two cleavages or sets of laminæ, made evident by particular circumstances of weathering, though generally only one which may be called the true cleavage* is practicable by blows. The oblique laminæ of false cleavage form what is technically called the "bate" of the slate; and, though less evident than those of the true cleavage, are generally regular and parallel to each other, and intersect the planes of true cleavage at certain angles constant for the same quarry; as in the thick slate dug near Horton in Ribblesdale. But sometimes these oblique laminæ change their direction in passing through contiguous layers of true cleavage, as in Leck Beck near Kirby Lonsdale. It is in consequence of the oblique intersection of the laminæ of bate and cleavage that the slates dug at Horton so generally break with edges bevelled on one side as to be called "Sheerbate stone."

From finding the surfaces of cleavage in the fissile granular varieties marked with superabundant mica, and from observing that the organic remains were laid in the same parallels, I have been induced to conclude that in these varieties of slate (as in sandstone, to which their composition seems analogous,) the laminæ of cleavage are indeed those of deposition.

But this conclusion will hardly apply to the unmicaceous slate rocks; for though near Horton the large tables of slate have knots parallel to their surfaces, and are even separated by softer greenish layers, yet the level top of this series as it lies exposed for miles under the limestone scar, must still make it hazardous to decide that the planes of cleavage and stratification are here

* Called "Spires" by the workman.

coincident. And it is so often found in the slate of the middle division in the Lake district, as in Langdale and Coniston Fells, that the planes of cleavage cross alternate layers of finer and coarser matter, that most persons conclude the cleavage of such slates to be nearly at right angles to the strata.

After taking much pains in measuring the angles at which the smooth planes of slate meet each other in different quarries, in order to ascertain what regularity might be ascribed to them, I was obliged to conclude that their symmetry is confined to particular places, and by no means to be stated in general terms. Indeed I found that next to the cleavage planes, the most constant of all the great joints were those which crossed the cleavage nearly at right angles in a vertical direction.

The "bate" or false cleavage, which some observers have taken to represent the laminæ of deposition, is indeed generally constant in the same place; but even this has exceptions;—and notwithstanding the seductive nature of the appearances, it will probably be found on full investigation that the only really constant planes in slate are those of the cleavage; and that they are not always parallel over even a moderate tract is evident, by inspecting the quarries near Horton, where, within the compass of half a mile, they dip in opposite directions under the level top of limestone.

Dislocation south of the range of Slate.

Besides the great dislocation which accompanies the southern border of these aberrant slate rocks, and depresses the limestone strata on that side, another very important fault of the same kind running in the same direction, and also depressing the beds on the south side, is clearly traceable across the valley of Ribblesdale, and over Malham Moors toward Wharfdale.

The general history of this great fault must be in some degree known to all geologists who have visited the rocks of Gordale and Malham, or travelled up the steep ascent of Giggleswick Scar. It may be without hesitation affirmed, that no dislocation of strata in the island is more distinctly marked on the surface, by the equal opposition along a certain line of rocks, which in their undisturbed places are separated by five hundred feet of other strata.

In order to understand the nature of the appearances presented in the neighbourhood of Settle, it will be convenient to examine the stratification of Ingleborough and Penygent.

Commencing with the top of Penygent, the series stated in general terms with estimated thicknesses appears in the following order:

		Feet.
Alternations of sandstone and shale with bad coal		100
Millstone grit, which forms the summit of Ingleborough		60 ?
Alternations of sandstone and shale		100
Upper belt of limestone.	Thin limestone 8 feet; Shale . . 10; Mural limestone 60	80
Alternations		120
Limestone at the foot of the conical parts of these mountains marked by ranges of swallow holes		——
Thick series of shales and sandstones, with thin limestones		150
Great scar limestone		400
Slate series of unknown thickness.		

Long and repeated investigation has shown me that the upper belt of limestone in Pendle Hill, Penygent, and Ingleborough, is the main or twelve-fathom limestone of Aldstone Moor and Swaledale; that the four-fathom or underset limestone of that district is to be sought at the foot of the conical parts of these mountains, and that the vast scars at their base are formed of the scar, Tyne-bottom, and other lower limestones of Mr. Foster's section. I forbear to enlarge on this subject, because I am not without hopes of preparing a general table of synonyms for the limestone beds over a great part of the north of England.

Coming on the road from Clapham toward Settle, we see on the left the grand limestone cliffs of Giggleswick in the form of a decided outbreak, and in conformity with common appearances might be led to look on the right of the road for some of the lower formations. Instead of this we find, at the very summit of the road, millstone grit close to and under the limestone scar, and stretching away to an eminence on the right a little lower than the highest point of the limestone*. According to the estimation of thicknesses given above, the dislocation here may be supposed = 510 feet. Perhaps neither of the opposed rocks is here complete, but the errors thus arising are of contrary values. At the edge of the scar the limestone beds "hang" toward the south, but on the top what dip they have is toward Feizer. But the millstone grit dips rapidly away toward the south; and as it approaches the village of Giggleswick changes this declination to S.W., withdraws its craggy edges behind the village, and allows the exposure of the upper belt of limestone in the Ribble at the bridge, and for the length of a quarter of a mile below. The dislocation here would seem to exceed eight hundred feet, unless the scar limestones dip toward the river.

* See Section G, Plate I.

Ascending the steep hill side, strewed with loose blocks of slate, we find the road from Settle toward Malham running like that toward Ingleton, nearly on the line of this dislocation; having on the left a dry limestone hill 150 feet high, and on the right a moist surface of millstone grit. The limestone is protruded to a bridge on the Kirby Malham road, (over a stream which comes round the western side of Ryeloaf Hill,) there forming a fine amphitheatre of rocks with a waterfall in the midst, and extending in cliffs about 200 yards down the stream, where it is suddenly succeeded by millstone grit. These appearances seem to indicate a flexure in the line of dislocation, which is afterwards most satisfactorily traced between the gritstone summit of Ryeloaf, and a limestone hill of at least equal height on the north *.

Supposing, what I believe is the case, that this hill contains the whole series of the lower limestones, the dislocation here may be taken at about 500 feet. The different aspect of the herbage continues to denote and accompany the dissimilar character of the contiguous strata by Lord Ribblesdale's Calamine mines to the valley of the Aire, a little below Malham. Afterwards, it proceeds between Brown Hill and Gordale Scar, toward the south of the village of Skythorne, beyond which point, whether its course be confused with the other dislocations of the Grassington mining field, or may be laid down by future observation, I have not yet ascertained.

* See Section II, Plate I.

II.—*On the Geological Relations of the Secondary Strata in the Isle of Arran.*

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[Read January 18th, and February 1st, 1828.]

§ 1. *Introduction.*

So much has been written on the physical structure of the Isle of Arran, that an attempt to add our own observations to those which have been already published may require some preliminary explanation *.

After a careful examination, during last summer, of the north-eastern shores of the island, we thought that we discovered a sufficient proof of the existence, in that region, of a succession of formations which are the representatives of the old red sandstone, the carboniferous series, and the new red sandstone of English geologists.

If this conclusion be true, the evidence upon which it is founded (depending upon the observed superposition of the several beds, and the organic remains contained in them) cannot be unimportant. For the details will not only assist in completing the natural history of Arran, but will connect its structure with that of the neighbouring main land of Scotland. We hope, also, that they will throw light upon the true relations of those masses of conglomerate which are spread out on both sides of the Murray Firth, which form a well-defined mountain chain in the southern part of Caithness, and are developed upon an enormous scale on the western coasts of Ross-shire and Sutherland. The determination of the age of these great deposits appears, after the facts published by one of the authors of this paper, to be the only thing wanted to fix the true epoch of all those interrupted fragments of

* We more particularly allude to "The Mineralogy of the Scottish Isles," by Professor Jameson; "The Mineralogy, &c. &c. of the Island of Arran," by the Rev. James Headrick; and "A description of the Western Islands of Scotland," by Dr. MacCulloch.

secondary formations which are found in so many parts of the Hebrides, and the northern coasts of Scotland.

We hope in a subsequent communication to prove, partly by the help of the Arran section, that the conglomerates above mentioned are the equivalents of the old red sandstone,—that they are in a few places, and without the intervention of the carboniferous order, surmounted by masses which probably represent a portion of the newer red sandstone and its conglomerates,—and that they thus exhibit, in strict conformity to the order of succession established among the English strata, a natural introduction to these superior deposits which had been previously identified with the lias, and a large portion of the oolitic series*.

General structure of the Island Arran.

Having thus briefly explained the objects we propose to ourselves in the present communication, it may be proper to describe in a few words the general structure of the Isle of Arran, with a view of exhibiting the true connexion between the formations which will be described in detail, and the inferior rocks of the neighbouring districts.

If a line be drawn from the south side of Brodick bay to Machrie water, it will divide the island into two nearly equal portions, which are alike distinguished by their external features and internal structure. The hills which rise in the interior of the southern region have generally neither a great elevation nor a striking form, and are almost exclusively composed of different varieties of trap. Near the coast we meet with extensive deposits of red sandstone, all apparently of one formation, and generally in an horizontal position; but overlaid, interrupted, and traversed by innumerable masses of trap, exhibiting every imaginable variety of combination.

In the northern region, on the contrary, all the central parts are occupied by lofty serrated mountains of granite, on the flanks of which repose a number of distinct formations, the subordinate beds of which are in some places much broken and contorted, and generally in a highly inclined position. All these several formations, from the granitic nucleus to the newest stratified deposits, are occasionally traversed by trap dykes, which perfectly resemble some of the innumerable dykes of the southern portion of the island.

Primary Slate of Arran, &c.

The northern, the western, and the southern slopes of the central mountains of granite are succeeded by chains of hills composed of different varieties of primary slate. On a part of the eastern slope, between North-Sannox and

* Geol. Trans. New Series, Vol. II. Part II. pp. 293, &c.—Part III. pp. 353, &c.

the hills above Brodick wood, the chain of schistose rocks is wanting, and enormous masses of secondary conglomerate may be traced nearly to the base of the precipices of granite, and probably rest immediately upon that formation.

From Iorsa water to the south side of Catacol bay, different varieties of micaceous and chloritic schist occupy the coast; and, on the whole, appear by their dip to conform to the mineralogical centre. At Catacol bay, two great spurs of granite advance towards the coast, and seem to have cleft asunder the whole chain of slate rocks, which on opposite sides of the bay dip to the N.W. and S.W.,—an effect apparently produced by dislocation.

From Catacol bay to the hills which rise on the north-eastern shore of Loch Ranza, the zone we are describing is chiefly composed of a quartzose variety of chloritic slate. The dips are various; but on the whole the beds incline towards the interior of the island, and appear, therefore, to abut against the granite.

From the mountains which rise to the N.E. of Loch Ranza, the primary slates form a continuous ridge stretching in a south-easterly direction; but they gradually thin off, and disappear in the upper part of the glen of North-Sannox. In this region the rocks no longer exhibit the same crystalline texture which they did in the former part of the range; and the dip again begins to conform to the mineralogical centre. In the slate quarries of Glen Halmidel they resemble some varieties of Cornish Killas; and in the hill above the salt-pans called Laggan Camp, we in one instance found them passing into a conglomerate form.

Above Brodick wood the zone of slate reappears, and again takes its place between the secondary formations and the granite, and ranges across the island to Iorsa water. Its superficial extent in this part of its range has not yet been well laid down, and its southern limits are perhaps obscured by overlying masses of trap. In the brow of the hill overhanging the south side of Glen Luig, we found it in a form often put on by the middle zone of the slate rocks of Cumberland, associated with an irregular bed of gray crystalline limestone, and traversed by a dyke of decomposing trap.

From all these facts, it follows that the slate rocks of Arran have not been successively deposited upon the granite in any regular order, which is indicated either by the mineralogical character, or the superposition of the component beds. Were there any doubt on this subject, it seems to be set at rest by the celebrated junction of Tornignion; where a whole mountain (composed of strata partaking of that dip to the interior, which was mentioned above,) is seen to abut against the granite, which moulds itself into the broken edges, and in the form of veins is prolonged into the fissures and gaps of the schistose mass.

These phænomena, and the conclusions derived from them, have been so often stated, that we only mention them in this place by way of introduction to the conclusions which follow from the relations of the same granitic nucleus to those secondary rocks of the neighbouring coast, which we now proceed to describe*.

§ 2. *Coast section from Loch Ranza to Brodick.* (See Plate III.)

Having thus in a general way explained our objects in writing this paper, we now proceed to describe in detail the coast section from Loch Ranza to Brodick, which exhibits at the same time the succession of all the secondary deposits, and their relation to the inferior rocks which form the nucleus of the northern part of the island.

In following the coast southwards from Loch Ranza, a patch of red sandstone and conglomerate of about three hundred yards in length occurs upon the shore under the farm of Newtown, resting unconformably in a depression of the schist; the sandstone dips at a moderate angle to the N.W., whilst the schist is highly inclined to the N.N.E. The junction of these rocks is well worthy of notice, the bed of conglomerate for a foot or two in depth appearing to graduate into the chlorite schist, and exhibiting lines of slaty cleavage. Near this place several trap dykes penetrate through the sandstone and schist.

At Aultmore (the large burn) the schist finally recedes from the shore, and the strata of red sandstone, consisting of coarse conglomerate alternating with beds of fine sandstone, rise in the cliff and form round-topped hills of the elevation of eight or nine hundred feet, from the side of which a vast *écroulement* called the Screeten† has encumbered the beach with fragments; one of the largest of which, The Cock, is a well known landmark, and is laid down in all the maps of the island.

To the south of the Screeten the sandstone and conglomerate form a succession of lofty terraces; and their junction with the slate range of the interior is marked by a deep depression or bowl, called by the natives Clach-rachen, near which the sandstone is in a finely comminuted state, alternating with marls and green earth. Looking back from the bay south of the Cock, the whole thickness of the red sandstone series above described is seen at one view; the lowest beds of it terminate in a very coarse conglomerate alternating

* The above sketch may serve as an introduction to the matter contained in the next section of this paper. For more perfect details respecting the general structure of the Isle of Arran, we must refer to the "Description of the Western Islands of Scotland," by Dr. MacCulloch.

† This and the other Celtic words made use of in the present memoir are written as they are pronounced by the islanders.

with layers of remarkably fine red sandstone. It is unnecessary to describe these beds in very great detail; many of them resemble the harder varieties of the new red sandstone of England, and exhibit a blotched and variegated character. Some of the conglomerates contain an extraordinary number of white quartz pebbles of various sizes, the presence of which can hardly be explained by the degradation of any of the neighbouring rocks; other beds of this conglomerate are, on the contrary, and agreeably to the general analogy of similar rocks in other parts of Scotland, made up of fragments derived from the neighbouring slate series. We did not remark any granite pebbles in the conglomerate,—an important fact, first noticed, we believe, by Dr. MacCulloch. Among the conglomerates were some in which the fragments were so far comminuted as to resemble coarse white sandstone; in other beds the pebbles were held together by a pure white calcareous cement. If the specimens were described at great length, it would be necessary to mention the different colours of the strata, arising from the varieties of the imbedded pebbles and the change of the cementing principle: on the whole, however, a red colour characterized both the conglomerate and sandstone. By reference to the coast section *, it will be seen that this group is superior to the formations about to be described; from which we infer that it must represent the new red sandstone of English geologists.

The preceding group is succeeded by a set of beds of considerable thickness, partaking of the same dip to the N.W. and exhibiting a character intermediate between the new red sandstone and the carboniferous series; the upper portion composed of red and gray variegated blotchy marls, alternating with soft white freestone, singularly meagre and harsh to the touch. Iron-stone nodules are interspersed among these beds, some of which have that false cleavage so characteristic of portions of the new red sandstone. Towards the bottom of this series the white freestone predominates, and gradually passes into sandstone and grits, apparently belonging to the upper part of the coal-measures. This intermediate group of the series is extended for a few hundred yards along the shore, and is terminated by six or eight thin beds of compact red limestone containing organic remains, which are of great importance in determining the true relations of the Arran secondary strata, and have not been noticed in any previous account of the structure of this island. The highest of these beds are of a deep red colour, thin and fissile, resembling an indurated calcareous shale, and contain numerous organic remains standing out in relief.

* Plate III.

The lowest beds are thicker, of a lighter red colour, and pass into a hard and nearly compact limestone, in which are many veins of a gray colour, and numerous impressions of the larger valves of *Producta Scotica ?*

The fossils of these beds which fell under our notice consist of

	Other Localities.
1. Producta lobata. T. 318, Min. Conch. ..	
2. ——— horrida. T. 319	In the magnesian limestone, Sunderland; and also above the coal, Derby.
3. ——— Martini. T. 317	Derbyshire.
4. ——— latissima. T. 330	Anglesea and Devon.
5. ——— spinosa? T. 69	In Scotland only.
6. ——— New species not figured	
1. Spirifer undulatus. T. 562	Magnesian limestone, E. Thickley, Durham.
2. ——— octoplicatus? T. 562	Ditto Ditto
Encrinites, 3 to 4 species	
Corals ?..............................	

Below these fossil beds follows a succession of white sandstones of rather a foliaceous structure, some of which however are amorphous and more compact, with a subordinate bed of red iron-stone in a septarian form; which, from being intersected by a number of cross fissures, resembles a tessellated pavement, and is described by Dr. MacCulloch; other associated beds consist of white honeycombed sandstone, and layers of sandstone blackened with carbonaceous matter. For a very short interval the strata are not clearly discernible on the shore, through the accumulation of shingle and debris; but, immediately to the north of the salt-pans, beds of white sandstone re-appear (identical with those above described), overlying and alternating with blue and black bituminous shales, most of which are highly calcareous, and full of encrinital stems and other organic remains. These latter pass into beds of regular coal shale, two and three feet in thickness, in which are found the characteristic plants, such as the *Phytolithus verrucosus* of Parkinson, reeds, and trunks of arborescent ferns flattened;—in some of these beds coal was formerly worked *. The alternations of shale and sandstone are continued for some distance, being succeeded by calcareo-bituminous shale, charged with Encrinites, and overlying white sandstone. This sandstone forms the cover of a black calcareous rock, perfectly analogous to some of the most common varieties of the mountain limestone of England, which contains throughout its mass many Productæ (*P. Scotica ?*), a spiral univalve resembling Rostellaria, spines of Echinites, Caryophyllia, Encrinites, and rarely an Orthoceras. This black limestone forms

* These works have for several years been closed up. The best published account of them may be seen in the work of Mr. Headrick, p. 212—219.

bands separated from each other by courses of shale called "till" by the natives, with many fine specimens of Productæ.

All the beds described in this coal series, viz. from the red to the black limestone, rise high on the sides of the schist mountains, which occupy the two terraces of Laggan on their inland or south-western flank. The two distant beds of limestone having been traced to a considerable elevation in the sides of the mountain, preserving the same range and dip as upon the shore, there can be no doubt that the intervening carboniferous and sandstone beds are also prolonged up the face of the mountain: we calculated the distance between these two beds of limestone to be from twelve to fourteen hundred paces. The account therefore which has represented this coal-field as a small triangular space inclosed by limestone must be erroneous. The error probably originated in the fact that the coal works here were interrupted by two trap dykes, which in intersecting each other, cut off a very small triangular portion of the coal-field, the only part of it in which the works were prosecuted*.

In a descending order, the next important beds are strong white grits, which, near Millstone Point, are much dislocated, and piled upon each other in large blocks of prismatic form: from thence, turning into Laggan-twine Bay, the strata consist of alternations of white sandstone and shale, the latter being generally of a red colour, and somewhat more indurated than nearer the coal pits. The open bay which follows is filled with small boulders, and on the other side of it is a repetition of the sandstone series with the same dip N.N.W.; but the angle is increased to 45° and 50°. A series of beds of trap next succeeds, which may be generally described as follows:

1. Dark porphyritic trap, with an earthy base, containing crystals of diallage metalloide.
2. Black porphyritic greenstone.
3. Lighter coloured, and more earthy varieties of porphyritic greenstone.
4. Claystone, with veins of green earth.
5. Various amygdaloids abounding in crystals of carbonate of lime, and having some of the cells filled with finely crystallized green earth; others with a dark steatitic substance, and more rarely with zeolite†.

These trap rocks occupy the shore for about a quarter of a mile, during which space they preserve all the appearance of regular beds, having the same range and dip as the superior and inferior strata of the coast section. They are followed by beds of shale so indurated as to put on all the characters of Lydian

* See the work of Mr. Headrick on the Island of Arran, quoted above.

† This description is taken from notes made on the spot. The specimens we collected from this remarkable group for the purpose of more careful examination were unfortunately lost.

stone, when in immediate contact with the trap; and these are again underlaid by thin beds of shale with obscure impressions of plants, and by beds of sandstone. The altered carbonaceous shale frequently breaks into rhomboidal fragments, and has associated with it thin laminæ of a substance resembling anthracite, probably derived from the vegetable remains which accompany these beds. Such changes, however, are not uniform; for other beds, possessing the ordinary soft shaly texture, are to be seen in absolute contact with the trap. The lowest shales rest upon, and alternate with, very hard light-coloured sandstone, which may be considered as terminating the carboniferous group.

Old Red Sandstone.

The line of demarcation between this formation and that just described must be regarded as in some degree arbitrary; since in following the line of coast for several hundred feet, the dip undergoes no change, and the physical character of the beds continues nearly the same, except that vegetable fossils are now absent.

On approaching Groggan Point, the beds are much changed in structure: highly indurated sandstone of a light red tinge alternates with masses of indurated shale of a red, gray, and greenish gray colour. Associated with the above are hard dark-coloured calcareous beds, containing many quartz pebbles, thus passing into a conglomerate form; and subordinate to the above, are many irregular concretions of nearly compact carbonate of lime not to be distinguished from the cornstone of Herefordshire. These characters, and the absence of vegetable fossils, induced us to separate this group from the carboniferous series, and to place it at the head of this section. At Groggan point are seen the first beds of unequivocal old red sandstone gradually passing from a pink-coloured grit into a very coarse conglomerate, which rising high upon the flank of the mountain, increases in the angle of dip, viz. from 45° to 70°, in proportion as it recedes from the shore. Here the schistose mountains approach rather abruptly towards the coast, but they never, as has been sometimes stated, entirely cut off the zone of secondary rocks we are now describing*.

In the adjoining small bay, white sandstone and purple-coloured shale are succeeded by a blood-coloured spotted sandstone, from beneath which a vast hill of conglomerate called Craig a Caajou (cheese crag) rises to a height of from eight to nine hundred feet. Here there is a most remarkable debacle of the conglomerate, enormous masses of which have fallen from the precipitous

* See Headrick on the Isle of Arran, p. 221, &c.

face of the hill, and are confusedly piled upon the steep ascent; and from hence the same beds are continued in a low mural escarpment to North Sannox, where the cliff disappears. This position has great geological interest: 1st, because it is here that we must place the anticlinal axis of the coast section; 2ndly, the primary schist thins out at this point, so that the old red sandstone and conglomerate range for upwards of two miles high in Glen Sannox, and may be traced even to the base of the serrated granitic ridge. Some of the lowest beds of the conglomerate in this region assume the character of very compact grauwacke slate; and these, as well as others of the same age on the shore, are traversed by dykes of very compact greenstone*. At Mid-Sannox the cliff viewed from the sea is a mural escarpment of conglomerate, the lines of stratification of which deviate little from horizontality; but at South Sannox the dip is decidedly reversed, being to the south of east. At the latter place a low cliff of conglomerate and sandstone is broken into by frequent transverse gullies, some of which may have been simply the result of denudation, whilst others may have been fissures produced by the vicinity of the granite; indeed the shore here is encumbered with a vast accumulation of boulders of granite, there being no longer any schistose range of mountains interposed between the granitic nucleus and the coast to impede the transportation of these blocks. At about one-third of a mile north of the village of Corry, the conglomerate beds are surmounted by white and spotted sandstone, and an impure concretionary limestone. As the latter is precisely similar in character to the cornstone described on the other side of the anticlinal axis near Groggan Point, its existence in this situation is important in the verification of the ascending series which we are now describing. This being the final appearance of the old red sandstone on the coast, it may be necessary to add a few words respecting its general composition. On a great scale it is to be viewed as a red conglomerate with many subordinate beds of sandstone, which cannot, either from the nature of the pebbles or the cementing principle, be distinguished from the newer conglomerate; neither can the sandstone of the one series be described as differing from that of the other. The existence, however, in the one deposit of beds of arenaceous grauwacke slate near the bottom, and that of the cornstone in the upper part of the formation, strongly identify it with the old red sandstone. Moreover, independently of any such distinctive characters, the intervention of the well developed groups of the carboniferous series enables us with certainty to separate the two great deposits of conglo-

* In the higher part of the burn at North Sannox, and very near the granitic nucleus, are large masses of sulphate of barytes associated with the conglomerate, with which they appear to have been contemporaneous.

merate from each other, and to arrange them with the analogous members of English geology. In one respect, however, these deposits differ materially from those of the same age in England, since there appear to have been no disturbing forces to interrupt the continuity and conformity of the beds from the base of the older conglomerate, through the carboniferous series, up to the highest beds of the new red conglomerate;—these several formations being not only parallel to, but actually graduating into each other.

Carboniferous Series.

At the north end of the village of Corry we meet with beds of white sandstone and grit, similar in the ascending order to those which have been described in the sections of the descending series as interposed between the old red sandstone and the mountain limestone; but here they occupy a much less breadth, which may easily be accounted for by the thinning out of the shale and coaly beds, and the omission of those large interpolated masses of trap which occur at Groggan Point. At Corry the mountain limestone succeeds, and is extensively quarried for several hundred yards along the hill side, from caverns which are excavated upon the dip, which is S.S.E. 40°. The beds are of strong and nearly compact grayish blue limestone, much veined, about twenty in number, from eight to ten inches thick, and separated by bands of red shale, the whole surmounted by a magnesian limestone of four feet in thickness. Beds of precisely the same magnesian composition are very common in all formations of mountain limestone, and are here simply worthy of remark, because they are found in the same position in other quarries of limestone in Arran.

Among the fossils, specimens of the large *Producta Scotica* are so abundant as entirely to form the lower layer of many of the beds; being arranged very symmetrically in the exact position of the living shale, with their convex valves downwards, and pressed into the red shale. Among the fossils are also *Spirifer striatus*, encrinital stems of large size, *Cardium alæforme*, and the madrepories so common in the mountain limestone.

The limestone is overlaid by a succession of strong beds of freestone, which have been much worked, but are now in disuse, the finest qualities of flagstone having been extracted: a series of specimens might however be derived from these quarries identical with the common grits of the English coal-measures; and the existence here of several coal plants in a position similar to those described at the salt-pans completes the analogy. To the south of Corry commences a series of dislocations marked by corresponding advances of the granite from the central ridge, each of which seems to have produced an upcast in the limestone. The first example of this is seen near a small cascade, where the limestone beds containing the Productæ are partially exposed. Again, nearly one mile further south, a most enormous throw has brought up the same limestone high in the face of the hill, and upwards of half a mile from the shore. The following is a section in ascending order of the beds exposed at this quarry.

	Feet.
1. Or lowest beds, in number eight or nine, of compact bluish limestone ..	5
2. Three thin beds alternating with shale, and charged with *Producta Scotica*	$1\frac{1}{2}$
3. Shale and limestone with fossils........	1
4. Strong bed of limestone, surmounted by several bands of red shale	12
5. Red cellular limestone—magnesian........	2
6. Strong micaceous reddish sandstone,—dip, S.S.E. 45°	10
About..	32

The higher part of this quarry is traversed by a dyke of whinstone.

From this point, in looking to the south, the carboniferous series is seen rising high above the limestone, even to the summit of the round-topped hill called Meal Doun, at least one thousand feet above the tidal level. The lowest part of the series is chiefly composed of white sandstone; and in the escarpment of the hill, coal and shale plants are found. The summit consists of bluish gray and reddish gritty flagstone of the coal-measures (resembling the Pennant grit of Bristol); and these beds dipping rapidly to the S.S.E. are brought down to the shore north of Brodick Wood, where they are extensively worked. On the north-western side, the summit and escarpment of Meal Doun are cut through by a trap dyke about eight yards wide, running nearly north and south. Few beds are visible on the shore along the line of these great faults, the coast being generally covered with very numerous boulders of the granite of Goat Fell, some of which are of enormous size. Nearer to the village of Brodick, the beds on the beach and in a low cliff indicate much disturbance; whilst another great fault carries down the strata to less than half the elevation they had attained in Meal Doun, the dip being changed to S.E. by S. and the angle increased to 70°: the course of these beds is traceable through Brodick Wood by the west side of the castle to the inn. Beyond the village of Brodick the same system of calcareous beds is apparently cut off by a wide denudation, in which is a rich alluvial tract forming the centre of the bay, but they reappear in order on the side of the new road leading to Shiskin, and occupy a conspicuous hill bounding the plain of Brodick on the west, and separating Glen Shiragh from Glen Leug. The old red sandstone reappears in Glen Shiragh below the above beds, dipping conformably, and at the same high angle of 70°:

and here again its lowest beds present the usual character of a fine micaceous compact and slaty sandstone resembling some varieties of grauwacke. The limestone and associated sandstone rise from the plain of Brodick to the summit of an adjoining hill, and in their prolongation to the S.W. pass under the trappean and porphyritic masses of the central and southern regions of the island; whilst towards the coast the same strata are by their range and high inclination carried under the newer conglomerate and red sandstone of Corygills on the south side of Brodick Bay; thus affording, in the short distance of about two miles, another exhibition of all the secondary formations previously described. The continuation of the new red sandstone along the southern shores, with the innumerable interruptions in it occasioned by the intrusion of every possible variety of trap rock, does not belong to the immediate objects of this memoir; but we may remark that this deposit soon loses the character of a coarse conglomerate, and assuming the aspect of the ordinary new red sandstone is associated with extensive beds of variegated marls, which probably belong to a higher part of that formation than any portion of the conglomerate which overlies the coal-measures to the north of the salt-pans*.

§ 3. *Concluding Remarks founded on the preceding details, &c. &c.*

I. It appears from the preceding details, that the principal conclusions we have endeavoured to establish are founded upon the unequivocal order of superposition, and the mineralogical character of the several formations, confirmed by the nature of the organic remains contained in some of the subordinate beds.

The lower conglomerate and sandstone are referred to the old red sandstone, because they are inferior to beds which are supposed to represent the carboniferous order; because they contain beds having the character of grauwacke; and also because they have subordinate beds of concretionary limestone resembling the cornstone of Herefordshire and South Wales.

The central group is referred to the carboniferous order, because it contains beds perfectly like mountain limestone, and having the same suite of fossils, but

* We are unwilling to mix up our conjectures with a statement of facts founded on perfect evidence; and the structure of the western shores of Arran seems almost to preclude the possibility of deciding upon the age of all the deposits in that quarter. The red sandstone north of Drumandoune, with its veins of pitchstone, &c. is very analogous to that of Corygills. From Tormore to Machrie Water, no strata show themselves in the coast; and it is possible that this wide depression may have been occupied by the coal-measures. In this case the highly inclined rocks between Machrie and Eorsa Waters must represent the old red sandstone.

resembling no other secondary limestone of the British series; and because the same beds are surmounted by a carboniferous deposit containing three or four of the most characteristic fossils of the true coal-measures. The mineralogical character, and the greater part of the fossils of the upper red beds of limestone, bring them also under the carboniferous order; and if so, only prove what is known to be true in many other places, that the mountain limestone and coal-measures alternate with each other. It must, however, be allowed that some of the fossils in this set of beds are also found in the magnesian limestone overlying the coal-measures of Durham; they may therefore by some geologists be classed with that formation, in perfect conformity with the order which we have attempted to establish.

Lastly, the upper red sandstone and conglomerate have the character and relations of the new red sandstone, and are therefore classed with that formation. We may add, by way of confirmation to this mass of evidence, that the preceding conclusions are rendered probable by the structure of the nearest main-land of Scotland.

If, however, we assume all this to be true, it must be allowed that there are some points in which these formations differ from their equivalents in many other parts of Great Britain: for the sandstones of the intermediate formation are generally of a more brilliant white colour and less coherent texture than the common gritstones of the coal strata; and the three formations are not only perfectly conformable, but, as above stated, graduate insensibly into each other. If, therefore, the rocks of the Arran section were assumed as the general type of all contemporaneous deposits, there would then be no serious objection to a classification attempted by some continental and British geologists; wherein all the rocks of the orders above described are considered as belonging to one great formation of red sandstone, of which the carboniferous series only forms a subordinate part: for as we extend our generalizations we must necessarily diminish the number of our geological groups. We therefore think that this classification may have its advantages in comparing the contemporaneous deposits of remote regions. It is certainly inapplicable to the English secondary rocks, because the newer red sandstone is there always unconformable to the carboniferous, and consequently finds its true place in the superior order. This demonstrates that the carboniferous order of England was dislocated before the existence of the next superior order: but all dislocations are probably, in a certain sense, local phænomena; and on that account we do not think that a want of conformity is one of the elements which will much assist us in grouping together or in separating contemporaneous deposits in distant parts of the earth.

II. Among these concluding observations we may remark the great symmetry of the coast section on both sides of the anticlinal axis. There is hardly a single characteristic group of the descending which may not also be detected in the ascending series. We were assisted in effecting this by the lower beds of mountain limestone, which cannot be mistaken, and which enabled us to discover, and in imagination to reassemble, the broken fragments of the several formations on the south side of the inferior conglomerates. To this observation there is one remarkable exception. The beds of trap at the south end of Laggan-twine Bay have, we believe, no representatives in any part of the coast section to the south of North Sannox. Does not this, among many other reasons, seem to prove that the trap in question did not originate in the same causes which produced the other beds among which it is interposed?

III. The same beds of mountain limestone enable us to ascertain the number and the extent of the great faults which interrupt the secondary formations. The marks of dislocation are most visible in the parts of our section where the secondary rocks are spread out at the base of the central mountains of granite; and the greatest transverse fractures are seen where some bulging protuberance of granite encroaches on the bearing of the stratified deposits. We believe that no system of subsidences could account for these phænomena, which appear to us inexplicable on any hypothesis which rejects the mechanical elevation of the granitic nucleus. This conclusion is in accordance with what we stated in our introductory remarks on the relations of the slate and granite at Tornigneon near Loch Ranza.

IV. The preceding conclusion derives a most striking confirmation from the fact, that many of the masses of secondary conglomerate which appear close to the base of the great precipices of granite, do not contain a single pebble of that rock. This fact, which has been frequently remarked before, seems to prove to demonstration, that when the conglomerates were formed, the granite could not have existed, at least at its present elevation*.

V. If the preceding observations prove that the great dislocations of the secondary strata were produced by the elevation of the granite, it follows that

* We do not mean to assert that granite pebbles are found in no part of the conglomerates mentioned in the text; the establishment of such a negative proposition would require more observations than are, perhaps, possible: we only assert a general fact, which is sufficient to bear out the conclusion we have drawn from it. During last summer we observed a great many masses of conglomerate, and always found them made up of pebbles derived from the nearest primary mountains. The old conglomerates in the southern parts of Caithness rest, in some instances, on the flanks of granite mountains, and contain so many fragments of the central rock, that it is difficult to determine where the granite ends and the conglomerates begin. Similar facts have been observed at two or three localities near Inverness.

the upheaving forces must have been in action some time after the deposition and consolidation of the new red sandstone. It also follows that the granite could not have been in a fluid state at the time of its elevation; for had that been the case, it could never have risen into lofty mountains and mural precipices, overhanging the secondary strata, without ever flowing over their broken edges, or penetrating their mass in the form of dykes. The phænomena at Tornigneon, before alluded to, may seem opposed to this conclusion. But we must remember that at the time of the elevation of the granitic nucleus, all parts of it were not necessarily at the same temperature. It is also probable that the first dislocations of the primary slate were not contemporaneous with the last elevation of the granite, by which the secondary rocks were broken in the manner above described, and upheaved into the positions they now occupy.

VI. If it appear from the preceding statements that the granite, in its present form, is posterior to the new red sandstone, we may also remark, that the trap of the southern division of the island is also posterior to that formation. For the trap not only traverses the sandstone in places without number, but has flowed over it, and formed mountain masses of overlying rock. It must, therefore, have been in a much more fluid state than the granite at the time of its eruption: and this is probably the chief reason why the stratified rocks are so incomparably less dislocated in the southern region of the island than they are in the northern.

VII. Respecting the exact age of the trap, we have no secure grounds of conjecture: in this respect, the only thing we can certainly determine is the limit of its antiquity. There may have been several periods of eruption: for the greatest part of the trap of the Hebrides is newer than the oolitic series, and in the north of Ireland it is newer than the chalk.

The *data* for determining the epoch of the last elevation of the granite of Arran are perhaps still more imperfect. As, however, all the elevated formations in the northern division of the island are occasionally traversed by trap dykes, we have a proof that those internal movements which produced the great eruptions of trap must have had their origin below the foundations of the granitic mountains. If these eruptive forces were not able to break through the thick covering of granite and primary schist, they may have acted on them in the mass, have partially penetrated them, and been the very agents by which they were lifted up to their present elevation*.

* The hypothesis advanced in the text is in accordance with what we observed in many of the primitive districts of Scotland. On reaching the centre of elevation we did not always find granite, but often found gneiss penetrated by granite veins. The analogy, presented by actual junctions

TABLE OF FOSSIL SHELLS.

Upper Limestone. Salt-pans.	*Other Localities.*
Producta lobata. T. 318. Min. Conch.	Honeypen Hill, Clifton.
——— scabricula. T. 59	Ditto Ditto.
——— horrida. T. 319	Magnesian limestone, Sunderland; and above the coal, Derbyshire.
——— Martini. T. 317	Derbyshire.
——— latissima. T. 330	Anglesea and Devonshire.
——— spinosa? T. 69................	
——— ——— New species	
Spirifer undulatus. T. 562................	Magnesian limestone. E. Thickley.
——— octoplicatus? T. 562	
Columns and auxiliary side arms of one of the Crinoidea (Poteriocrinites crassus?) Miller's Crinoidea, p. 68	Bristol beds near the river Avon. 1. and 9. (See Geol. Trans. Old Series, vol. iv. pp. 197 & 199.)
Flustra crinoidea (Miller MSS.)	Ditto, rarely in bed 1.
Retepora flabelliformis (Ditto)	Ditto, not uncommon in bed 1.
Favosites? ramosa (Ditto)	Ditto, common in bed 1.
Lower Black Limestone. Salt-pans below coal.	
Spiral Univalve resembling Rostellaria	
Producta Scotica	Figured by Sowerby from Closeburn, Dumfries, Tab. 561, as *P. hemisphærica.* The two are now identified as one species, which is peculiar to Scotland, and very abundant.
Bivalve resembling Venus?	
Caryophyllia?	
Echinites	
Lower Corry Red Limestone.	
Cardium alæforme T. 552. fig. 2	Queen's County Ireland, Isle of Man, Torquay, &c.
Producta Scotica (large variety)	Bristol: bed No. 1. in abundance.
Spirifer striatus? T. 270	
Madreporites............................	
Crinoidal stems of large size (Poteriocrinites crassus?)	Ditto. Ditto. Ditto*.

of gneiss and granite, led us to suppose, that in such cases the granite lay concealed below the veined gneiss; that it had, while in a fluid state, acted upon the gneiss, penetrated it in the form of veins, and raised up its mass in such a way as to produce all the phænomena of elevation. The sutors of Cromarty are good examples of what is here stated. Many other examples may, if we mistake not, be derived from the works of Dr. MacCulloch.

* The Crinoidal remains mentioned in this table were obligingly examined by Mr. Miller, who found them to be identical with those occurring in the limestone of the Avon beds 1. and 9.—Geol. Trans. Old Series, vol. iv. pp. 197 & 199.—See also Geol. Trans. New Series, vol. i. Part 2. p. 240.

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.*

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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 continues 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

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 Scarecroft 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 Coniscliff 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 ou 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 $1\frac{1}{4}$ 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 $\frac{1}{4}$ 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 †.

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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.

IV.—*On the Structure and Relations of the Deposits contained between the Primary Rocks and the Oolitic Series in the North of Scotland.*

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[Read May 16th, and June 6th, 1828.]

§ 1. *Introduction.*

ALTHOUGH no good geological map of Scotland has yet been published, enough is known of its general structure to enable us to state, that nearly all the interior portions of the Highlands are composed of primary rocks generally exhibiting a slaty texture; and that, on the north-eastern and north-western coasts, as well as on the southern flank of the Grampian chain, these primary rocks are succeeded by enormous masses of red sandstone and conglomerate, which, in several places (already described by one of the authors of this paper), are surmounted by a system of beds referrible to the lias and oolitic series of England. Our object in this communication is to describe the lower portion of these secondary deposits, viz. the masses of red sandstone and conglomerate;—to consider the natural groups into which they may be separated,—and, as far as possible, to bring them (as we have already done in describing the carboniferous series of the Isle of Arran) into comparison with formations of the same age in the southern parts of our island. The accompanying outline map*, partly constructed from our own observations, and partly derived from the works of M^cCulloch, M. Boué, and other writers on the geology of Scotland, will convey a general notion of the geographical distribution of the masses we are about to describe. A glance of the eye over the map might induce us to suspect that they all belonged to one epoch, and even a slight examination of them would confirm the conclusion; for the conglomerates on the south-east flank of the Grampians are perfectly identical with those at the base of the secondary deposits of the Murray Firth and Caithness: and these, as will be hereafter shown, are strictly analogous to the conglome-

* See Plate XIII.

rate and red sandstone system on the western coasts of Ross-shire and Sutherland. On this subject we are not aware that there is any difference of opinion among those who have studied the general structure of Scotland. It forms no part of our object to describe the secondary deposits on the south-eastern flank of the Grampian chain: and the history of the red sandstone and conglomerate series of the N.W. coasts has been written by Dr. M^cCulloch with so many excellent details, that little more will be necessary for us than to refer to his narrative; adding, however, such observations as may seem to connect it with the statements which we are about to offer.

The greater part of the subsequent details will therefore be devoted to a description of the secondary formations which appear on the shores of the Murray Firth, and occupy nearly the whole of Caithness. We commence with an account of the range of the old red conglomerates which rest immediately on the primary rocks, and stretch in one nearly continuous mass through these extensive tracts of country; for their range when once ascertained, not only gives us a base line to which all transverse sections may be afterwards referred, but at the same time gives us a good approximation to the superficial extent of the deposits which are included between this base line and the coast.

We wish it were in our power at once to exhibit in a connected point of view the several deposits of Caithness and the Murray Firth, which are built upon the base of these old conglomerates. This task, however, we are not able to accomplish; and we are compelled to arrive at the conclusions we wish to establish through the intervention of many distinct natural sections. We, therefore, in the next place proceed to examine the sections on the coasts of Caithness*, and by their help we show that the secondary formations of the county are divided into three great natural groups; viz. the old red conglomerates and sandstone; the group of bituminous schist and siliceous flagstone; and the upper red sandstone. We then describe in considerable detail two transverse sections through the deposits which are based upon the old red conglomerates on the north-western and south-eastern shores of the Murray Firth; and, by a comparison of the several sections, have endeavoured to identify the upper portion of these secondary deposits with those of Caithness. Lastly, we consider the analogies presented by the red sandstone series on the north-west coasts of Ross-shire and Sutherland. This manner of treating the subject necessarily leads us into some repetitions, and into details which may be tedious, but are, we think, unavoidable. It has, however, the great advantage of separating matters of fact from all hypothesis, and of exhibiting the phænomena nearly in the order in which they must present themselves to any

* See Plate XIV.

one who may hereafter examine the country. These introductory remarks are, we hope, sufficient to explain the objects we have in view, and the manner in which we purpose to introduce them in the following communication.

§ 2. *Range of the Old Red Conglomerates through Caithness, and on the Shores of the Murray Firth, &c. &c.*

After doubling Cape Wrath from the west, and proceeding nearly three miles along the northern coasts of Scotland, we first meet with the old red conglomerates in Kerwick bay. They are distinctly stratified, and dip towards the north at an angle which is inconsiderable when compared with the high inclination of the primary rocks on which they rest. They stretch along the coast towards Loch Durness, forming a succession of lofty precipices, which, here and there, are worn down into grotesque forms and detached pinnacles by the encroachments of the sea. Towards the interior they are also considerably extended, rising into an elevated ridge called Scrisish Ben, from which they descend to the south-west, and pass under the deep morasses of the district. From Loch Durness to the Kyle of Tongue we found no secondary rocks upon the coast; but immediately to the north-east of Lord Reay's house rises a remarkable, pyramidal hill called Craig-na-Vreckan to the height of about twelve hundred feet, which is entirely composed of the old conglomerate dipping off the coast at a low angle, and, like the deposit last described, resting unconformably upon the micaceous slate rocks of the district. On one side, these conglomerates descend into the cliff; on the other, they are prolonged into the heart of the country, and form several distinct, round-topped hills on the east side of a chain connected with Ben Loyal. Again, on the hills which stretch along the coast from Tongue to Strathy-head, we find no traces of undisturbed secondary rock: but, on approaching Strathy-water, there are a few loose blocks of conglomerate scattered on the surface; and thence to Glen Halladale boulders of the same kind are found in great abundance.

It will appear from the subsequent descriptions of the formations of Caithness, that beds of sandstone and bituminous fetid limestone are first seen on the coast to the east of Strathy-water, and that the old conglomerate, forming the base of the whole system, is also seen in the cliff of Port Skerry. Combining this fact with the appearance of the boulders before mentioned, there can be no doubt that the old conglomerate is continued into the interior. We did not trace the whole of this zone, and therefore cannot assert its unbroken continuity; but we believe that a region of low conical hills forming an irregular south-eastern boundary to the morasses of Caithness, is chiefly composed of the same deposit. Further towards the south-east the conglomerate hills gradually rise into a finely serrated mountain chain called the Maiden Paps, the highest point of which, Mor Bheim, reaches the elevation of 3500 feet above the level of the sea, and overlooks all the primary rocks of the district. This enormous deposit extending still further to the south-east, clasps nearly round the primary quartz rock of the Scarabins, and being prolonged (though not perhaps without some interruptions) between that chain and the granite of the Ord, terminates in the cliff between Ousdale and Berridale *.

From the north side of the Ord of Caithness to the immediate neighbourhood of Clyne, the old conglomerates retire from the coast, which is occupied by a chain of granitic mountains. This chain declines in elevation, and gradually sinks below the level of the other rocks near Loch Brora. To the west of this chain, lofty hills of the conglomerates are prolonged from the region of the Maiden Paps; and, above Clyne Kirk, pass over the tops of the granitic hills, overlooking in that position (as has been stated in a former paper) the Brora coal-field, though, geologically, much inferior to it †. To the south of Loch Brora they regain what may be considered their natural position, and form a fine picturesque chain, broken into several distinct, truncated, and somewhat pyramidal masses, which range at no great distance from the coast, following the sinuosities of the Firth of Dornoch.

Near Creech they pass to the south side of the Firth, and the whole system becomes much more expanded, forming two interrupted ridges of broken conglomerate mountains, bearing nearly parallel to the general range of the Cromarty Firth, and, when seen from a distance, appearing to be embossed upon the sides of the more lofty elevations which are connected with Ben Wyvis. Without, however, anticipating the description of those subdivisions into which these secondary deposits may be separated, we may state generally, that the oldest portion of them appears on the south of the Kyle of Dornoch, between Ardmore and Kincardine;—that it rises on the sides of the neighbouring hills of gneiss;—that it is seen in the upper part of the Alness abutting against the gneiss;—that it is found in the same position in the Alt Grant, about a mile below Loch Glass;—that it forms a well-defined ridge on the flank of Ben Wyvis;—that it descends into the lower part of Strath Connon, and abuts against the gneiss of Tor-Achilty to the east of Coul;—that it is seen to rest unconformably upon the primary slate above Fairburn;—that pre-

* The Scarabins, formed by four principal elevations ranging nearly east and west, are entirely composed of beautifully white compact quartz rock. Their summits and southern flanks are so bare of vegetation, that when seen from a distance they look like mountains capped with snow.

† See Geol. Trans. Second Series, vol. ii. Part III. p. 356.

serving the same relations it ranges into the denudation of the Beauley river, —and that it follows the sinuosities of the valley, and ascends towards the west several miles beyond the boundary line, which is indicated by its position on the neighbouring hills.

On the south shore of Loch Beauly the conglomerates are contracted into a narrow zone, and for a short space are entirely cut off. They then resume their range, and occupy the whole extremity of the projecting ridge which comes down to the coast near Inverness, between the Beauly Loch and the valley of the great canal; appearing in their most characteristic form, like great independent protuberances embossed upon the sides of the mountains. From Inverness they ascend far up the ancient transverse valley of the Highlands. Near the north-eastern extremity of Loch Ness they are interrupted by projecting masses of granite and of gneiss, beyond which they again set on; and to the west of Glen Urquhart they compose a mountain range, and reach the summit of Meal-Fourvonie, from which they gradually descend to a lower elevation, and are continued to the neighbourhood of Fort Augustus. Their range and general appearance on the south-east side of Loch Ness have been too often described to require any additional notice: we may however remark (on the authority of Mr. Anderson of Inverness), that although interrupted by a hill of gneiss on the west side of Foyers, they afterwards range by the side of the loch at a lower level; and that they have also been traced along the shores of Loch Oich. All the northern portions of the counties of Nairn, Elgin, and Banff, present a dull outline, and are of comparatively low elevation; but in these districts the old conglomerates are occasionally laid bare, and are represented, though in an obscure and degraded form, by the lower beds on the Findhorn and on the Spey,—by the conglomerates on the hills to the south of Forhabres,—and by the detached rocks in the bay of Cullen. At the promontory of Cullen the whole system is cut off by the line of coast; but, at Troup Head, a conglomerate rock reappears, agreeing in its general character with the masses which we have been attempting to describe*.

The preceding sketch may serve to convey a general notion of the range of the old conglomerate through Caithness and along the Murray Firth, and of its relations to the more ancient rocks of the neighbouring districts.

General Structure of Caithness.

The external form of the county approaches to that of a triangle, the two sides of which are washed by the North Sea and the Pentland Firth. The

* See Geol. Trans. Second Series, vol. ii. Part III. p. 363.

base of the figure may be represented by the old conglomerates, which range, as before stated, from Port Skerry to the Ord; and its vertex must be placed on the shores of the Pentland Firth, among the masses of red sandstone which compose the newest strata of the whole district*. The beds which form the subsoil of the intermediate plains and morasses of the county, pass on their north-eastern limits under the red sandstone of the Firth; while, to the south-west, they rise up to, and distinctly repose upon, the old conglomerates. From this arrangement, it follows that the sections laid bare on the northern and on the eastern coast, must exhibit the same order of superposition. The map* will, however, show that the eastern side of the imaginary triangle is longer than the other; a fact which is partly explained by the direction of the two sections—partly by the greater expansion of the conglomerates in the neighbourhood of the Ord—and perhaps still more, by some great dislocations which have modified the arrangement of the intermediate system of beds on a part of the eastern coast.

We proceed to describe the several formations in the order in which we examined them. 1st. In an ascending series from the lowest conglomerate of Strathy Bay up to the newer sandstone of Dunnet Head. 2nd. From the headlands of sandstone on the Pentland Firth in a descending series, down to the conglomerates which rest against the granite of the Ord.

Coast Section of Caithness.

1st. *Ascending Series from Strathy-water to the Upper Red Sandstone of the Pentland Firth.*

The secondary strata of Caithness are divided on the north-west from the primary rocks of Sutherland by a small river called Strathy-water, which thus forms their western limit.

The lowest beds of the conglomerate are finely exhibited at the small fishing-cove of Port Skerry, where they rest upon ledges of a compact red granite. This conglomerate is almost entirely composed of fragments of granite and quartz, united by a red-coloured argillaceous cement; and, at the points of junction with the granite, it is difficult to decide with precision where the unstratified crystalline rock terminates, and the depository beds commence. Some varieties of this conglomerate contain much green earth. The superior beds are here exposed in a low cliff of about thirty feet in height, and gradually pass into a coarse-grained sandstone, which, in some of its lowest members, exhibits an occasional pebble of granite. These again graduate upwards into

* See Plate XIII.

a brownish grey, thin-bedded sandstone, which appears on the whole to conform to the dip of the conglomerate. Two masses of granite interrupt the regular range of the sandstone strata, which are in consequence tilted in opposite directions from these granitic nuclei.

The upper beds of the same sandstone rise high in the hills between Strathy Kirk and Bighouse Bay; and although these hills are much obscured by vast masses of alluvium, a good section is seen on the side of the high road near the summit of the hill, where the sandstone, being very fine-grained, is extensively quarried. Here also are observed thin, flaggy, calcareous beds, sometimes separated from each other by black laminæ, apparently of carbonaceous matter, and overlaid by a compact, lamellar limestone, which is burnt for use, and forms a most powerful cement. The dip of these beds is N.N.E. and their inclination varies from horizontal to an angle of 7° or 8°.

After a short interruption, the cliff recommences on the eastern side of Bighouse Bay, and rises to a considerable height. Its lowest beds are analogous to the highest part of the Port Skerry section; and over them is a succession of thick deposits nearly in the following ascending order.

Dip E.N.E. 25°.

1. Bluish, calciferous, gritty, thick beds, with reddish exterior.
2. Greenish, flaggy sandstone, alternating with calcareous beds.
3. Brown sandstone of great thickness, fifty to sixty feet, but very finely laminated.
4. Shaly beds, with some calcareous matter.
5. Whitish sandstone.
6. Lamellar, smoke-grey limestone, same as described on the hill above Strathy Kirk; and here also burnt for use.
7. Thin-bedded, flaggy sandstone.
8. Summit—alluvial detritus of considerable thickness.

The only organic remains we discovered in this series, were the scales of fish, irregularly distributed between the laminæ of some of the more calcareous and slaty beds.

In proceeding eastwards from Bighouse to Sandside, the cliffs, increasing in altitude, become more fissile and slaty towards their summits; and, for the first time, are perceived those deep and long transverse ravines so peculiar to the coast of Caithness, perhaps originally produced by disturbing forces which cracked and split up the fissile beds, and which, in many instances, have been subsequently modified by the encroachments of the sea. Many of these clefts look like great empty metalliferous veins, and afford excellent detailed sections of the strata*: in one of them we observed the order to be as follows, beginning with the lowest bed.

	Feet.
1. Thin-bedded calcareous shale and impure limestone, with four strong bands of calcareous sandstone	40
2. Brownish grey sandstone	20
3. Coarse, calcareous sandstone	7
4. Thicker sandstone	15
5. Transported and broken materials	14

The effect of abrasion in these cliffs is shown in numerous detached pinnacles and turrets standing out in the sea, some of which are still connected with the main land by ridges of the sandstone and calcareous shale. Imme-

* See Plate XIV. fig. 1.

diately to the east of the deepest of these indentations, there is a projecting portion of the cliff, which, when seen from a distance, appears of a deep red colour. A mass of granite, in rude prismatic forms, here intrudes upon the stratified rocks, and occupies the coast for three or four hundred feet. On the western side of this junction the beds are in the utmost confusion, the limestone being not only highly inclined, but also crystalline and cellular. Close to the point of contact these same beds assume a brecciated structure, and even contain many fragments of the granite itself*.

The contiguous portions of the cliff are chiefly composed of this breccia, through which the red granite protrudes with much irregularity. Some masses of the conglomerate rest upon the tilted edges of the limestone, whilst others are of a wedge shape, and appear as if they had been mechanically driven in among the shattered edges of the higher beds of limestone and sandstone. The cement of the conglomerate is generally granitic; it is, however, in some parts calcareous, and in other places it approaches to the character of sandstone:—one great block of sandstone, with the usual undulating surface, seemed to be entangled in the granite. At the eastern extremity of this disturbed portion of the cliff there is no conglomerate, and the stratified beds cannot be traced into immediate contact with the intruding granite; neither do their dip and direction appear to have been much disturbed*.

This mass of well-characterized granite may be considered as the extreme spur of a ridge of that rock, which, in retiring from the coast, is first seen in rounded knolls on the north of Sandside House, whence it ranges to the south-east, and rises into a low chain called the Dornery Hills, which are peninsulated amidst the plains of calcareous schist and sandstone of Caithness. The peculiar effects described as having been produced by its contact with the secondary strata on the coast, cannot be observed in the interior, owing to the thick covering of alluvial matter and morass which are so extensively spread over the surface of these vast plains†.

The cliffs of sandstone and schist subside to the east of Sandside Bay; and the strata, for a considerable distance, are only seen in ledges on a shelving shore, and occasionally much concealed by blown sand; but they again rise gradually into a low projecting headland called Broomness (Brimness). The same lamellar limestone mentioned, as occurring at Strathy Bighouse, &c. is quarried here and there on the coast: whilst, in the interior, calcareous schists occupy the

* See Plate XIV. fig. 1.

† It appeared to us on the spot, that the disturbed and brecciated masses described in the text could not be brought into comparison with the old conglomerates of Port Skerry. They seemed rather to resemble in their origin the breccia on the south side of the Ord (see Geol. Trans. Second Series, vol. ii. Part II. p. 306.), and to have been formed by the mechanical action of the granite, which must, in that case, have been protruded in this place, after the deposition of the part of the secondary system above described.

district between Reay Kirk and Forse ; and good roofing slate is quarried at a short distance south of the latter place. The summit of Howburn-head, a promontory N.N.W. of the town of Thurso, consists of very fissile and nearly horizontal beds of sandstone flag and schist, with a slight dip to the north ; and, in the more calcareous and slaty portions, are remains of fish, and abundance of black, brilliant, quadrangular scales. Much pyrites occurs in this part of the formation, especially in small concretions upon the surface of the flag beds, so that upon exposure in the dykes they acquire from decomposition a ferruginous and yellow tinge, although of a blue colour when freshly quarried*. In descending from Howburn-head to the town of Thurso, lower beds of white and greenish white sandstone are quarried ; and between the laminæ of these, small portions of black bitumen are sometimes interposed, and frequently associated with calcareous spar. East of Thurso, the shore is composed of a number of low reefs of the calcareous flag-beds, which, at Howburn-head, have been mentioned as occupying the summit of a cliff of considerable elevation : the dip is still north 10°. Advancing towards Murkle Bay, the top of the cliff is composed of fine, calcareous grit alternating with calcareous shale. In the lower part, is a green sandy micaceous slate-clay, covered with pyritous markings at the separation of the beds, and the dip follows the flexures of the headlands changing to N.N.E. and E.N.E. These changes are not effected without several breaks, which run nearly transverse to the bearing of the strata. Under all the preceding are blue, calcareous flag-beds, containing fish-scales, &c. They are, at first, of an intermediate mineralogical character ; but, following them in the ascending order, they gradually conform to a new type, and, from their mode of weathering and false bedding, as well as from the blotches and red streaks with which many of them are coloured, they may be compared with some of the harder and lower divisions of the new red sandstone. In our attempts at classification, we depend very little upon these characters, which apply with equal precision to many varieties of the old red sandstone series.

Still further to the east is a small bay, where the strata are in great confusion ; but, on the whole, they dip towards the north. Beyond this, the calcareous grit and green pyritiferous shales occur as before, and are succeeded by the calcareous, blue flagstone, with impressions of fish. There is again a great break in the strata, and several indications of a concretionary structure. The dip varies to the E. of N. ; and, at the slate quarry of Castle Hill, it is N.E. by N. ; so that the whole system of these flag beds is evidently carried under the red sandstone of Dunnet-head, the most northern promontory of Scotland †. The lowest beds of that great headland are seen beyond the eastern shore of Dunnet Bay, in which the intervening strata are buried under blown sand. The upper beds of this headland, which rises to the height of about six hundred feet, are also composed of red sandstone, with a slight inclination to the north ; and their general character has been described in a previous memoir in the Geological Transactions by one of the authors of this paper ‡.

At the point of junction between the calcareous flagstone and the red sandstone on the eastern

* This change of colour is very characteristic of the fissile beds throughout large districts, and seems in all cases to be due to the decomposition of the small nodules of pyrites which coat over the calcareous flagstones when they are first raised in the quarries.

† This very valuable slate quarry is described in a former memoir: Geol. Trans. Second Series, vol. ii. Part II. p. 314.

‡ Although it is not proposed on this occasion to enter into any geological description of the Orkney Islands, yet it may be stated that those magnificent headlands which lie upon the northern side of the Pentland Firth are composed of the same red sandstone as that of Dunnet Head ; whilst, in many of their lower bays, the Caithness schists and flagstones reappear from beneath the sandstone. For the memoir referred to above, see Geol. Trans. Second Series, Part II. p. 314.

flank of the headland there is much confusion; the thin beds of the former being contorted and brought up by a fault against the edges of the latter. On the southern shore of the Pentland Firth, between Dunnet and Duncansby Heads, the various projections consist either of the upper red sandstone, or of the beds which pass into it; whilst the indentations of the coast expose the flagstone beneath them. It is, however, essential to our purpose to describe in some detail a part of the coast east of Barrogill Castle, where the strata of an intermediate character between the flagstones and the newer sandstone are more particularly developed; since a great portion of these beds, as has before been stated, are obscured by blown sand in the section of Dunnet Bay.

Near Barrogill Castle, the lowest beds visible are calcareous and micaceous schists of a bluish colour; and in one place they enclose a bed of brown schist so highly bituminous, as to be occasionally used for fuel (dip E.N.E. 20°). The ascending series from these flag beds consists of bluish and greyish siliceous schists, sometimes slightly calcareous, alternating with shivery, thin folia of sandy shale. These are, in their turn, surmounted by tabular, calcareous sandstones associated with highly pyritiferous beds, much indurated, and of a fissile structure; and, continuing in the same order, the beds thicken, acquire a honeycombed aspect, and have a bright yellow exterior, alternating with green-coloured shale. Some of the siliceous beds take a lozenge-shaped concretional form, splitting into regular septaria, and are of exceeding hardness. The beds just described occupy a shelving shore; but they afterwards rise into a cliff towards the east, of thirty or forty feet in height, which is cut into by straight-lined fissures, forming caverns and creeks. Here the flagstones are partially covered with blotches of thick black bitumen, soft to the touch, and as adhesive as tar*. Some of the lamellar beds are so highly calcareous as to be burnt for lime; and with these are associated innumerable scales and other portions of fish.

The above system of beds runs out to form the base of St. John's Head, and their total thickness cannot be estimated at less than from three to four hundred feet. To the S.E. of that promontory, the coast is indented in the form of a small round bay called Scotland's Haven, on the west of which the beds above described, dipping to the east, pass under the upper red sandstone, which shows itself on the opposite side of the bay under its most decided characters. Towards Cannisby, the red sandstone becomes nearly horizontal, and is spread over a mile of low shore, the cliffs being entirely occupied by vast masses of modern detritus. Previously to reaching Cannisby, a fault suddenly brings up the flag series against the newer sandstone, which again rises to form the cliff at Cannisby; from whence to John-o-Groats the shore is low, and is only occasionally occupied by reefs of the upper sandstone, the beds of which at the latter place are fine-grained, and in some places nearly compact. A slight north-easterly dip continues to that elevation of the coast called Duncansby Head, where there is a great disturbance in the strata, the upper red sandstone being suddenly thrown up at 70°, dipping W.N.W. By this fault the lower beds of flagstone are brought to the summit of the cliff, which is fissured in many directions by deep, straight, perpendicular gullies. Some of these cut off from the headland great masses of the horizontal strata, which in the progress of degradation look like ruined buildings; whilst others cleave their way through a cliff more than 250 feet in height, and range towards the interior of the country. These phænomena are of no ordinary grandeur, and they derive a local interest from being connected with the extreme north-eastern promontory of Scotland.

* In the slaty schists of Seefeld in the Tyrol, there is such an abundance of a similar bitumen, that it is largely extracted for medicinal purposes: a notice of this deposit, and the fossil fish contained in it, has been given by one of the authors of this memoir. See Phil. Mag. July, 1829.

A short distance to the south of Duncansby Head, and immediately opposite the detached pinnacles called the Stacks of Duncansby, the red sandstone reappears, and is continued for about a mile, when it is cut off by a fault which again brings up the lower flagstone group. From thence to the granite of the Ord of Caithness, the newer sandstone (with the exception of a small patch on the north side of Freswick Bay) is not again seen on the coast; and the beds, as was before stated, are exhibited in the descending order.

2nd. *Descending Series exhibited in the Coast Section from the Upper Sandstone to the Granite of the Ord.*

A little to the south of the last-mentioned fault, the cliffs exhibit one of the most curious of the indentations abounding on this coast. The sea washes far into a deep straight-cut reservoir, of about 250 or 300 yards in length, nearly 300 feet in depth, and from 40 to 50 feet in width. Three entrances lead from the sea to this dark creek, two of which are open clefts, and the third is a tunnel of about 20 feet in width, and 40 feet in height; having therefore above 200 feet of solid rock for its roof. These cliffs lower gradually to the sandy beach of Freswick; and, after a short reappearance south of that place, where they are chiefly composed of brown, grey, and greenish thin-bedded sandstone alternating with pyritous shale, they again disappear in the large sandy bay of Keiss.

In the interior of the tracts of country bordering upon the coasts we have been describing, the strata are obscured by vast expanses of moor and moss; the only portion of sound ground in many places being close to the cliff, which is frequently capped by a belt of verdant turf, which thus affords the only line of road to the traveller.

At the old castles of Sinclair and Gornigo, there is a good section of the stony, dark bluish, calcareous flagstones which are continuous along the coast, from thence to the cliffs on the south side of Wick. At these places they differ from the fissile calcareous beds of the north coast, chiefly in being less interrupted by alternating masses of grey sandstone, and in being stronger and more thick-bedded, on which account they are much used in building*. Some of them are micaceous, and they are all highly calcareous. The purer and thicker beds contain a few contemporaneous veins of carbonate of lime, and approach the mineralogical character of some dark beds of transi-

* The old castles mentioned in the text, the pier at Wick, and a considerable part of the town, are built of this stone. In the other parts of the coasts, the best building-stone is derived from the strong, alternating beds of grey and brownish sandstone. The finer beds of the dark calcareous flagstone, are commonly used as roofing-slate.

tion limestone, which alternate with grauwacke slate in the north of England. The resemblance must not, however, be pushed too far; as even the purer and stronger beds, on a cross fracture, give indications of the ordinary texture and foliated structure of the common Caithness schist. The general dip of this part of the system is about N.E.; not, however, without many interruptions. In the cliffs to the south of Wick Bay it is N.N.E.; and the flagstone is surmounted by a soft, greenish grey, micaceous shale and sandstone.

About four miles to the south of Wick, the line of bearing of the schistose beds is altered; and from a point near Ulbster, where they begin to dip westerly or inland, a great change is observed in the physical characters of the country. To the north and west of this point, all the interior parts of the country are composed of one vast, moory, undulating plain, of which the geological structure can be detected only by the occasional outcrop from below the mosses of a few calcareous fissile beds—whilst the southern portion of the country which remains to be elucidated, is hilly, stony, and considerably diversified. In the former region scarcely a rivulet is to be seen, nearly all the superfluous water stagnating in low mosses; in the latter, the valleys and depressions are occupied by numerous streams.

An elevated portion of this district rises from a low and knotty promontory on the coast called Clyth-Ness, and forms a number of terraces in the parish of Bruen, which present their escarpment to the east. In the lowest of these terraces, the beds dip westerly or inland, at angles varying from 25° to 30°, whilst, in those nearer the summits, the inclination is only 8° to 10°; and, as the highest beds are not less than 400 or 500 feet above the sea, the total depth of this part of the series would be enormous, were we not to refer some of these terraces to a succession of hitches or breaks in the strata;—and yet in such a case, their perfect parallelism is almost inexplicable. Near the base of these terraces, the blue calcareous flagstone is burnt for lime, and is overlaid by a series of sandstone beds of considerable thickness, of a very compact structure, much resembling the grauwacke of many parts of England, being highly compact, siliceous, and micaceous, with colours varying from blue to dark dingy red*. These hills subside towards Clyth; and the strata of which they are composed are seen upon the coast. Slate and lime-

* In many parts of the coast to the south of Ulbster, the Caithness flagstone, not merely in hand specimens, but in large sections, puts on the external characters of grauwacke, and, in its structure and mode of weathering, may be compared with the highest portion of the schistose rocks of Westmoreland. These characters, however, often fail; and on the north coast of the county are hardly ever met with, as the beds from Port Skerry to Dunnet Head have a much newer appearance.

stone are extensively quarried at various places in this hilly tract; and one of the finest specimens of the characteristic fossil fish was found in a thick calcareous flag bed N.W. of Lybster.

Ben-na-Cheilt is the highest point of this region, and is seen from all parts of the northern and western plains. The strata are arranged in a fan-shaped form around this hill; so that the same beds which at Nottinghan and Latheron Kirk, near the coast, dip westerly, at Braelungie, five miles inland, have veered round and dip to N.E.; and still further in the interior, at Ach-na-Vainish inn, the dip is brought round to E.S.E. With this great change in their lines of bearing, the beds, from being nearly horizontal on the coast near Latheron, increase in their angle of inclination so much, that at Ach-na-Vainish they dip from 30° to 40°. This lower part of the slaty series differs from the upper chiefly, in being more thick-bedded and siliceous. At Latheron Wheel on the coast, the beds are nearly horizontal; but they rise between that place and Dunbeath into micaceous sandstones, alternating with blue calcareous flagstones: and, as the latter are here abundantly charged with fossil fish of the very same species which are found in the highest part of the system, it is evident that the whole schistose series of which the greatest part of Caithness is composed, must be referred to one great and protracted epoch.

At Dunbeath, the beds consist of bluish and grey, close-grained sandstone, having a tendency to exfoliate parallel to the laminæ of deposit, which are highly micaceous. These alternate with certain greenish and bluish coloured flagstones, and are prolonged high into the hills until they distinctly repose upon, and graduate into, the old red conglomerate of Braemore, which is connected with the chain of the Maiden Paps. On the coast, the same slaty beds extend considerably to the south of Berridale, with the exception of an intruding mass of the old conglomerate at Borgue Head, where its presence is probably owing to the degradation of the nearest points of the primary rocks of the Scarabin Hills. This isolated mass of conglomerate is nearly vertical, and disintegrates into irregular prismatic forms; and the flagstone in the cliff on both sides, dips away from it at a rapid angle to the S.W. and S.E.; but at a little distance from it, it recovers its average inclination. All these lower slaty beds exhibit the same forms as those of the higher parts of the series, in their mode of disintegration, and in having the same vertical gulleys or indentations, the sides of which are frequently of a red colour on the exterior, but of a greyish blue when freshly fractured.

Coast Section of the Old Red Conglomerate of Caithness, &c.

The general range of this deposit, and its enormous development in the southern part of the county, have already been noticed in the introductory part of this paper. It consists essentially of fragments, more or less rounded, of the nearest primary rocks, but never contains any substance resembling the Caithness schist and sandstone. Thus, in the hills of the interior, between Dunbeath and Braemore, it contains much quartz rock like that of the adjoining Scarabins, granite like that of the Ord, gneiss, micaceous slate, &c. &c.

With the exception of the masses in almost immediate contact with the primary rocks, it is generally held together by a red-coloured cement, which is more or less siliceous; and the finer and coarser varieties frequently succeed each other in regular beds; so that we may meet with finely foliated red sandstone alternating with the very coarsest varieties of the conglomerate. In this way the dip is easily ascertained, and is not generally greater than that of the superior schists, except in the immediate vicinity of the primary rocks. Thus, in the narrow valley which separates the Scarabins from the Maiden Paps, the conglomerates dip at 45° towards the great northern plain; but, at the Schmian, which is further removed from the central quartz rock, the dip of the same conglomerate system is in the same direction, but not more than 10° or 12°.

That this conglomerate system forms the lowest part of the secondary deposits is evident, from its position and range in the county, compared with the general dip of the beds which descend into the great northern plain. For example, in ascending from Dunbeath towards the higher part of Braemore, the beds of hard, siliceous flagstone rise toward the interior, and, in some places, pass into a hard, thin-bedded, red, micaceous sandstone. From beneath this series, and at the same angle of inclination (10° or 12°), rise, in succession, beds of red conglomerate, containing a few subordinate beds of red sandstone, by which we are led, in regular descending geological order, to the great mountain masses of the Schmian and Mor-Bheim. The same facts present themselves in ascending from Berridale up the denudation of the Langwell river.

Independently of all this evidence, and of the analogy presented by the section of Port Skerry (which may, however, be considered of less importance, inasmuch as the conglomerate has there degenerated into a comparatively thin mass), the coast section between Berridale and the Ord seems to place the true relations of the deposits here described beyond the reach of doubt. The conglomerate system, as before stated, clasps round the Scarabin Hills, so that a part of it ranges on the north side of that chain, and, passing under the Caithness flagstones, does not appear upon the coast; with the exception of one protruding mass at Borgue Head, which is seen in the cliff in the manner before stated*. Another part of it ranges from the serrated ridge of the Maiden Paps, on the other side of the Scarabins, and descends to the coast, being bounded towards the south by the granitic chain which terminates in the bluff headland of the Ord. It, therefore, remains for us only to describe the coast section from Berridale to the Ord, in order to complete the history of this system. We have before stated that the lower part of the Caithness schist extends considerably to the south of the Berridale river; and it may, perhaps, be considered to terminate a little beyond the detached pinnacle called "The Man of the Ord." In this part of the range, the strata are of an unusually red colour, and contain few subordinate calcareous beds. In other respects they are perfectly analogous in structure to the corresponding parts of the formation. These red micaceous flagstones are succeeded towards the south (in regular descending order) by some beds resembling indurated shale of a deep red colour; and these indurated shales repose upon a great succession of still lower beds, which are entirely composed of red sandstone, and rise into a perpendicular cliff, three or four hundred feet high, called Trefad. The upper part of this system of strata is somewhat thin-bedded, like the Caithness flagstone, but is of a more uniformly red colour, and of a coarser texture. The lower part passes here and there into a coarse, red sandstone; and near the base some of the beds contain a great deal of kaolin, and are nearly incoherent. We also remarked near the same part of the series, many thin beds of conglomerate alternating with the red sandstone. From beneath this whole series, which dips towards the east, rises an enormous mass of conglomerate, occupying, for about half a mile, a lofty but singularly ruinous cliff, under a village called Bad-na-Bae. It is almost exclusively composed of fragments of granite, for which rock it might, without examination, be easily mistaken; as, in its colour, mode of weathering, and its rude prismatic forms, derived from decomposition, it strikingly resembles a crystalline granitoid mass. We succeeded, however, in landing among these ruins, and we effected a passage through them, though not without difficulty, to the top of the cliff: and when examined *in situ* and under the blows of a hammer, their true nature is easily made manifest†. These conglomerates pass into the interior in the manner before pointed out, and rise into the hills which flank and surmount the north side of the chain connected with the Ord.

At Ach-na-Craig the cliff again changes its character, and is occupied by

* See Section, Plate XIV. fig. 2.

† We conceive that the fragments of granite which enter so largely into the composition of this conglomerate, are derived from a mass which lies buried under the mounds of the fragmentary rock.

enormous crumbling dislocated masses of red marl and sandstone, containing a few bands of bluish flagstone which resemble the Caithness schist. These masses gradually pass into a strong red sandstone like that of Trefad, and extend towards the headland of the Ord. They are not, however, brought into contact with it, but are cut off from it by a mass of highly inclined conglomerate forming a lofty cliff, which terminates against the granite. The junction is nearly marked by a cascade of the Ousedale rivulet, which tumbles from the height of about 100 feet over these conglomerates into the sea. We here observe a somewhat startling phænomenon, which we do not however believe to be of unfrequent occurrence. A part of the conglomerate is so perfectly granitoid, that neither by hand specimens, nor even by an examination of the sections in the cliff, is it easy to determine where the depository mass ends, and the crystalline rock begins. What was the exact state of the granite at the time the formation of the old conglomerate commenced, it is not perhaps necessary to inquire; but it is evident that mechanical agents by some means or other produced a separation (almost without any fracture) of the crystalline constituents of the rock. In this way was produced a granitic sand composed of nearly unbroken crystals of quartz, felspar, and mica, which, on being re-cemented, produced that portion of the conglomerate rocks we are here describing. They do not, however, extend far from the granite, but soon begin to present a coarser texture, and pass into a well-marked mechanical rock.

With these conglomerates terminates the whole Caithness secondary system, being here cut off by the granite of the Ord, which, after forming a bold headland for about two miles, is brought into contact with, and has brecciated a great mass of, the oolitic series*.

It appears, therefore, that the secondary deposits of Caithness may be divided into three great natural groups. 1st. The old conglomerates which contain some subordinate masses of red sandstone, flagstone, and red marl, and which, through the intervention of thin beds of red sandstone, sometimes graduate into the next system†. 2ndly. A great formation of alternating beds of siliceous and calcareo-siliceous flagstone; dark, foliated, bituminous lime-

* The description in the text plainly shows that the granite of the Ord must have existed prior to the formation of the old conglomerates. This fact does not, however, prove that it then existed at its present elevation; nor, according to our view of the subject, does it in any way invalidate the hypothesis which considers the brecciated structure of the oolite to have originated in the last elevation of the primary crystalline masses of the Ord. (See Geol. Trans. Second Series, vol. ii. Part II. p. 307, &c.)

† The sandstones of this part of the series are not always of a red colour. At Port Skerry the conglomerates (which are, however, in a very degenerated form) graduate through the intervention of brown and greyish sandstone into the upper system.

stone, pyritous shale, sandstone, &c. &c. The siliceous beds give the type to the lower part of the formation, and the calcareo-bituminous bed to the intermediate part—again becoming more siliceous and arenaceous at the upper portion, and so appearing to graduate into the superior division. 3rdly. A great formation of red, brown, and variegated sandstone, which on the opposite side of the Pentland Firth reappears in the lofty red cliffs of the Orkneys, and there also, as in Caithness, reposes upon a calcareo-bituminous schist.

The aggregate thickness of these deposits is enormous: and their original extent was probably much greater than it is at present; as it, perhaps, once filled up a great hollow or trough of the primary rocks, which, towards the north, are seen in the Shetlands and some of the Orkneys, and, towards the south, rise into the mountains of Sutherland.

Fossil Fish of the Caithness Schist.

When the attention of geologists was first drawn to these ichthyolites, it was not known that specimens of them were to be found in any other quarry than that of Banniskirk. The authors of this memoir have, however, since discovered that similar remains are extensively, it may even be said universally, spread over the Caithness deposit; and that their occurrence is not confined to one particular stratum, but is characteristic of this vast schistose formation from the highest to the lowest beds. In the superior beds, the fish, or fragments of them, occur abundantly near Howburn Head, north of Thurso, and also at various places along the shores of the Pentland Firth; on the north side of which, beds containing the same fish are prolonged into the opposite islands of the Orkneys.

In the transverse section across the interior of Caithness*, these ichthyolites were successively met with at Widel slate quarries, three miles south-east of Thurso, at Banniskirk, at Clythe and Lybster, and finally at Latheron Wheel near the base of the formation. The fish occur invariably in beds of dark grey calcareous schists, highly bituminous and micaceous, which beds at Banniskirk and at most of the above localities immediately overlie the best and largest roofing-slate. In general, the animal remains are easily distinguished from the matrix by their darker colour; but, at Banniskirk, they are also remarkable in changing their hue, upon exposure to the atmosphere, from the usual dark grey to a purple plum colour, as formerly remarked†. By chemical analysis, which was kindly undertaken by Mr. Herschel, it appears, as might be expected, that the ichthyolites differ from

* See Plate XIV. fig. 2.

† See Geol. Trans. Second Series, vol. ii. Part II. p. 314—315.

each other considerably in composition. One of them gave the following result.

Silex	68.1
Alumine	7.2
Protoxyd of iron	10.5
Carbonate of lime and magnesia .	14.2
	100.0

The proportion of magnesia is very small. The blue matter of the fish is phosphate of iron, and the whole stone contains phosphoric acid in the proportion of $\frac{1}{4}$ per cent, and a little carbonaceous and bituminous matter. The iron being a protoxyd, the fresh fracture is black; but, by absorbing oxygen, it becomes yellow, and the phosphate passes into a per-phosphate, becoming blue. Thus the fish are visibly marked with blue streaks on a yellow ground.

With respect to the systematic arrangement of these fossil fish, Baron Cuvier has communicated the following valuable description of those from Banniskirk, which were sent to him (1827) for his opinion*.

"To describe the characters of the fossil fish on which Mr. Murchison has requested my opinion, I have endeavoured to trace an outline of an entire one, by reassembling the parts as seen in the different specimens. The result is the accompanying sketch†, which exhibits, as an essential character, a pointed tail, all the rays of which are on the lower side. This character is found in the fish of the copper schists of Mansfeldt and Eisleben. In animated nature, I am acquainted with no fish having this distinction, except the bony pike (*Esox osseus*‡, Linn.), and in a slighter degree the sturgeon; but as these fossil fish have strong scales, I should rather refer them to the bony pike. They are not, however, of the same genus, since they have not an elongated snout. The fish of Mansfeldt and Eisleben are, therefore, very nearly of the same genus (*genre*), as those of Banniskirk, except that the latter have a double dorsal fin, whilst those of Thuringia have only a single dorsal, which is placed further forward. The pectoral and ventral fins (*nageoirs pairs*) are alone wanting for the complete determination of these individuals; they exhibit some remains of pectoral fins, but I have not yet been able to discover more than one vestige of a ventral fin. I am of opinion, however, that the ventral fins are placed so far behind the pectoral fins, that, consequently, this genus is of the order Malacopterygii abdominales, and is, therefore, analogous to the bony pike."

* These specimens consisted only of a small number of the whole series afterwards examined by Messrs. Valenciennes and Pentland.

† Plate XV. fig. 4.

‡ *Lepisosteus*, Lacép.

Since the specimens here described were sent to Paris, more perfect remains have been discovered; and from a careful study of these, M. Valenciennes and Mr. Pentland have not only confirmed the opinion of Baron Cuvier, but have enabled us to add the following details.

The specimens of the order above mentioned belong to two new genera; and the first of these it is proposed, on account of the double dorsal fin, to call Dipterus. Of this there are the following species.

The first and most abundant* is recognized by the shortness of the anal fin, which does not exceed half the length of the inferior lobe of the caudal fin. This species, which may be named *Dipterus brachypygopterus,* seems to have occasionally attained a considerable size, the scales measuring rather more than the sixth part of an inch.

A second species†, which may be named *Dipterus macropygopterus,* is equal in size to the preceding; from which, however, it is easily distinguished by the length of the anal fin, which is very acutely pointed, and is prolonged beneath the caudal fin almost as far as the inferior lobe. The scales of this species are much larger than those above described, being one-fourth of an inch broad.

A third species appears never to have attained the size of those above described, although it is remarkable for the much greater magnitude of its scales. The anal fin, although long, never equals that of *Dipterus macropygopterus,* from which, as well as from *D. brachypygopterus*, it further differs in having a rounded tail.

A fourth‡ and much smaller species has been named *Dipterus Valenciennesii,* after the acute observer who first distinguished its characters.

Among the fragments is one specimen consisting of many large scales§, showing nothing of the shape of the head, nor any traces of the fins, but exhibiting, with another specimen ||, fragments of what appear to be bones of the head and opercula. It is therefore impossible to determine with certainty whether the remains of this fish are those of a species of Dipterus: analogy, however, would lead to that conclusion; for the scales are round, imbricated, and covered with granulations, in all of which characters it is similar to the other Dipteri. Until new observations shall afford materials for pronouncing decidedly on the genus to which this fish belongs, it may be named, provisionally, *Dipterus macrolepidotus.*

The specimen represented in Plate XVI. fig. 2. appears to be a young individual of the same species.

The second genus of fish discovered in Caithness¶, approaches to the cha-

* Plate XVII. fig. 1. 2. 3.

† Plate XV. fig. 1. 2. 3.

‡ Plate XVI. fig. 1. 3.

§ Plate XVI. fig. 4.

|| Plate XVI. fig. 5.

¶ At Widel quarries some miles north of Banniskirk.

racter of the Lepisosteus in the shape of its scales. The ventral fins are placed very much behind the body, and the anal fin is almost below the dorsal fin, which is consequently placed very far backward. We have not seen enough of the head, nor sufficient of the caudal fin, to judge of its form; but from what remains of this fin, M. Valenciennes is inclined to think it was forked, which peculiarity would distinguish this fish from the Lepisosteus, and would bring it nearer to the genus Amia. He proposes to name this genus Osteolepis; and as two species are indicated by the different size of the scales in each, they may be distinguished by the names *Osteolepis macrolepidotus*, and *Osteolepis microlepidotus*.

The naturalists who have examined these fish are disposed to think that they were the inhabitants of fresh-water; a conjecture which seems strengthened by the fact, that the remains of a tortoise nearly allied to Trionyx, are found both in the bituminous schists of Caithness and the Orkneys*. We found an imperfect fossil stem of a plant and other traces of vegetable matter among the ichthyolites, but never observed a single fossil shell or zoophyte in any part of the schistose formation.

§ 3. *Secondary Deposits on the Shores of the Murray Firth.*

We now proceed, in the order pointed out in the introductory part of this paper, to describe the secondary deposits on the shores of the Murray Firth. The range of the old conglomerates from the granitic mountains which separate Caithness from Sutherland, down to the highest parts of the Beauly Loch and of Loch Ness, and from thence along the north coasts of Nairn, Elgin, and Banff, has already been given with sufficient detail; and, between this line of range and the shores of the Murray Firth, are comprehended all the rocks which now fall under our notice. An inspection of the map will show that they are bounded to the north-west by the mountains of Sutherland, Ross, and Inverness; and to the south-east by the higher regions of Nairn, Elgin, and Banff: from which facts, independently of more direct evidence, we should be led to infer, that they had been deposited in a great trough of the primary formations, which expands towards the north-east, and declines into the Murray Firth, and, towards the south-west, is prolonged across the mainland of Scotland†. A detailed examination of the secondary formations

* Plate XVI. fig. 6.

† It is obvious from the above statements, that the conglomerates must have been formed upon a very uneven surface of the more ancient rock; and that a part, at least, of the great trough which affords a passage to the Caledonian canal must have existed before the commencement of the secondary deposits, and at a time when the greater part of Scotland was probably sub-marine. The conglomerates could not by any conceivable force have been piled up into mountains three

on this part of the coast leads to the same conclusion; for we find them with mere local exceptions, which do not affect the rule, dipping towards the central line of this imaginary trough. Thus on the coasts of Sutherland and Ross they generally dip towards the south-east, but on the shores of Nairn, Elgin, and Banff, the prevailing dip is north-west.

As the whole line of coast is nearly parallel to the secondary deposits, it follows that we can only become acquainted with their relations by examining a number of transverse sections, commencing with the primary mountains, and ending with those points of the sea shore which exhibit the highest visible parts of the series. To this observation there is, however, one very remarkable exception. Two great masses of gneiss* penetrated in all directions by veins of granite, appear to have been elevated after the deposit of the whole secondary system; and, at the time of their protrusion, not only to have lifted up several beds of the lias formation, but to have produced a considerable derangement in the upper part of the red sandstone and conglomerate series†. In consequence perhaps of this derangement, the beds between the North Sutor of Cromarty and Tarbet Ness are seen with a northern dip, and inclined at a high angle; and a coast section of about fifteen miles in extent conducts us, step by step, through a great succession of deposits, ending at Tarbet Ness in the highest part of the series, which may be compared with the upper red sandstone on the shores of the Pentland Firth.

1. *Transverse Sections of the Secondary System in Ross-shire, &c. &c. in ascending order.*

We before stated, that the conglomerate system was greatly expanded to the south of the Dornoch Firth; and as deep transverse gorges have been cut through it by the Alness and the Alt-Grant rivers, which greatly favoured our examination, we commence our first section with the old conglomerates which appear in the higher part of those rivers resting upon the primary mountains.

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thousand feet high on the side of Mealfourvonie, or even into the lower elevations in the neighbourhood of Foyers, without filling up a great portion of the valley of Loch Ness. This valley must, therefore, have existed anterior to the secondary epoch, and must have been then choked up; and, in after times, it must have again been opened out by those operations (perhaps referrible to many successive epochs) which have formed the greater denudations of our secondary strata, and of which the lofty pyramidal mountains of stratified sandstone and conglomerate are among the most imposing monuments. On this subject we refer to the descriptions of Dr. MacCulloch. (Geology of the Western Isles, vol. ii. pp. 90, 93, &c.)

* See Geol. Trans. Second Series, vol. ii. Part II. p. 308—309. Part III. p. 355.

† See Plate XIV. fig. 3.

The first appearance of the oldest conglomerates in the course of the Alt-Grant, is at Meul Turach, about a mile below Loch Glass, where it forms a bold pyramidal mass, which rises more than a thousand feet above the level of the river. It rests unconformably on gneiss, and is almost entirely composed of large and imperfectly rounded fragments of that rock, with a small proportion of red-coloured cement. This mountain mass is, in its general character and relations, perfectly identical with the lowest conglomerates of the chain of the Maiden Paps, and is prolonged towards the north and the south in the form of an irregular, broken chain of pyramidal hills, resting upon, or abutting against, the primary mountains. The phænomena at the points of junction, and the true relations of this immense deposit, may be studied in many parts of the range already pointed out*. Below Meul Turach, the banks of the river are for some distance occupied by morass, but it afterwards makes its way through narrow gorges of the conglomerate; and, after many devious windings, pierces through the solid rock, and falls at a single plunge into a lower part of the valley.

As the whole system dips at a considerable angle towards the Cromarty Firth, we must obviously, in descending the transverse valleys, reach in succession the newer portions of the conglomerate series. Continuing then to descend by the banks of the Alt-Grant, we meet with great masses of conglomerate associated with sandstone or flagstone resembling grauwacke. These are succeeded by great alluvial terraces, which are chiefly composed of white incoherent sand, and which, for some distance, entirely cover the regular strata.

About a quarter of a mile above a deep gorge which enters a second zone of conglomerate mountains, there appears on the banks of the river a succession of beds composed of calcareo-bituminous schist, calciferous grit, and flagstone of a red or greenish red colour, and which cannot be mineralogically distinguished from many of the lower beds associated with the bituminous schists of Caithness. These beds alternate with many masses of sandstone and conglomerate; and they enter essentially into the composition of a remarkable system of deposits which are interposed between the first and second ridge of conglomerate mountains. They appear in the Alness nearly in the same form, but more mixed with red and greenish red marls. In the hills near Tulloch Castle, they are associated with micaceous sandstone, are less calcareous, and in a great measure lose their mineralogical characters; but they may easily be detected when struck by the hammer, by their offensively bituminous odour. Near Coul (the seat of Sir George Mackenzie), and for

* For example, in the higher part of the Alness, Tor Achilty; in the hills above Fairburn, Mealfourvonie, Foyers, &c. &c.

a considerable way down Strath Peffer, they regain the most characteristic form of a dark-coloured calcareo-bituminous schist, foliated, and sometimes contorted, much mixed with pyritous shale, and giving rise to springs of sulphureous water. Their last appearance (at least as far as we noticed them) is about two miles to the south-east of Inverness, where, in several places, they form a considerable system of beds composed of grauwacke, sandstone, indurated pyritous shale, dark, laminated limestone, &c. &c.* In this last locality their relations are, however, somewhat obscure; partly from the want of good natural sections, and perhaps still more from the gradually thinning off of the older conglomerates.

Returning to the former line of section, we enter upon the inner zone of conglomerate mountains at a deep gorge, which offers a passage to the Alt-Grant. The waters descend for about two miles in a narrow perpendicular cleft, about two hundred feet deep, which must cut in succession through all the beds in this part of the system. Its sides are, however, absolutely inaccessible: we are, therefore, obliged to seek on the banks of the Alness for sections exhibiting in perfect detail the structure of this part of the series. We there find that the chain is composed of an indefinite number of conglomerate beds, some of which are of coarse texture, and are not to be distinguished from the outer zone, which is in contact with the primary mountains; others (in the ascending order) are of finer texture, and pass into thin-bedded, red sandstone. The coarse conglomerates gradually sink in importance, and, at length, become decidedly subordinate to the sandstone, which in some places is soft and nearly incoherent, exhibits many lines of false bedding or cleavage not parallel to the planes of stratification, and is partly associated with a meagre, micaceous slate-clay. In these varieties the prevailing colour is red, or reddish grey, variegated with red streaks or blotches.

Near the lower gorge (where the river escapes into the plains, which stretch between the shores of the Firth of Cromarty and the base of the round-topped conglomerate mountains), the more prevailing colour of the sandstone is grey, or brownish grey, often ironshot, and here and there exhibiting a red tinge. Some of these varieties have a coarse texture, like millstone grit, and occasionally pass into conglomerate; but more usually they are of a finer texture, and have thick, hard (but ill-defined) beds, which are extensively quarried for building. In many of these quarries, which are opened in the lower part of the Alt-Grant and of the Alness, the rock cannot be distinguished from the commonest varieties of gritstone which are subordinate to the English coal-

* This system of beds is well exposed at Inche's quarry, and on the banks of a neighbouring rivulet.

measures. In general, however, a red tinge is more prevalent in the rocks we are describing, than in the ordinary gritstone of the carboniferous strata; and the more coarse and rubbly beds associated with them, as well as the subordinate strata of flagstone and micaceous slate clay, are almost universally red or variegated. The same observations may be applied to most of the varieties of sandstone which are extensively quarried on the north shores of the Beauly Loch in the Black Isle, and in many other parts of Easter Ross.

This second range of conglomerate mountains gradually declines in elevation towards the south-western angle of the Cromarty Firth, but is prolonged, if we mistake not, into the hills above Brahan Castle; and the same part of the system is probably represented by the great masses of conglomerate which form the hills on the north side of the Beauly Loch, immediately opposite Inverness *.

So far there appears a very strict analogy between the conglomerate system of Caithness (especially as it is laid down in the eastern coast section), and the successive deposits which we have last described; the mineralogical distinctions arising naturally from the different characters of the primary rocks, out of the degradation of which the secondary formations have arisen. But in leaving the conglomerate mountains, and descending to the lower regions of Easter Ross, we lose all distinct traces of this analogy; and the whole subsoil (not only in the low region bordering on the north shore of the Cromarty Firth, but also in the greater part of the Black Isle), appears to be composed of sandstone having the general characters already described. The district is much covered by accumulations of turf-bog, and of alluvial matter; so that we should find it difficult to determine whether any other beds were subordinate to the sandstone, had not the two Sutors of Cromarty produced an inversion of dip and a great derangement, by which a considerable succession of beds is exposed in fine open coast sections. In the low region before alluded to, the dip is inconsiderable, but on the whole tends to the south-east. Taking the line of section towards the North Sutor, the dip becomes inverted; and before reaching the protruding gneiss, the sandstone beds are nearly vertical †.

* The structure of the country near Inverness appears to be strictly analogous to that which is described in the text. The primary rocks are immediately succeeded by conglomerate. To the north-west of the town, the bituminous schist (like that in the higher part of Alt-Grant) does not appear: but it does appear (as above stated) to the south-east; and a portion of it may perhaps be buried under the Murray Firth. At all events, beds of sandstone like those which are associated with the bituminous schist are quarried on the north shores of the Loch, and these are surmounted by the conglomerates of the Black Isle, which, in this view of the subject, must represent the inner zone of the Ross-shire conglomerate.

† See Plate XIV. fig. 3.

Precisely the same phænomena are seen at the other Sutor on the east side of the town of Cromarty. These highly inclined beds are separated from the gneiss of the Sutors by a mass of conglomerate. They are principally composed of siliceous sandstone more or less ferruginous: subordinate to which are, however, some thin beds of shale, containing calcareo-bituminous schist, not to be distinguished from that of Caithness.

By these beds we therefore establish an analogy which otherwise would be wanting, as the sandstones of Easter Ross have in general but little resemblance to any part of the series connected with the dark blue flagstone of Caithness.

2. *Coast Section from the North Sutor of Cromarty to Tarbet Ness. In ascending order.*

The peculiar position of the beds on this part of the coast, their northern dip, and high inclination, have already been noticed; and they may be naturally described in this place, as they not only conduct us to the highest deposits which are connected with the red sandstones of the Murray Firth, but also appear to commence exactly at that part of the series with which the preceding transverse section terminated. We shall endeavour to omit all details which are not essential to our present object.

Immediately on the north side of the Sutor are some conglomerates perfectly analogous to the similar masses which appear on the south side of the same rock. They are succeeded by highly inclined beds of sandstone, which form a lofty but ruinous cliff extending to the south-west side of the bay of Shandwick. Their prevailing colour is red, but they exhibit in more or less perfection all the modifications above described, and might pass for hard varieties of either old or new red sandstone. On the low sandy shore of the bay are many similar beds; and associated with them are masses of hard greenish grey sandstone, which form a good material for building.

Under Cadbolt, where the cliff recommences, and from thence to Geanie's Mill, the mineralogical phænomena are of great interest. The sandstone beds are extremely variable, both in their thickness and in their state of induration. The cliffs are generally red or variegated, but many of the subordinate harder beds are greenish grey, grey, or brown. The colours are, however, seldom constant even in the same bed. Almost all the softer varieties are either red, or marked with red streaks and blotches; and subordinate to them are thin, micaceous, flaggy beds, passing into meagre, micaceous shale. Some of these beds of shale are red; others green or variegated: they are here and there pyritous and bituminous; and subordinate to them, in at least eight or ten places, are thinly laminated beds of dark bluish grey, or dark smoke-grey impure limestone*.

* The most remarkable of these beds is seen down on the beach near the road turning up to Cadbolt. It is dark smoke-grey, partially lamellar, and has been occasionally quarried for use. Between Cadbolt and Geanie's Mill are some singular dislocations, and an anteclinal axis running for some way parallel to the base of the cliff. We have thought it unnecessary to notice these phænomena in detail, as they do not produce any effect upon the general relations of the strata.

Under Geanie's Mill are seen some grey, brownish grey, and greenish grey calciferous sandstones, alternating with some bituminous, laminated, calcareous beds, on one of which were some fish scales, and some fragments which appear to be analogous to the plates of a tortoise, resembling a *Trionyx* found in the bituminous schist of Caithness.

Between Geanie's Mill and Balloan Castle the phænomena are of less interest: the beds in the ascending order preserve nearly the same characters; and in one place they contain a subordinate mass of pyritous shale, which throws out a spring of fetid sulphureous water*.

From Balloan Castle to the extreme point of Tarbet Ness, we did not remark any subordinate calcareous beds like those above described, although some of the greenish grey sandstones were calciferous. The general aspect and mode of weathering of the crumbling ruinous cliff reminded us of many varieties of new red sandstone. Among the soft red and variegated masses were, however, many strong beds of brown ironshot sandstone (at Port Mahomich, containing stains of coaly matter), and of brownish grey, grey, greenish grey, and white gritstone, and micaceous flagstone hardly to be distinguished from the ordinary sandstones of the carboniferous series.

From the preceding details, we think there can be no doubt that a part of the sandstone series in Easter Ross and Cromarty (especially that portion of it above described betwen the North Sutor and Balloan Castle), must be identified with the middle system of deposits of Caithness. And after a careful examination of all the phænomena, we were disposed to identify the series of beds to the north of Balloan Castle with the sandstones of Dunnet Head on the Pentland Firth.

In Caithness, three great subdivisions of the secondary deposits are natural and well defined; for the flagstone series forms a complete physical separation between the lower conglomerates and the upper red sandstones. But, on the Murray Firth these divisions are in some measure arbitrary; for the calcareous beds are entirely subordinate to the various sandstones, and produce no change in the general aspect of the cliffs, or in the natural features of the country. Hence, even allowing the classification we are attempting to establish, it is perhaps impossible to draw a precise line between the middle and upper system of the sandstone series of Ross-shire.

3. *Transverse Sections of the Secondary System on the Southern Shores of the Murray Firth.*†

We think it necessary briefly to notice some of these sections, although the coarse conglomerates have on this part of the coast thinned off, and nearly

* The calciferous portions which appear in this part of the coast are generally concretionary, and may often be distinguished from the other parts of the rock by being partially penetrated by Pholades.

† Plate XIV. fig. 4.

disappeared, and the true order of succession is much concealed by superficial accumulations of incoherent matter. They derive a considerable part of their interest from the numerous beds of concretionary limestone (resembling the *cornstone* of Herefordshire) which appear to be subordinate to them, and are associated with green, purple, and variegated marls.

The lower part of this system is in many places, and probably throughout, composed of a very fine conglomerate alternating with red sandstone. These masses are succeeded in the ascending order by various beds of sandstone, sometimes so coarse as to pass into a conglomerate form. They are well exposed both on the banks of the Findhorn and the Spey, and nearly resemble the sandstones of the lower parts of Easter Ross and Cromarty. Their prevailing colour is red, and on the Spey they are of a deep hæmatite-red colour.

The beds of sandstone last mentioned, are surmounted by the cornstone and variegated marls, which, although not forming continuous strata of great extent, appear to be characteristic of this portion of the series. Quarries have been opened in them in the following places, which may be traced on the map of Scotland, and will be sufficient to convey a correct general notion of their position and line of range.

1. Letham or Clewan, about six miles west of the Findhorn.
2. Cothall on the Findhorn, three miles south-west of Forres.
3. Sherra Mill, one mile east of Elgin.
4. Glass Green, one mile and a half south of Elgin.
5. Linksfield or Catley Hill, one mile north of Elgin.
6. Wark Mill, two miles north-east of Elgin, near the turnpike on the road to Fochabers.
7. Stone-walls near the house of Innes, four or five miles E.N.E. of Elgin.

This is the last of the cornstone quarries in this direction; but there are probably several other localities which escaped our notice.

In all these places the quality of the limestone was nearly the same. The most solid portions of it are compact or subcrystalline, and generally of a yellowish grey colour: they are, however, seldom of great extent even in the strongest beds, but are mixed with, and pass into masses which are less coherent, and have a green, reddish green, or variegated colour, derived from the marls with which they are associated. Their structure is obviously concretionary; and when the softer portions are washed away, the forms are in some instances so irregular, as to give the masses an appearance of being brecciated. It is unnecessary to accumulate details; but the following section in descending order, exhibited in the quarries on the right bank of the Findhorn near Cothall, will serve to explain the nature of these deposits.

1. Green and purple-coloured beds impure, and confusedly mixed with gravel.

2. Sandy marl, about one foot.

3. Green marl and concretionary limestone, four feet.

4. Irregular, brown, sandy bed, with green stains, one foot.

5. Irregular bed of concretionary limestone, very impure, and much mixed with green, red, and violet-coloured marls, some of which are penetrated by veins of carbonate of lime, and much mixed with pyrites; eight feet.

6. Strong bed of yellowish grey limestone, ten feet.

This bed contains more calcareous matter than the others, but many parts of it are distinctly concretionary, and much mixed with green pyritous marls. Portions of it are cherty, contain chalcedonic veins, and small flattened cells coated over with mammillated, reddish chalcedony. Other portions exhibit a compact, yellowish grey limestone marked with dendritic stains. These pass into the softer varieties mixed with, and subordinate to, green pyritous marls. The whole of this irregular mass is penetrated by veins of carbonate of lime, which sometimes aggregates in balls exhibiting diverging radii; and the breaks and fissures of the bed are commonly coated over with agaric mineral.

7. Below the limestone is a system of beds of sandstone which may be traced up the river, and which are of considerable thickness. They are chiefly composed of a brownish sandstone, here and there streaked and stained with red, of rather coarser texture, and passing, in one or two places, into a pebbly conglomerate. It is associated with beds of finer texture, which are nearly incoherent; and, about half a mile further up the river, are some inferior beds of fine texture and pink colour, which make a good building-stone. The dip is here north by west, about 8°.

The beds associated with the cornstone are, in the neighbourhood of Elgin (and we believe we might add along the whole line of their range), surmounted by a great system of sandstone strata, which are generally of a yellowish grey colour, and in which quarries have been opened, affording one of the most beautiful, light-coloured building-stones in the North of Scotland. Three of these quarries in a lofty hill of sandstone on the west side of Elgin, lay bare a very fine and characteristic assemblage of these beds of freestone. The lowest of them exposes about twenty-five feet of good, yellowish white, siliceous sandstone, surmounted by ten or twelve feet of rubbly beds. The best portions are very finely grained, with small specks of kaolin. In the middle quarry, which is in a higher part of the deposit, several of the masses exhibit partial spots and stains of black, and there are thin bands of green marl between the stronger beds. The upper quarry exposes about thirty feet of strong brown sandstone. The beds are very regular, vary from four to six or seven feet in thickness, and from some of them single blocks have been raised more than forty feet in length, for the purpose of constructing columns. They are all hewn out into large troughs and cisterns, and the hardest of the blocks have been occasionally used for millstones,—a purpose for which, however, they do not seem to be well adapted. The higher parts of the hill seem to be composed of stone of nearly the same quality, but no quarries have yet been opened in them.

We do not attempt to enter upon any further details respecting the secondary deposits on the southern shores of the Murray Firth, but, from what has been stated, it appears that they may be divided into three groups, the lowest of which is composed of red sandstone and conglomerate—the middle, of sandstone associated with variegated marls and cornstone—and the highest, of light-coloured siliceous sandstone. These three groups are, however, very ill-defined; and, as in our examination of this part of the country we did not visit all the successive promontories to the east of Burg-head, there may be other beds superior to the white sandstone which are not noticed in this transverse section.

A peculiar character is given to the deposits here described by the great abundance of cornstone, which may perhaps be considered to replace the lower portions of the calcareo-bituminous schist. Whatever be its relations, its appearance is not to be regarded as altogether anomalous; for, in the county of Sutherland (especially in the immediate neighbourhood of Golspie, and between that place and Loch Fleet), there are several examples of this peculiar, concretionary limestone associated with the red sandstone which alternates with, and overlies the old conglomerates. And there may be many other examples of cornstone with similar relations, which, in the transverse sections through the secondary series, entirely escaped our notice.

Red Sandstone and Conglomerate Series of the North-west Coast of Sutherland and Ross-shire.

These deposits stretch almost without interruption from the neighbourhood of Cape Wrath to the southern extremity of Applecross, and are developed on an enormous scale, sometimes rising into pyramidal mountains more than 3500 feet in height. For their general description and mineralogical characters, we must refer to the works of Dr. MacCulloch; but it may be proper, very briefly, to notice the phænomena exposed by the excavations for the new road over the red sandstone mountains of Applecross, as this great work had not commenced at the time he visited the western Highlands. The road ascends by traverses, frequently conducted in the solid rock, to a great elevation, and affords an admirable opportunity for studying in detail the structure of the formation we are describing. The beds which we observed between the shore of Loch Kishorn and the top of the mountain were nearly in the following order, beginning with the lowest visible.

1. Very hard, thick beds of red sandstone, chiefly composed of fragments of quartz and felspar; in some instances of very coarse texture.

2. Beds similar to the preceding, associated with others containing decomposing felspar.

3. Hard, close-grained, siliceous beds, containing many fragments of green, indurated, slate-clay.

4. Many thick beds, very hard, close-grained, and variegated with red and yellowish blotches.

5. Beds thinner and more fissile, variegated with red and yellowish stripes.

6. Fissile or flaggy beds, with flakes of mica between the laminæ.

7. Thin beds separated by bands of greenish marl, and alternating with sandy micaceous slate-clay.

8. At the top of the mountain, thin beds externally of a red and yellowish red colour, and, in their mode of weathering, resembling the commonest varieties of old or new red sandstone*.

This outline of a more detailed section may serve to convey a general notion of the red sandstone of Applecross; and we have little hesitation in identifying it with the older part of the conglomerate series of Caithness and the Murray Firth. The same observation may, we think, be applied to all the larger masses of red sandstone on the north-western coast. They are not only formed by the degradation of the primary strata of gneiss, quartz rock, &c. &c., but they are unconformable to them, and are generally separated from them, by masses of conglomerate.

For a proof of the general want of conformity of the red sandstone series to the true primary rocks, we may refer to numerous passages in the excellent description of this coast by Dr. MacCulloch, especially to his delineations of the mountains of red sandstone in the neighbourhood of Assynt. The same fact is beautifully exhibited at the junction of the red sandstone and conglomerate with the gneiss, in a deep gulley two or three miles to the south of Cape Wrath. The laminæ of the gneiss are nearly vertical, while the beds of the secondary rock are not inclined at a greater angle than 25°, and dip (W.N.W.) from the coast into the sea. The same observation may be applied to a magnificent succession of cliffs which range towards Loch Inchard.

We found many traces of the old conglomerates which separate the secondary deposits from the primary rocks on the hills between Loch Ewe and Loch Groignard; and we discovered two instructive junctions of the red sandstone with the primary schistose rocks between Loch Ewe and Gairloch.

* The assertion that no mica is contained in the red sandstone of the north-west coast, is shown by this section to be erroneous.

In both instances the sandstone was perfectly unconformable to the older schists, and separated from them by thick masses of conglomerate. Lastly, the mountains of Applecross, the mineralogical character of which has already been noticed, are regularly bedded, and have a constant dip from the coast into the sea (about N.W.), at an angle which is inconsiderable when compared with the average inclination of the older schistose rocks. They have unquestionably the external character and the structure, and we believe also the relations of secondary mountains.

Again, the red sandstone series of the west coast, has been traced to a point of junction not more than two or three miles south of Cape Wrath; and, on doubling the Cape, it appears on the north shore with the same character and relations. Moreover, we have shown that these several deposits are, through the intervention of other similar masses, connected with the old conglomerate range of Caithness. We think it absolutely impossible to refer these several deposits to distinct epochs; and we therefore conclude, that the unconformable red sandstones and conglomerates of the north-western coast, are not older than the lower portion of the secondary formations of Caithness and the Murray Firth, and that they must be classed with the older secondary deposits of England.

In making this statement, we by no means intend to assert that there is no such thing on the north-west coasts of Scotland as a primary red sandstone. We agree with Dr. MacCulloch in thinking that many of the masses of quartz rock which alternate with formations universally regarded as primary, are of mechanical origin. These rocks occasionally become of a red colour; and we know from experience, that it is not always possible, even on the spot, to distinguish them from true secondary red sandstones. One of the most striking examples of this kind may be seen immediately behind the village of Ullapool. There are, therefore, great, and perhaps in some instances insurmountable, difficulties (for example, in the Isle of Skye) in the way of classifying the old red sandstones of the Highlands. But, fortunately, it is no part of our present object to undertake their solution; nor do they appear in any way to affect the general truth of the conclusions at which we have attempted to arrive.

The difficulty of drawing a precise line between the primary and secondary rocks of Scotland, would be greatly increased, if organic remains could be found (as has been stated by Dr. MacCulloch) in any part of the older series which has hitherto been regarded as primary. On the eastern shores of Loch Eribol, and at the very spot indicated by the author above mentioned, we found boulders of quartz rock containing conical impressions, which he supposed to be derived from Orthoceratites, but which we cannot regard as organic.

Before terminating this short description of the sandstone and conglomerate of the north-west coast, it is necessary to notice a deposit which commences a little to the west of an ancient chapel on the south shore of Loch Groinard, and extends, with some interruptions, nearly two miles towards the south-east. Its lower portion is composed of beds of red conglomerate, of red and variegated micaceous sandstone, of incoherent red sand, and of red and variegated marls. In its upper portion are beds of micaceous slate-clay, and of marl, red, green, and variegated; and these alternate with irregular beds of grey, greenish grey, and white siliceous sandstone. This upper series very nearly resembles some beds which in the Isle of Skye and in Applecross underlie the lias; and the whole system (which is inclined at a small angle, and is entirely unconformable to the prevailing red sandstone of this part of the north-west coast) might represent the new red sandstone of England in its most characteristic form.

Conclusion.

It only remains for us by way of conclusion, to compare the deposits described in this paper with the corresponding formations of the English secondary series. We see no reason for believing that the old conglomerates and sandstones of Caithness and the Murray Firth, belong to an epoch anterior to the old red sandstone of England; and the same conclusion must, we think, be applied to the red sandstone on the north-west coast of Scotland, between Applecross and Cape Wrath. They must, therefore, be contemporaneous with some of the English series between the old red sandstone and the lias.

We have little hesitation in identifying them with the old red sandstone, for the following reasons.

1st. They are identical in structure with the older red conglomerates of Cumberland and the Isle of Arran.

2nd. They alternate with, and are inferior to, many beds resembling grauwacke, but not resembling any rock subordinate to the new red sandstone in England.

3rd. They contain many extensive, concretionary masses of limestone in no respect differing from the cornstone of Herefordshire, which is subordinate to the old red sandstone.

4th. They are identical with the conglomerates on the south flank of the Grampians, which appear to be older than the coal-measures of Scotland.

5th. They are, in Easter Ross, associated with a deposit of sandstone, which appears to be unconformable to the lias, and on the west coast of the same county. They are unconformable to the newer red sandstone of Loch Groinard, and to the lias of Applecross. In regard to the great central deposit of Caithness schist, we are not able to identify it with any part of the English series which has hitherto been described. It is of great thickness,—is void of shells or corals,—exhibits a very few obscure vegetable impressions,—but contains from the highest down to the lowest beds a great number of fish of two new genera, as well as a species of Trionyx (?), probably all of fresh-water origin. Considered as a whole, it has a much older character than the magnesian limestone series; and the bottom beds alternate with the old conglomerates, and cannot, therefore, be entirely separated from them. Moreover, the fish are not of the same species with any which have yet been discovered, either in the marl-slate of Durham, or in the copper-slate of Germany. We are, for these reasons, unwilling to consider the Caithness schist as the equivalent of the Thuringerwald marl-slate. It appears to be nearly of the same age with the carboniferous order, and the conjecture is fortified by the mineralogical characters of the middle deposit on the shores of the Murray Firth. The calcareo-bituminous strata are there subordinate to sandstone, many beds of which are perfectly analogous to the white and reddish sandstones which form the greatest part of the carboniferous group in the Isle of Arran.

Pursuing the analogies presented by the Arran section, we were led to conclude that the upper red sandstone of Dunnet Head, and of the opposite cliffs of the Orkneys, was the representative of the lowest division of the new red sandstone group, to which in position it seems to approximate; but its mineralogical character is not decisive; and with the exception of Loch Groinard, the upper or new red conglomerates do not appear in any part of the coast we have examined. Again, there is a break in the continuity of the secondary deposits above described; for there is no single section which conducts, uninterruptedly, from the old conglomerates to the lias, and the equivalent of the oolites. We believe it to be impossible to determine where the interruption of continuity takes place.

The exact relations of the upper red sandstone of the Pentland Firth must, therefore, remain in some degree of doubt. In external character, it perhaps most nearly resembles that system of red sandstone beds which, in the Isle of Arran, are interposed between the true carboniferous strata and the upper red conglomerates.

As a general result of the previous details, it follows that the enormous masses of red sandstone and conglomerate on the coasts of the Highlands are, for the most part, to be classed with the old red sandstone of England,—that the new red sandstone, with a few limited exceptions, has no representative,—and that the rocks of the carboniferous order either do not appear at all, or conform to so new a type as to leave no hope for the discovery of those beds of coal which characterize the formations of the same age in the south part of the island.

Table, in descending order, of the Secondary Formations in the North of Scotland and the Western Isles.

Formations.	*Localities.*
1. Chalk. Flints containing many fossils of this formation. (Geol. Trans. Second Series, vol. ii. Part III. p. 365.)	Plains of Aberdeenshire west of Peterhead.
2. Blue clay and shale, containing fresh-water fossils of the Weald clay and Hastings sand. (Geol. Trans. Second Series, vol. ii. Part III. p. 366.)	Loch Staffin, Isle of Skye.
3. Grit of the Coral-rag (calcareous grit of England. (Geol. Trans. Second Series, vol. ii. Part II. p. 318.)	Braambury Hill, Brora, &c.
4. Shale beds, &c. with fossils of the Oxford clay. (Geol. Trans. Second Series, vol. ii. Part. II. p. 319.)	Dunrobin coast. Brora.
5. Upper beds of the Great Oolite, resembling Cornbrash and Forest marble, and with characteristic fossils. (Geol. Trans. Second Series, vol. ii. Part. II. p. 321. Part. III. p. 367.)	East coast of Trotternish, Skye; Beal, near Portree, Skye; Scrapidale, Rasay.
6. Great formation (occupying the place of the Great and Inferior Oolite); the upper part composed of sand and sandstone; the lower part of carboniferous shales and sandstones, with many organic remains. (Geol. Trans. Second Series, vol. ii. Part II. p. 320, &c. Part III. p. 360, &c.)	The sand and sandstone on the east coasts of Trotternish and Rasay; Carsaig, south coast of Mull; Strathsteven, Brora, &c.—The inferior carboniferous shales and sandstones; Brora coal-pits; cliffs opposite Portree, Skye; Holme water-fall, Skye; South coast of Mull.
7. Lias. The upper part composed of micaceous shales graduating into the superior formation; the lower part of blue limestone. The whole group charged with Gryphites, Belemnites, &c. &c. (Geol. Trans. *ut supra.*)....................	Upper part; base of cliff, Holme, Skye; Scalpa; Pabba; Carsaig and Tobermory, &c. Mull; Coast north and south of Cromarty Sutors; lower limestone; Broadford, Skye, Applecross; coasts of Morven.—N.B. At Strath in Skye the whole formation near the Syenite is white and crystalline. (See MacCulloch, West. Islands, vol. i. p. 352.)

Formations.	*Localities.*
8. Newer red sandstone and conglomerate...	Inch-Kenneth, and opposite coast of Mull (?); sands of Groinard Ross; Brochel Castle, Rasay.—The lowest part of this system (?) in the headlands of Tarbet Ness, Dunnet-head, and the southern cliffs of the Orkneys, &c. &c.
9. Calcareo-bituminous schists; the upper part graduating into the superior sandstone; the lower part alternating with siliceous flagstone sometimes resembling grau-wacke. (See the preceding pages.) The whole group charged with fossil fish .... (N.B. North of the Grampians the true coal-measures do not appear.)	Plains of Caithness, Castle Hill, Banniskirk, Lybster, Wick, Thurso, &c. In Ross-shire, Coul, Inchcoulter, Geanies, Tulloch Castle, Banks of the Orron-under-Fairburn, &c. &c. Inches near Inverness, &c. &c.
10. Old red sandstone and conglomerate; upper part graduating into No. 9.; lower part composed of the debris of the neighbour-ing primary rocks, and generally resting unconformably upon them.	Conglomerate hills forming the south flank of the Grampians; axis of the secondary rocks on the east coast of Arran. Coast and islands near Oban; detached masses in the line of the Caledonian Canal. Great Headlands of the western coasts of Ross and Sutherland, viz. Applecross, Gareloch, Assynt, Loch In-chard, &c. &c. Detached mountain masses in the interior. Masses flanking the gneiss of Cape Wrath; Loch Tongue. Great interior zone of Caithness from Port Skerry to the Ord of Caithness; hills bounding the Brora coal-field; sides of Ben Wyvis; Fairburn and Beauley hills; Mealfourvony; Fall of Foyers; sandstone and concretionary lime-stone of Nairn and Elgin; Troup Head and Kings of Cullen.

Secondary Formations in the South of Scotland.

We had no opportunity of examining in any detail the secondary forma-tions of Scotland south of the Ochill chain. We may, however, state that they differ from the series given in the preceding table in the following par-ticulars.

1st. In the less development of the old red sandstone and conglomerates.

2nd. In the extensive development of the true coal-measures which are not represented (at least in any ordinary form) in the preceding series.

3rd. In the greater expansion of the newer red sandstone, e. g. in Dum-friesshire, and on the north shores of the Solway Firth, &c. &c.

4th. In the entire absence of the oolitic series.

The secondary rocks of Arran belong to the southern system; and in the coast section described in a former paper*, the several formations there exhibited in one view are as follows:

1st. Newer red sandstone and conglomerates.

2nd. Coal-measures and mountain limestone.

3rd. Older red sandstone and conglomerates.

We believe that these older conglomerates are distinctly contemporaneous with No. 10. of the northern series. The separation between the newer and older conglomerates of Arran is clearly defined by the intervention of the coal-measures and mountain limestone containing the characteristic fossils: and in the northern extremity of Scotland, the upper red sandstone is as distinctly separated from the lower sandstone and conglomerate series, by the intervention of the ichthyolites and bituminous schist. In the absence of the characteristic fossils and of the upper conglomerates, we however consider the true place of the upper sandstone of the Pentland Firth as in some degree ambiguous.

* See Plate III. and p. 24.

V.—*On the Geology of Tor and Babbacombe Bays, Devon.*

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[Read November 16th, 1827.]

THE district to be noticed in this communication enables us to trace the disturbance of the Exeter red conglomerate, carboniferous limestone, and old red sandstone of the coasts of Tor and Babbacombe Bays, to the intrusion of trap rocks, subsequent to the formation of the Exeter red conglomerate.

The following is a general sketch of the coast. There is no beach to the cliffs from near the Ness-point, at the mouth of the Teign, to Hope's Nose, the northern point of Tor Bay, with the exception of the bottom of a few coves, and the Babbacombe-sands, and their continuation the Oddicombe-sands, both misnomers, for they are shingle beaches. The cliffs plunge directly into the sea, and are well seen only from a boat. The coast is equally bold from Hope's Nose to Torquay, with the exception of Meadfoot-sands, which are, however, backed by a high broken hill. After passing the hill between Torquay and Tor Abbey, the coast assumes a milder character: the cliffs, where they occur, are of no great elevation; and there are extensive sands both at Paington and Goodrington, separated by Roundham Head. Further south, low cliffs intervene between Goodrington-sands and the Broad-sands. Beyond the low rocky land of Galmpton Point, the cliffs are bolder, and continue so to the Berry Head, being, in a few places, broken into coves, the most considerable of which is occupied by the harbour of Brixham.

This range of coast is backed by hills, varying in height from 200 to 500 feet. Furland Hill, between Brixham and Dartmouth, is 589 feet above the sea, according to the Ordnance Survey.

I shall now proceed to describe the stratified rocks of this district, commencing with the uppermost.

Exeter Red Conglomerate.—*Rothe Todte Liegende. Grès Rouge.*

The red conglomerate of Babbacombe and Tor Bays is similar to that of Heavitree and the neighbourhood of Exeter. It consists, generally, of a fine-grained conglomerate of small fragments of carboniferous limestone, old red sandstone, shale, quartz, grauwacke, and red quartziferous porphyry, cemented by a red paste, generally argillaceous, and frequently very compact; so that the mass affords a very good building stone. This fine-grained conglomerate often contains small earthy crystals of felspar.

Besides the preceding, there is a large-grained conglomerate containing fragments that are sometimes a ton or more in weight. In this the cement varies, being principally loose and sandy, and seldom containing crystals of felspar. Interstratified with these are red sandstones and marls. These conglomerates may, for more easy description, be divided into three small districts: 1. That of St. Mary Church and Watcombe; 2. That of Tor Moham, extending up to King's Kerswell; and 3. That of Paington.

1. *Red Conglomerate of St. Mary Church and Watcombe.*

The range of cliffs extending west from the Ness-point at Teignmouth, exposes a section of this rock, which varies from fine-grained to coarse, the latter greatly predominating: the most abundant fragments are pieces of the limestones, on which the conglomerate here frequently rests; pieces of red quartziferous porphyry are, however, by no means rare, as in the east of Teignmouth. These porphyritic fragments are most decidedly rolled pieces, derived from some other rocks than the conglomerate that now contains them.

The only interruption to the continuation of these conglomerates to their termination at the fault at Oddicombe-sands, is caused by the carboniferous limestones of Petit Tor*. These limestones are nearly isolated, being bounded on all sides but the sea by red conglomerate. The conglomerate would appear to rise to the carboniferous limestone on both sides.

A short distance further south, the conglomerate abuts against trap†. This fault seems to continue through the village of St. Mary Church, where the conglomerate abuts against carboniferous limestone. The church stands on the latter rock, sections of which are seen in the village on the new road to Torquay; nevertheless, close to these places, a mason sunk a well 100 feet deep without going through the red conglomerate.

A porphyritic conglomerate, resembling that of Heavitree, is seen on Holloway Hill, over which both the roads from Torquay to Teignmouth pass.

2. *Red Conglomerate of Tor Moham.*

This portion is joined to that previously noticed by a kind of isthmus of the same rock, passing round from Holloway Hill by King's Kerswell. The conglomerate stretches from King's Kerswell south-west to Tor Abbey-sands, re-

* Coast section, Plate XVIII. fig. 1.

† Plate XVIII. fig. 1.

posing upon the limestone and old red sandstone, and attaining considerable elevation between King's Kerswell and Cockington.

At the Corbons, a small cliff at the south extremity of Tor Abbey-sands, is a good section of this rock. It is generally fine-grained, and the cement contains crystals of felspar. There is also a coarse variety with many fragments of carboniferous limestone; a fault is here observable in it.

At the northern extremity of these sands, the red conglomerate suddenly abuts against the carboniferous limestone, its strata becoming vertical*.

On the south side of the Corbons, the conglomerate is seen close to a fault, resting on red sandstone with green spots:—some of the strata have various tints, and some are greenish. The Livermead-cliffs are composed of the same conglomerate and sandstone as the Corbons, containing rounded pieces of quartziferous, red porphyry.

3. *Red Conglomerate of Paington.*

This is connected with the former by a stripe in front of the cliffs between Livermead and Preston, or Paington-sands. Here the Exeter red conglomerate seems brought into contact with the old red sandstone, probably by a concealed fault, affording the appearance of the former underlying the latter, whereas it only mantles round it. Fortunately, the distinctive characters of these two rocks is very clear in this district; and moreover, the red conglomerate contains abundantly portions of the old red sandstone,—a clear proof that the latter was a pre-existing rock.

The Exeter conglomerate of Paington resembles those previously mentioned, and is exposed in many good sections. At Rowndham Head, the strata dip north at about 10°. They are often of considerable thickness, contain rounded pieces, varying in size, of carboniferous limestone, old red sandstone, grauwacke, slate, &c. and are interstratified with red sandstone.

At Collaton Kirkham the conglomerate rests on old red sandstone.

Carboniferous Limestone.—*Neuere Uebergangs-kalk. Calcaire à Encrines.*

The rocks to which I here give this title, have usually been referred to the transition limestone of English geologists, that is, a limestone which occurs beneath the old red sandstone; they, however, rest upon that rock, contain fossils that have been discovered in the carboniferous limestone of other places, and, though a matter of minor importance, mineralogically resemble it:—they are, moreover, separated from the old red sandstone by a shale, which may be considered the equivalent of the lower limestone shale.

* Plate XVIII. fig. 5.

These limestones occur in beds from a few inches to several feet in thickness; the usual colour is grey, varying in intensity; they are frequently traversed by calcareous veins, and, in texture, vary from compact to semi-crystalline, the latter predominating in the vicinity of trap, and when the strata are much disturbed. The semi-crystalline limestones afford a great variety of beautifully tinted marbles, not so well known, nor so much employed for ornamental purposes as they deserve to be.

These limestones are, here and there, interstratified with shale: they also rest upon a considerable thickness of argillaceous shale, into which they seem to pass. The shale is usually reddish in the upper part, brownish grey in the lower and larger portion, and strongly reminded me of the shale similarly situated in Pembrokeshire.

The most abundant organic remains are encrinites and corals. The limestones at Daddy's Hole near Torquay, are so full of pieces of encrinites, as to resemble, in this respect, the Black Rock of Bristol. The following is a list of the organic remains which I met with in this rock, including those found at Bradley quarries near Newton Bushel:

Corals.

Encrinites.

Trilobites.

A very singular fossil*, specimens of which were collected in the vicinity of St. Mary Church. The sections which have been made of these specimens exhibit no internal structure which enables me to refer them to any known class of organic bodies.

Cardium alæforme............Min. Con. T. 552. f. 2.
Megalodon cucullatus ....Sow. Gen. & Sp. Nov. Min. Con. T. 568.
Terebratula porrecta..........Sow. Sp. Nov.
Ibid.........................with 5 or 6 small plaits in front.
Ibid.........................with 8 or 10 ditto.
Ibid.? ....Trigonal, depressed, with four large plaits on the elevated front, and as many on each side.
Spirifer decurrens ....Sp. Nov.
——— rotundatus? ....Min. Con. T. 461. f. 1.
Ibid.........................Sp. Nov.

* Plate XX. figs. 1. & 2.—It is not improbable that the fossil here referred to may have belonged to the Tunicata. The structure of the external covering appears to have some resemblance to that of *Chelyosoma MacLeayanum*, a new genus and species of that group, brought home by Lieut. Belcher, R.N. presented by him to the Zoological Society, and described and figured in the Zoological Journal, vol. v. p. 46. Tab. III. figs. 4. 5. & 6.; but, in none of the specimens of *C. MacLeayanum* examined by the writer of this note, does the number of plates, which are coriaceous and confined to the upper surface, exceed eight.—W.J.B.

Natica ? .... small and indistinct.
Euomphalus .... small and indistinct.
Bellerophon tenuifascia........ Min. Con. T. 470. f. 2. 3.
Turritella abbreviata.......... Sow. Sp. Nov. Min. Con. 565.
Turritella ? .... small ill-defined species, found also in Ireland.
Murex ? Harpula .... Sow. Sp. Nov.
Buccinum spinosum........... Min. Con. T. 566. f. 4.
——— breve.............. Min. Con. T. 566. f. 3.
——— imbricatum .... Min. Con. T. 566. f. 2.
Pleurotoma (Helix Min. Con.) like Helix carinatus. T. 10.
Nautilus....................
Orthoceras..................

1. *Limestones of St. Mary Church, Babbacombe, and the Northern Side of Tor Bay.*

These encircle the old red sandstone, which extends from Meadfoot-sands towards Upham. The section on the south side of Meadfoot-sands shows the limestones resting on old red sandstone. The quarry at the south-west points, opposite a rock called the Shag Rock, is worked in grey and reddish, compact limestone, dipping south-west: beneath, is an argillaceous shale, reddish in the upper part and grey in the lower,—the latter is slightly micaceous. This forms the cliff from the point to a short distance east of the place where the road descends to the beach; and to this succeeds a red siliceous grit traversed by veins of quartz, and containing iron. The cliff composed of red grit is much concealed.

The limestones in the vicinity of Torquay are much disturbed, as are also, more or less, all the stratified rocks of the district. These beds are observed to be contorted along the whole coast, from the town to the point opposite the Shag Rock; they seem, however, to have a general dip away from the old red sandstone, between which and the body of limestone the argillaceous shale is always interposed.

I have selected two examples of contorted strata near Torquay *, because, though the sections are only about eighty yards apart, and both across the range of the strata, they show the contortions that must have taken place in all directions †.

So much confusion exists in the vicinity of Torquay, that no regular dip of the limestones can there be determined. They dip S.S.W. at an angle of 35° near the turnpike, and at the quarry near the baths to the south-west. They are perpendicular, with a north and south direction, at the little hill near Tor Moham, at the Chapel Hill, and under Torwood House. At Stantaway

* Plate XIX.

† The birds marked in the two figures show the same points of the hill viewed from opposite sides.

Hill, between Tor Moham and Upham, the calcareous slate and limestones are much confused. At Butterhill quarry the limestones are much disturbed. On the new road from Torquay to St. Mary Church, at the entrance of the rocky defile, irregular, detached and arched strata, have a very picturesque effect, the arch appearing to be almost a work of art.

The coast also from Babbacombe to the Black Head, exhibits confused strata of limestone and argillaceous shale; at the latter place we may observe a thick, bent stratum of limestone included in the solid trap*: this limestone is very crystalline. Hope's Nose, with the Leadstone, Oarstone, and Thatcher Rocks lying immediately near it, are composed of limestone much contorted at the cove north of the Thatcher†. This mass of limestone is detached from the limestones on the west, that is, above the level of the sea; and, beneath, they are probably connected with the Torquay beds, for the Thatcher Rock is composed of them. Kent's Cavern, lately celebrated on account of the remains of elephants, rhinoceroses, hyænas, bears, deer, wolves, &c. found in it, is situated in these limestones‡.

From Barton the limestone extends along the hill to King's Kerswell, where Exeter red conglomerate covers it for a short distance: but, at the lower part of the village on the old Dartmouth road, the limestones again come in, and are continued to the top of the hill, where a quarry exhibits their contortions§.

2. *Limestones on the South of Tor Bay.*

Like those on the north of the same bay, these are greatly disturbed, as may be seen along the coast from the Berry Head to Saltern Cove, near Goodrington. At Marstink quarry near Paington, thin strata of semi-crystalline limestone dip north about 20°. At Saltern Cove, limestones are mixed with, and disturbed by, trap, which has greatly altered the character of the limestone at the points of contact. In one of the projecting points the altered limestone does not effervesce freely with acids; it contains corals.

Reddish shale resembling that on the north side of Tor Bay, and similarly situated beneath the limestone, occurs much contorted at the western point of Saltern Cove. In some places it is traversed by quartz veins.

Old Red Sandstone.—*Jüngere Grauwacke. Grès Rouge Intermediaire.*

The general character of this rock is best exhibited near Cockington.

* Plate XVIII. fig. 1. † Plate XVIII. fig. 4.

‡ The Rev. John M^cEnery, who has formed a very valuable collection of these remains, intends, I believe, to publish an account of them; and Professor Buckland will probably do the same in the continuation of his "Reliquiæ Diluvianæ."

§ Plate XVIII. fig. 3.

Between this place and Livermead-sands are two quarries of chocolate-coloured, micaceous, siliceous, and very compact sandstone. In both a slaty variety, splitting easily in the line of the laminæ, which are filled with mica, is mixed with compact and micaceous beds, which vary in thickness from a few inches to two feet. The strata are much confused, some are curved, and some dip in all directions.

In its great hardness, in its colour, in being micaceous, and in general appearance, it differs entirely from the red sandstone associated with the Exeter conglomerate of the Corbons and Livermead. After passing Livermead on the road to Paington, a new cut exposes a slaty variety of this rock, apparently passing into grauwacke. Among the strata are a few of the more compact and solid sandstones.

Thick beds of old red sandstone are observable on the rise of the hill west of Cockington, on the old road to Totness, but they are quickly covered up by Exeter conglomerate, which latter continues to conceal it as far as a small rivulet about half a mile east from Ockham, where it again emerges. From the vicinity of Ockham to Westerland, this rock passes gradually into grauwacke slate, losing its red colour, but preserving its mica.

At Collaton Kirkham, the same slaty and compact varieties are seen as in the Cockington quarries; their dip is E.N.E. at an angle of about 20°, the beds being sometimes curved. They are much more highly inclined in the same vicinity. Exeter red conglomerate covers these rocks on the same hill, and contains rolled pieces both of its slaty and compact varieties. The old red sandstone passes into grauwacke on the high hill N.N.W. of Paington.

The red compact sandstone beneath the argillaceous shale at Meadfoot-sands, very much resembles the Cockington compact old red sandstone. At Hope Farm the resemblance between the two will be found most striking; and there can be no doubt that the limestone shale rests upon it in the vicinity: in fact, the wedge-shaped mass of old red sandstone extending from Meadfoot-sands and Hope Farm towards Upham, is bounded by a mantle of argillaceous shale.

Sandstone and Slate of Meadfoot-sands.

These may almost be considered as the passage of old red sandstone into grauwacke, or they may be the old red sandstone strata altered by the vicinity of trap. Beneath the red grit of the Meadfoot-sands is a grey, compact, fissile, and very micaceous sandstone, resembling in every thing but colour, the semi-schistose varieties of the Cockington red sandstones. Their angle of dip varies considerably; it is at first towards the south-west at about 65° or 70°. These strata rest upon, and pass into a slaty rock resembling the old red sandstone schist of the vicinity of Ockham in every thing but colour. They are here dark-coloured. These rocks traverse the point of land, named at its extremity Hope's Nose; and upon them the limestone of that place appears to rest.

Small trap veins are observable both in this rock and the red grit of Mead-foot-sands.

Grauwacke.

A very small portion of this rock comes within the scope of the present communication. The old red sandstones pass into grauwacke between Ockham and Westerland, at which latter place there is a quarry of grauwacke rather micaceous. It contains the vertebral columns of encrinites, corals, and bivalve shells. The schist is used to line the interior of the neighbouring lime-kilns. The dip is E.S.E. about 45°.

Trap Rocks.

On the east of Babbacombe, trap rocks advance into the sea and form a small headland. They consist principally of greenstone, varying in grain, and containing abundantly particles of iron pyrites; some of it approaches the character of a reddish sandstone, and the whole is occasionally traversed by veins of quartz, jasper, and very rich iron ore. Between this headland and the compact, and sometimes semi-crystalline limestone of the main land, argillaceous shale is interposed.

Another small headland, on the west of Babbacombe, is formed of greenstone and greenstone porphyry. Very often the rock assumes a porphyritic and amygdaloïdal character at the same time, the amygdaloïdal cavities being filled with carbonate of lime. In all cases, iron pyrites, often in cubical crystals, is disseminated through the mass:—calcareous and quartz veins traverse the trap, particularly on the Babbacombe side.

This trap has evidently been protruded into the argillaceous shale from beneath: the strata are cut off and twisted by it; considerable portions also of the shale are included in the trap. The limestones, forming the upper part of the cliff, rest on the shale, and are also disturbed.

From hence north-west to Oddicombe-sands, the same kind of trap is observed intermixed with the shale at the base of the cliff, and appears to have forced its way high up among it, and, probably, also among the limestones; the cliff is inaccessible, but presents the appearance of different rocks irregularly mixed. The trap becomes so altered in its character as it ascends, that the highest portions scarcely deserve the name, presenting, when in contact with the limestone, a base that effervesces and contains green specks and crystals of iron pyrites. This may perhaps be an altered limestone. The general character of this mass of trap is the same as that of the small point previously mentioned, being only more porphyritic and less amygdaloïdal. Good greenstone also occurs.

At the fault in Oddicombe-sands the trap attains greater elevation, forcing up the shale, and causing it to occupy the top of the cliff. This trap forms the eastern part of the fault to which the Exeter red conglomerate rises, as if also elevated by it.

We here learn that the trap was intruded among, and caused disturbance in, the shale and carboniferous limestone after the formation of the Exeter red conglomerate; for the latter also appears affected by it. As this conglomerate contains rounded portions of the limestones and shales, the fault presents two distinct, geological epochs; one, when the limestones and shales were partially destroyed, affording some of the materials of the conglomerate; and another, when the trap was intruded among, and disturbed all these strata*.

A small portion of trap is also seen among the limestones between Babbacombe and the northern head of Anstis Cove†. At the bottom of the cove, greenstone, traversed by veins of jasper, is observed among the shale situated between the base of the cliff and the limestones on its summit; the shales seem disturbed. The greatest mass of trap on the coast constitutes the Black Head near Ilsam‡. The principal rock is a greenstone, varying much in grain, and containing iron pyrites; a very abundant mineral in the trap of this coast. At the base of this head, a thick, arched stratum of limestone is included in the trap. This limestone cannot fail to remind the geologist of those situations where calcareous rocks have become hardened, and rendered more or less crystalline in contact with trappean rocks. The limestones of Ilsam are much disturbed, probably from their vicinity to the Black Head trap.

No more trap of any importance is found on the north of Tor Bay, and little on the south. Saltern Cove near Goodrington, presents another instance of the limestones and their accompanying shale being altered and disturbed by this rock, which is very compact, fine-grained, and of a mixed greenish and chocolate colour. It sometimes has an arenaceous structure and a reddish tint. Pieces of limestone, much altered, seem in a few instances included in the trap.

The only remaining trap that I shall here notice, is situated near the high road between King's Kerswell and Dartmouth, not far distant from the con-

* No pebbles of greenstone are found in this conglomerate.

† Plate XVIII. fig. 1. ‡ Plate XVIII. figs. 1. & 2.

torted limestones before mentioned, and is probably the cause of their present appearance.

I consider that the whole disturbance of this district, is attributable to the causes that produced the trap,—causes which probably also occasioned all those faults and contortions here so common. What the geological date of this event may be, it would be difficult to say, as we have no stratified rock resting peaceably on the trap. That this rock was here intruded after the formation of Exeter red conglomerate, is probable from reasons before assigned, and I feel disposed to connect the disturbance of the Tor Bay district with the catastrophe that elevated the strata in the line of Weymouth and the Isle of Wight, and caused the contortions and faults so common on the coast;—a catastrophe perhaps corresponding in date with that which raised the great range of the Alps.

VI.—*On the Geology of the Environs of Nice, and the Coast thence to Vintimiglia.*

By HENRY THOMAS DE LA BECHE, Esq. F.G.S. F.R.S. F.L.S., &c.

[Read Nov. 21st, 1828.]

NICE, the capital of the county of that name, stands on the Paglion torrent, on a small plain, bounded on the north by Mont Cao and its ramifications; on the south by the Mediterranean; on the east by the chain of Mont Moron, Mont Alban, Mont Venagrie, and Mont Gros; on the west by tertiary hills, generally fertile, and succeeded beyond the Var by high mountains. The Castle Hill of Nice rises out of this plain.

The plain and adjacent slopes covered with gardens of peaches, oranges, lemons, and extensive olive-grounds, contrast strikingly with the rugged mountain summits which stretch from Genoa to Marseilles. This contrast I have endeavoured to represent in the annexed sketch of a view taken from Mont Moron *.

M. Verany of Nice has determined, with a barometer of M. Gay Lussac's construction, the heights of the principal mountains above the level of the sea;—they are as follows:

	English Feet.
M. Cao	2800
M. Moron	542
M. Alban	731
M. Gros	1187
Pacanaïa	1950

I was present when some of these measurements were taken, and suspect that they rather exceed than fall short of the true height.

The accounts already given of the geology of this neighbourhood are enumerated in the sketch which M. Risso has prefixed to his *Histoire Naturelle de l'Europe Meridionale,* which, notwithstanding its title, treats of little more than the environs of Nice.

The most valuable of these are Faujas St. Fond's paper in the *Annales du Museum* †, on the osseous breccias, and the pretended discovery of a

* Plate XXII.

† Tom. x. p. 409.

copper nail in the limestone;—and that of Mr. Allan in the Transactions of the Royal Society of Edinburgh*, to which is added a list of the fossil and sub-fossil shells by Captain Brown.

Brèche en place.

The most recent deposits of this country present several peculiarities which claim attention. They assume in general the form of a breccia; but of this breccia there are two kinds, the one consisting of deposits on the surface, the other lodged in fissures and caverns:—they appear to be very much connected.

The fragments included in the surface breccias agree for the most part with the substance of the rocks immediately beneath; a few only are rounded, and appear to have been brought from a distance. Their cement is mostly calcareous, and varies in hardness and colour with the nature of the substratum; when it rests on dolomite or light-coloured compact limestone, it is often so hard as to require blasting: it is sometimes reddish and vesicular, the vesicles being lined with minute crystals of carbonate of lime: where it rests on marly or sandy limestones, or on tertiary beds, it is soft, friable, and for the greater part white.

Most of the breccias in place are derived from the rocks in their immediate vicinity; thus resembling many of those deposits in England and France which clearly show a destruction of the rocks almost in place, as may be well seen in the accumulation of chalk flints and chert upon the hills near Lyme Regis and Sidmouth, and is particularly well exhibited in Normandy.

Sub-fossil Shells.

Between Villefranche and St. Hospice, the breccia reposes on a loose light-coloured sand, full of shells, which so nearly resemble those of the Mediterranean, that they have been called sub-fossil: though generally bleached, there are some which retain traces of their native colours.—Lists of these shells are published in M. Risso's work, and in the Transactions of the Royal Society of Edinburgh†.

In Villefranche Bay and Beaulieu, this shell bed is covered with whitish marl, including fragments of calcareous grit: the marl occurs over the whole tongue of land; and the shell bed is probably beneath it, though not every where visible.

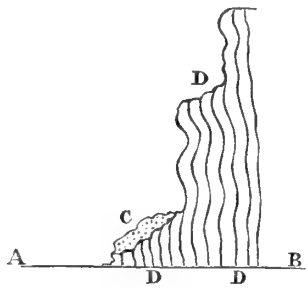
The shell bed in Villefranche Bay is from ten to twenty feet above the Mediterranean, shelving to the sea level at Beaulieu.

* Vol. viii. p. 427.

† Vol. viii. p. 459.

At Bausi Raussi Cliff is a breccia containing pebbles of serpentine as well as of compact limestone,—the latter are perforated by Lithodomi; the cement contains sub-fossil shells, and the breccia rests on vertical strata of light-coloured, compact limestone.

The accompanying section will give a clearer idea of the position of this breccia at Bausi Raussi than the most elaborate description.



A B level of the sea. C breccia or conglomerate. D D D perpendicular waving strata of compact light-coloured limestone.

Osseous Breccia.

The osseous breccias seem to occur only in fissures and cavities. Of these, the first I shall notice is situate on the south-east of the Castle Hill, in a cleft of brecciated dolomite. The north side of this fissure from top to bottom is bored by Lithodomi, and their shells are still found abundantly in the holes which are stopped up by the cement. This cliff has in a great measure been destroyed by quarrying. The bones, here discovered, have been described by M. Cuvier. The breccia containing them is red, and full of angular fragments of dolomite and light-coloured compact limestone. Beneath this red breccia is another, the pebbles of which are rounded and of grey blue limestone, and in which no bones have hitherto been discovered.

The blasting which had destroyed so much of this rock, afforded, when I was at Nice, a very instructive section, pointed out to me by M. Verany. It would appear that the osseous breccia had extended to a cave, which is now destroyed; and there were fissures connected with it also filled with osseous breccia. One of these on the road to the Port is shown*; the blue pebbles changing the colour of the breccia to grey, strikingly contrasts with the red tint of that which is osseous and uppermost.

Here then we may trace four distinct epochs: viz.

1. An open fissure into which the sea entered at a much higher level than at present, enabling the Lithodomi quietly to bore their holes;—for they are of all ages.

* Plate XXIV. fig. 2.

2. The fissure partially filled by rounded, grey-blue pebbles brought from a distance.
3. The remainder of the fissures filled by broken bones of animals, shells (marine and terrestrial), and fragments of rocks, mostly, but not solely, those of the neighbourhood.
4. The rise of the land, or the fall of the sea, to their present relative position.

Osseous breccia is observed also near the town on the side of the harbour, and other veins are found in the same hill, not osseous. The osseous breccia contains several marine shells like those of the present Mediterranean, and also land shells.—M. Risso has published a list of all these; and there are specimens in the cabinet of M. Verany.

M. Verany pointed out to me a large cleft filled with osseous breccia, more than 500 feet above the sea, on the top of Mont Moron. The cement of this breccia is red, and the vesicles coated with small crystals of carbonate of lime;—the fragments are angular, and consist of the same limestone and dolomite as the main body of the hill.

M. Risso has noticed a similar cleft containing bones on the south side of the same hill. There is another patch of red osseous breccia at Villefranche, whether in a fissure or not, can only be ascertained by blasting, which the authorities would not permit, considering it too near the citadel. In the cement of this breccia I observed small corals, with as fresh a fracture as recent corals, and not derivative from the limestone rock.

Another vein, not yet found to be osseous, occurs west of the Fanal or light-house at the end of Villefranche Bay; it is very compact;—the cement reddish above, greyish below; it traverses dolomite, and contains, among other shells, an inhabitant of the present Mediterranean, viz. the *Terebratula emarginata* of M. Risso.

M. Faujas St. Fond found osseous breccia at the Cimiez*. After mentioning that some Englishmen had been searching for medals where the restored convent now stands, he proceeds: "Les excavations faites pour rechercher des monumens antiques, ont mis à découvert, à une des extrémités meridionale du parc, la structure de la montagne, et ici comme à Nice, ce sont des masses énormes du même calcaire compacte, dont les bancs ont éprouvé de violentes commotions, des ruptures et des écarts qui en ont dérangé l'assiette; le spath calcaire les a ressoudés ensuite, et des filons de trois à quatre pieds d'épaisseur, qui les coupent transversalement en divers sens, sont remplies de la brèche osseuse à ciment rouge, et se prolongent depuis le haut

* *Annales du Muséum*, tom. x. p. 419.

jusqu'à la base de la montagne, en decrivant des diagonales qui se joignent à d'autres filons et forment diverses ramifications qui atteignent les collines environnantes." Perhaps the breccia vein here described is now covered up, at least I was not fortunate enough to find it.

Another vein (not osseous) traverses the light-coloured limestone and dolomite on the east of the lighthouse: it has a reddish cement, contains marine shells, and is so hard as to protrude beyond the rocks in which it lies, and which have been removed by the united action of the sea and air.

Similar veins (not osseous) occur in the arenaceous limestones of the peninsula of St. Hospice: the cement is not red, but generally sandy. One vein in particular traverses the low hill on which are the remains of the old works erected by the Saracens. Faujas St. Fond notices the breccia on Mont Alban: it has a red cement like that which envelops the bones at the Chateau de Nice, but it here envelops fragments of the rocks immediately subjacent. He thought that the grey breccia of the same mountain lay over the red; but it seems to me that the whole belongs to the same epoch, notwithstanding the difference of colour and the greater or less angularity of the fragments.

Veins occur in the marly, sandy limestones of Beaulieu, the cement of which is more argillaceous, and the fragments derived apparently from the rocks which inclose them: similar veins are seen in the hill of marly limestone that bounds the eastern entrance of the valley of St. André, and its junction with that of the Paglion.

Other veins of the same nature, one in particular very large, traverse the arenaceous limestone on the east of Mont Gros, on the road to Genoa; and an attentive examination along the coast, or in the interior, would probably bring to light many more than are here enumerated.

I. Superior or Tertiary Rocks.

These form a considerable tract of country to the west and north-west of Nice*, and admit of the following division.

1. Sand, sandstone, and conglomerate of rolled pebbles.
2. Blue marl,—shell-marl.
3. Grey marl, calcareous grit, and breccia.

1. *Sand, Sandstones, and Conglomerate of rolled pebbles (alluvial gravel of Allan).*

These strata constitute most of the hills on the west and north-west of the town*, being a part of the tertiary rocks described by M. Risso, as extending

* Map, Plate XXI.

from north to south, from between the villages of Levens and La Roquette near the mouth of the Vesubia to the sea.

They consist of an irregular mixture of sand, sandstone, and conglomerate composed of rounded pebbles of granite, gneiss, slates of different kinds, red sandstone, porphyry, compact, grey limestones, various sandstones, and in fact of every rock which the Alps can furnish.

The cement is sand or sandstone, composed of more comminuted portions of the same rocks as the pebbles, with much mica.

The picturesque appearance of the deep valleys that intersect these beds is well described by Mr. Allan*. "Near the banks of the Var," he observes, "I have seen cliffs cut in the gravel of at least 400 feet high, and quite perpendicular. The operations of the various little streams which occupy the water-courses in wet weather,—for in dry weather there is little or no water to be seen in them,—are very remarkable: sometimes I have followed them up, having barely room to squeeze myself through between the perpendicular walls, and found the cut suddenly terminate in a circular aperture, like a deep well, into which a little stream precipitated itself. In the Vallon Obscur, the opening is in some places not more than three or four feet, and the walls rise to at least one hundred feet on each side, fringed at top with shrubs and trees."

The sand and sandstones alternate with the conglomerates; they all dip to the south, except on the flanks of a mountain, as at Mont Cao. They are undisturbed, though the rocks on which they rest are much contorted.

2. *Blue marl (sub-appenine marl-marna turchina of Brocchi).*

Though this marl is generally blue or of a lead colour, yet it is light brown near the upper portions; it is used as brick earth, and abounds in shells, many of which agree with the recent. See the lists of M. Risso† and Mr. Allan‡.

M. Risso attributes to this bed the relative position which is here assigned to it, and cites Dr. Buckland, perhaps erroneously, as considering it the equivalent of the plastic clay of Paris, which M. Brongniart found at Marseilles: the marl of that place, however, contains abundance of lignite and fresh-water productions; that of Nice contains no fresh-water shells, and but little lignite. The section§ will afford an idea of its appearance in the valleys of La Madelaine and Magnan: it occurs also in the valley de la Mantega, and above the close part of the Vallée Obscur; its most common and characteristic fossil is a Natica‖.

* See Trans. of Royal Soc. Edin. vol. viii. p. 442.

† Hist. Nat. de l'Europe Merid. vol. i. p. 126.

‡ Trans. Royal Soc. Edin. vol. viii. p. 455.

§ Plate XXIII. fig. 2.

‖ This grey marl or clay is observed to alternate, and to be intimately connected with the conglomerate at Vintimiglia.

2ª. *Shell-bed behind La Trinité.*

This bed may be considered the equivalent of that last described. Its most characteristic fossil is a Dentalium: its shells are enumerated by M. Risso*, and are nearly the same as those of the preceding stratum.

3. *Grey Marl, Sandstone, and Breccia.*

These beds occur at the Fontaine du Temple, probably of Roman construction. The tunnel there is driven through a pyritous marl. On the rough ground, on the north, is a sandstone (siliceous grains), cemented by calcareous matter, forming itself the cement of a breccia, the angular fragments of which vary from hand-specimens to blocks of some hundred weight: they agree in character with the limestone and dolomite on which they rest. Many of these blocks are perforated by Lithodomi; the holes vary in size, and are lined with calcareous spar, and often contain pieces of shell:—to some blocks also are attached the lower valves of Spondyli with their fine edges uninjured. The epoch in which these animals were imbedded must have been one of repose.

The cement contains numerous remains of two or three species of Pecten, one of them gigantic, several inches in length; oysters; and teeth, perhaps, of a saurian; but the specimen of tooth which I found was too mutilated for accurate determination. The breccia may be traced up the mountain to the north of the Fontaine with its Lithodomi, 1017† English feet above the sea. Spondyli are also found at the height of 680 feet.

This breccia must not be confounded with that of Bausi Raussi; they differ not only in geological position, but in the nature of their fossils. Bausi Raussi is more recent.

* The following is a sketch of his list:

"Vaginula, 1 species.—Polystomella, 1.—Robulina, 1.—Turbinulina, 3.—Bulla, 1.—Scaphander, 3.—Bullina, 2.—Pyramidella, 2.—Turritella, 11.—Natica, 1.—Nacca, 1.—Eulima, 2.—Nerita, 1.—Bolma, 1.—Trochus, 2.—Gibbula, 3.—Solanum, 3.—Scalaria, 1.—Cerithium, 4.—Buccinum, 10.—Purpura, 1.—Cyclope, 1.—Eione, 1.—Planaxis, 3.—Dolium, 1.—Cassis, 3.—Cassidaria, 1.—Cancellaria, 3.—Murex, 7.—Fusus, 6.—Turbinella, 1.—Pyrula, 1.—Otus, 1.—Pleurotoma, 8.—Mangelia, 1.—Turbonilla, 2.—Rostellaria, 1.—Conus, 4.—Marginella, 1.—Cypræa, 1.—Mitra, 3.—Stomatia, 1.—Fissurella, 1.—Patella, 1.—Ostrea, 3.—Anomia, 1.—Pecten, 5.—Lima, 3.—Pinna, 1.—Arca, 5.—Pectunculus, 7.—Nucula, 1.—Lembulus, 2.—Cardita, 3.—Cypricardia, 1.—Venericardia, 1.—Tridacna, 1.—Chama, 2.—Cardium, 7.—Donax, 1.—Lucina, 1.—Loripes, 1.—Taras, 1.—Tellina, 8.—Capsa, 1.—Cyprina, 1.—Crassina, 2.—Cytherea, 3.—Venus, 8.—Arctoe, 1.—Venerupis, 1.—Corbula, 4.—Erycina, 1.—Mactra, 2.—Mactrula, 1.—Mya, 1.—Pandora, 1.—Teredo, 1.—Teredina, 1.—Balanus, 1.—Terebratula, 1.—Dentalium, 7.—*Of Polypifers:* Turbinolia, 8.—Fungia, 2."

† From barometrical observations made in company with M. Verany.

On reviewing the superior or tertiary rocks, we seem entitled to assume,

1. A state of repose; the blocks of the lower breccia being angular with the inferior valves of Spondyli adhering to them, and often perforated by Lithodomi.
2. An epoch still of repose, in which Mollusca abounded, and were enveloped in clay or marl.
3. An epoch of violent disturbance, proved by the nature, size, and roundness of the fragments in the sandstone and conglomerates.

It is exceedingly difficult to identify any of these tertiary beds with those of the London and Paris basins. The more minute our divisions, the narrower must be the area to which they apply.

The conglomerates, the lower beds of which alternate sometimes with clay, may possibly be referred to some epoch when the Alps were broken up. They are found on all sides of the chain, and of so great thickness, that the catastrophe which produced them, must have been felt at considerable distances. In the vicinity of Nice they seem to have suffered little or no disturbance since their deposit. All the tertiary rocks indeed of this neighbourhood rest quietly on the disturbed strata of the secondary:—this is not, however, the case on the Swiss side of the Alps, for there the tertiary rocks are disturbed with the secondary.

II. Supermedial or Secondary Rocks.

1. Green-Sand Formation.

The series next to be described presents an intimate admixture of siliceous, argillaceous, and calcareous matter, in proportions which frequently vary: the whole may be referred, in my opinion, (and I am happy to add in the opinion also of M. Elie de Beaumont and Professor Buckland), to the green-sand series of England and of France. The individual members of it, or at least the principal, are as follow, commencing with that which usually occupies the highest place.

Brown micaceous Sandstone, with Marl.

This rock occurs at Menton, and between Cap de la Mortola and Vintimiglia, being at the latter place covered by tertiary conglomerates and grey marl. The section afforded by ascending the Latte for a short distance, and mounting towards the Castel d'Appio*, is very instructive. The following is the descending order beneath the great mass of grey clay-marl there observable.

1. Compact, brown, siliceous sandstone, with Nummulites; (strata rather thick.)
2. Grey sandstone and marl.
3. Coarse, quartzose sandstone, or fine-grained conglomerate.

* Plate XXIII. fig. 4.

4. Brown, siliceous sandstone.
5. Grey marl.
6. Compact, brown, micaceous sandstone.
7. Compact or schistose, siliceous, and micaceous sandstone.

Lignite is observable in these beds near Vintimiglia.

Grey-Blue Limestone with Nummulites.

This formation occurs near Cap de la Mortola, where there is the following section.

1. Grey-blue limestone, with Nummulites; it forms a thick bed near the village of La Mortola, and occurs beneath the micaceous, brown sandstones above noticed.
2. Grey marl and micaceous sandstone, containing lignite.
3. Grey, marly limestone, containing Nummulites and Gryphites or Ostrea.
4. Dark-coloured limestone, containing white shells and corals.
5. Thick, grey-blue limestone bed, full of large-bombed Nummulites.
6. White marl.
7. Grey, marly, and arenaceous strata.
8. Compact, light-coloured limestone of Pont St. Louis.

Let it not be supposed that the presence or abundance of Nummulites disproves the opinion I have given, that this series of rocks corresponds with the green-sand of England. In England, indeed, Nummulites are rare in that formation; but M. Elie de Beaumont* met with them in the green-sand of Martigues (Bouches du Rhone) in company with Gryphites, Hippurites, and Terebratulæ. He adds†, "Je citerai aussi une Cucullée (*Cucullæa carinata*) dont j'ai retrouvé l'analogue dans des couches qui se rapportent incontestablement à la formation du grès ferrugineux et du grès vert à Saint Ils, près Castellane (Basses Alpes), aux Granges de Bellevue, près Uchaux (Vaucluse), à Brousseval, près Vassy (Haute Marne), et à la côte de S[te] Catherine, près Rouen: un Trochus, ou Pleurotomaire, et une Melanie ou Phasianelle dont les analogues existent dans le grès vert en Angleterre et en Normandie, et un Fuseau que M. Desnoyers croit très voisin de l'un de ceux que M. Miller a trouvé dans le Green-sand des Black Down Hills‡."

Nummulites are intimately mixed with Gryphites, in the rock to be next noticed, at Bausi Raussi and Beaulieu Bays. This connection is important, as it shows that the rocks No. 1. and No. 2. above enumerated, and those which follow, do not belong to different systems. At the bottom of Beaulieu

* M. Brongniart, M. Cordier, and M. Elie de Beaumont, who had examined the South of France before I went there, obligingly communicated the information they possessed respecting it on my return through Paris.

† *Mém. de la Soc. Linnéenne de Normandie*, vol. iii. p. 141. ‡ p. 142.

Bay we find a few thick, light-brown and arenaceous beds, containing such an abundance of small Nummulites, that the rock has sometimes the appearance of being composed of them. They dip, highly inclined, to the E.N.E., and rest on thick sandstone strata, which rest on marno-arenaceous limestone full of Gryphites. The nummulitic beds also contain Pectens and Serpulæ. These beds re-appear in the direction of the strata in Bausi Raussi Bay; and their passage into the gryphitic limestone may there be seen, one bed containing a mixture of Gryphites and Nummulites. The whole is subordinate to the marno-arenaceous limestone of the vicinity, which both covers and supports it.

Marno-Arenaceous Limestone.

This stratum occurs at St. Hospice, Mont Revel, Mont Gros, &c. &c.

It is very variable in its nature. Sometimes the marly character prevails, sometimes the arenaceous; but the whole is so intimately connected, that it cannot be separated. The colour is generally grey; it is the 2nd limestone of Mr. Allan,—the *calcaire marneux stratifié* or lias of M. Risso, and the green-sand of M. Elie de Beaumont.

Fossils.—Alcyonic bodies, almost always siliceous.
Large *Gryphæa columba* (*bisulcata* of M. Risso), chalcedonified; central part of the thickness of the shell frequently calcareous spar.
Small Gryphites, numerous, chalcedonified.
Echinites.
Pecten.
Nummulites.
Serpula.
Inoceramus sulcatus. North side of Mont Gros; discovered by M. Verany.
Turrilites.
Hamites compressus.—M. Risso.
Ammonites. } Same rock at Grasse.—M. Martin du Martigues.
Ostrea carinata. }

A cretaceous bed in a valley marked on a lithographic map of the environs of Nice, as the valley of St. Pons, contains black, cherty flints: this bed supports the tertiary conglomerates which are stratified horizontally. Good sections of the marno-arenaceous limestone are seen at the Peninsula of St. Hospice, Mont Revel, Mont Gros, Valley of Falicon, Valley of St. André, and the neighbourhood of La Trinité.

Light-coloured Limestone with green grains.

This limestone occupies in general the lower part of the formation, though it is sometimes interstratified with the marno-arenaceous limestone, described above.

Fossils.—Belemnites, very abundant.
Ammonites.
Nautili.
Pectens.

Mr. Allan compares this bed to the Mulatto limestone of Antrim; but erroneously supposes it to be adventitious, extremely irregular, and of small extent: it is by no means rare, and occurs regularly in its place. Localities,—near the Port of Nice, Col de Villefranche, eastern flank of Mont Alban, Peninsula of St. Hospice, Bausi Raussi Bay, Mont Revel, Mont Gros, Valley of Falicon, &c.

M. Risso justly considers the light-coloured limestone with green grains, and the gryphitic and nummulitic beds to be the equivalents of the green-sand of England; but, inverting the order in which they really occur, he places the marno-arenaceous limestone beneath the green beds, and the light-coloured limestone and dolomite, and supposes it to be the equivalent of lias. The true order of superposition is, however, very apparent when examined with care.

The rocks above enumerated as members of the green-sand formation, are everywhere disturbed and contorted: so much so in some places, that they might easily induce an unguarded observer to suppose them inferior to the compact light-coloured limestones and dolomite, upon which they are in reality incumbent. Striking instances of these disturbances are observable between St. Hospice, Bausi Raussi, and Villefranche; for example, in the Valley of Falicon, near La Trinité, and on the road from Nice to Menton and Vintimiglia.

These beds appear to have been once more extensively distributed than at present. A detached portion of them occurs near the Col de Villefranche, not far from the little chapel:—other patches also occur on Mont Alban, the east side of the valley of St. André, and on the road between Nice and Menton. The plastic clay with lignite, which M. Risso describes on the southern side of the Castalets, is improperly so called; it is an outlier of the green-sand formation.

At the Col de Villefranche this green-sand formation seems to pass into the light-coloured limestones beneath it; for green-grained beds seem included in the upper beds of the latter: this appearance is not, however, common. The following sections will show the manner in which these rocks usually come in contact,—order ascending.

a. *Peninsula of St. Hospice.*

1. Dolomite.
2. Compact, light-coloured limestone; beds nearly vertical; direction N.N.W. and S.S.E.

3. Green-grained beds full of Belemnites, Ammonites, Nautili, Pectens.
4. Grey marl.
5. Grey, arenaceous limestones, containing large *Gryphæa columba*, chalcedonified strata nearly vertical.
6. Grey limestones, more arenaceous, containing small siliceous Gryphites, (dip becoming less highly inclined.)
7. Brown, calcareous gritstone.
8. Brown and grey arenaceous beds, containing numerous alcyonic remains mostly siliceous, Echinites, Pectens, Terebratulæ.

b. *Mont Revel.*

1. Dolomite.
2. Compact, light-coloured limestone, dip small, E.N.E.
3. Green-grained beds, containing Belemnites, Ammonites, Nautili.
4. Grey marl of considerable thickness, containing a few beds of marly limestone.
5. Grey, arenaceous limestone, mixed with a little marl.
6. Arenaceous beds, containing siliceous alcyonic bodies—dip N.E. highly inclined.

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2. Light-coloured Limestone and Dolomite.

Limestone of Mr. Allan.

These rocks are so intimately connected as to constitute only parts of one formation. They are the base of all the country near Nice, and form the mass of Mont Cao and Pacanaïa; the former, according to M. Verany's observations, is 2800, and the latter 1950 feet above the sea.

a. Limestone.

De Saussure first noticed the resemblance of this to the limestone which occurs at the base of the Saleve near Geneva*. It is light-coloured, very compact, and sometimes veined with calcareous spar, and sometimes, though rarely, with cherty flint; the strata are two, three, or four feet in thickness, and generally well defined.

At Turbiglia it supplies crushing-stones for the olive mills. Near the same place it was quarried by the ancients to build the tower or trophy of Augustus, whence the town derived its ancient, and, by corruption, its modern name. The quarries there are nearly in the state now in which they were left by the Romans.

b. Dolomite (Saccharine Limestone of Faujas St. Fond, Allan, and Risso).

The dolomite when most crystalline is white; the other varieties present

* Voyage dans les Alpes, vol. iii.

various shades of grey or light brown: the stratification is indistinct, sometimes imperceptible.

Fossil remains are exceedingly rare, as has been observed by Mr. Allan, in both these rocks. He mentions an Ammonite, an Echinus, a Pecten, and Corals: the latter are in great abundance near the light-house at St. Hospice. Perhaps the Echinus may have been an Encrinus, as there is little difference in the fracture of these fossils. The rest of the organic remains which he enumerates belong, I believe, to the green-sand formation. In the limestone now under consideration, I have observed only, here and there, a solitary Terebratula.

Gypsum.

To the same formation I am disposed to refer the gypsum found along the southern slope of the Cimiéz; for its apparent continuation at the base of the Venagrie is included in the dolomite and light-coloured limestone, as is also the gypsum of the Requiéz. It is of various shades of grey and red, generally more or less crystalline, with little coherence, and rather massive than stratified.

There would not appear to be any regular order in which the dolomite and limestone are disposed; they are so singularly mixed, that it is impossible to calculate upon the occurrence of dolomite in any particular part of the series: when the latter is very crystalline and stratification has ceased, it has sometimes even the appearance of an intruded mass.

I agree with M. Brongniart in considering these beds of limestone, dolomite, and gypsum, the representatives of the Jura limestone, which occurs extensively along the western side of the Alps, from Geneva to the Mediterranean. That the compact limestone near Nice closely resembles that of the Saleve has been already noticed, and the Saleve limestone is usually considered synonymous with the oolite range of England.

These limestones, dolomites, and gypsums, are so intimately associated, that no rational classification can disconnect them. In this respect they agree entirely with those great ranges of rock which traverse the Tyrol, Carinthia, Stiria, and the North of Italy, and probably Dalmatia, as described by Von Buch, Maraschini, and Fortis. Von Buch's theory of the change of common limestone into dolomite, by the escape of magnesia from the subjacent pyroxenic rocks, and of the disturbance of the strata wherever this change has taken place by the protrusion of pyroxenic porphyry and trap, if true in regard to the Tyrolese rocks, may be applicable to the maritime Alps.

In the immediate neighbourhood of Nice, it is true, no trap rocks have as yet been discovered, though there is no want either of trap or porphyry among the rolled pebbles of the tertiary conglomerates. Greenstone rocks, &c. occur abundantly in the mountains of St. Tropez, and at the Estrelles the black trap rocks intersect the red quartzose porphyries, as, according to M. Von Buch they do in the Tyrol.

The highly inclined position, and the frequent and violent contortions of the dolomite and its accompaniments near Nice, and of the green-sand formation by which it is covered, connect these rocks still more closely with the Tyrolese and those of Switzerland. I agree with M. Von Buch in ascribing these phænomena to the upheaving of the Alps by igneous rocks. The presence of dolomite and even gypsum is, taken singly, characteristic of no formation. Magnesian limestone, if not actually crystalline dolomite, is well known in carboniferous limestone; both dolomite and gypsum are also well known in the zechstein or Alpine limestone, and crystalline dolomite occurs at Feigenstein* near Nassareith. Dolomite and gypsum are met with in the muschelkalk of Toulon†; and the lower parts of that rock are magnesian also in the Vosges‡. Dolomite and gypsum occur in the lias or lower members of the oolite beds in the south-west of France§; there is no reason, therefore, why the occurrence of these substances in the neighbourhood of Nice, should make it at all improbable that the formation to which they belong is, as I have represented, the Jura or oolite formation.

There appears to be not unfrequently an intimate, and as yet unexplained, affinity between gypsum and dolomite. Some rhombic crystals, which M. Verany discovered in great abundance in the gypsum at Sospello, M. Cordier, to whom I gave them for examination, reports to be carbonate of magnesia or dolomite, which, he adds, is found under another form in the gypsum of the Tyrol. On the other hand, rocks which contain magnesian strata often afford gypsum—as the zechstein, the new red sandstone, the muschelkalk, the keuper, and the Jura beds.

In a former communication to the Society, I pointed out the marked changes which rocks sometimes undergo within the range of a few miles. The changes here observed are much greater, as the range is more extensive. Near the extremity of the peninsula of St. Hospice, included among the dolomitic, are some beds of common limestone, which contain Encrinites, traces of coral, and particularly a Favosites, to which M. Risso has given the specific title *democraticus*. These beds, with the dolomite adjacent, he considers the

* Von Buch: Lettre à M. de Humboldt, p. 16. Plate II. fig. 9.

† Von Buch. He was the first to notice it.

‡ Elie de Beaumont.

§ Dufrenoy, Ann. des Mines 1827, vol. ii. p. 345.

equivalent of coral-rag. To assign equivalents for beds which we have never seen, and which we know only by description and very imperfectly, is a practice highly reprehensible, and tends to nothing but confusion.

The very great importance frequently attached to hand-specimens is injurious to the progress of geology. It leads those who are unaccustomed to examine the development of the same formation in different and distant countries, to believe, that a similarity of external mineralogical character is necessary to establish its geological identity. That this is not true in regard to the dark clay of London, and the light coarse limestone of the Paris basin, is well known; yet many geologists are not so completely sensible of the little value of mineralogical character under such circumstances, as to find, without surprise, that beds of gypsum and dolomite are members of the oolite formations. They, however, have every appearance of being so in the neighbourhood of Nice; and the anomalies which the green-sand formation present to us in the same neighbourhood, afford another practical lesson, that a minute attention to mineralogical distinctions, and an accurate examination of hand-specimens are, on many occasions, even worse than useless, and tend rather to mislead the geologist than to instruct him.

Additional Note, August 5, 1829.—Since the above was written, much additional information, derived more particularly from my friend M. Elie de Beaumont, would seem to render it probable that the Nice light-coloured limestones and dolomite, either constitute the lower part of the great green-sand formation, or the upper part of the oolite system. From an extensive series of observations, M. Elie de Beaumont is led to consider the nummulitic beds of the Alps as intimately connected with the light-coloured limestones of Nice, of Provence, of La Fontaine de Vaucluse, of Mont Ventoux, of the departments of the Drome, the Isere, &c.; the nummulite-rocks at the same time being connected with the well characterized deposits of Briançonnet (Basses Alpes), of Villard de Lans (Isere), of the mountains of the Grande Chartreuse, of Mont du Chat, of the high longitudinal valleys of the Jura, of the Perte du Rhone, of Thonne, and of La Montagne des Fis. Whatever may be the age eventually given to the Nice limestones, it would appear from the observations above noticed, and others, which it would be out of place here to detail, that the nummulite-beds of the same neighbourhood belong to the green-sand formation, and not, as might be supposed, from a partial examination of the Alpine nummulite-rocks, to any tertiary deposit.

VIII.—*Observations on the Secondary Formations between Nice and the Col di Tendi.*

By the Rev. W. BUCKLAND, D.D. V.P.G.S., F.R.S. F.L.S. &c. &c.
PROFESSOR OF MINERALOGY AND GEOLOGY IN THE UNIVERSITY OF OXFORD.

[Read January 16th, 1829.]

HAVING occasion to visit the neighbourhood of Nice in the spring of 1826, I am gratified to bear testimony to the accuracy of the description of that district given by Mr. De la Beche in the preceding paper, and beg to subjoin a few observations which I made in company with M. Risso along nearly fifty miles of the high road that runs north-east from Nice towards the Col di Tendi.

The hill, one mile south of the village of Scarena and twelve miles north-east of Nice, affords a section of the green-sand formation, the details of which I noted on the spot, and which coincide with those given by Mr. De la Beche in other localities nearer to Nice. The mass of the stratum is a blue and grey marlstone, like the chalk-marl or firestone of England; through this are dispersed, subordinately, beds of a coarse and gritty limestone, with large calcareous masses containing green earth, and nodules of chert and of coarse jasper resembling the chert and jasper of the green-sand formation at Lyme and Sidmouth. The beds near Scarena abound with Nummulites, Turrilites, Ammonites, and the usual shells of the English green-sand formation. All these characters, however, disappear in the compact grey limestone, which both covers and lies beneath the well defined beds of green-sand; and it deserves investigation, whether the superior compact limestone is a modified condition of chalk, or an equivalent to the sandy and argillaceous deposits that make up the great bulk of the green-sand formation of England; the study of its fossils will hereafter probably be decisive of this question.

On the road from Scarena to Sospello, at a spot called Rocca Tagliata, the Mountain of Braus exhibits strata almost entirely composed of grains of green earth, and loaded with Ammonites, Belemnites, and Nummulites. Three distinct and thick beds of this green-sand alternate with beds of blue marl and of blue limestone: all these dip inwards to the centre of the mountain, and are covered by a vast thickness of compact limestone; they again emerge from beneath this limestone a few miles further north along the road, and mark at each of these places the outcrop of the decided green-sand beds, dipping as if to a common centre in the interior of the mountain.

Descending from the northern outcrop of this green-sand towards Sospello and the Col di Tendi, we find, in a regular descending order, the following series of rocks:—1. Green-sand; 2. Jura, oolitic, or younger Alpine limestone; 3. Lias; 4. Red marl; 5. Older Alpine limestone, strongly dolomitic, and abounding in rauchwacke, and mixed with enormous beds of gypsum. Nearly the same order of succession is repeated in the calcareous mountain called Brois, between Sospello and Breglio; but I saw no green-sand near the road over this mountain.

The descent from Brois towards Breglio, affords a section of at least 1500 feet in the new red sandstone formation, in which we have the same association of masses of gypsum, with various forms of yellow, red, and saccharine dolomite, of rauchwacke, and zechstein, that characterize the older Alpine limestone, and the new red sandstone formation in the Alps, as well as in Germany and England. Following this section still further towards the primitive chain of Col di Tendi, we find the valley of the Roya exposing various beds of the new red sandstone formation from Breglio to Saorgio: near this latter place they become more loaded with pebbles, approaching the character of the new red conglomerate or rothe-todte-liegende; and three miles further north, at the village of Il Fontana, we have the junction of this conglomerate with coarse red micaceous beds of grauwacke slate.

Beyond Fontana, it may be seen by M. Risso's map of the maritime Alps* that only transition and primitive rocks appear along the whole road to the Col di Tendi.

These sections afford an important sequel to the information which Mr. De la Beche has given respecting the limestone in the immediate vicinity of Nice, and supply details of the strata in the lower regions of this great calcareous deposit, which show them to be the regular continuation, in a descending series, of the same component members of the new red sandstone formation and older Alpine limestone, which in my paper on the Alps†, I have stated to maintain a general harmony and uniform order of succession in the Alps of Switzerland and the Tyrol, as well as in Germany and England.

This conclusion is corroborated by the following opinion of M. Risso. He says‡, "I consider as the most ancient formation of the secondary epoch, the alpine calk or magnesian limestone, compact, sparkling, of a dark blue

* *Hist. Nat. de l'Europe Meridionale*, vol. i.

† Annals of Philosophy, June 1821.

‡ Vol. i. p. 82.

colour, but giving rise to many springs, ordinarily containing no fossils, but presenting sometimes in its superior beds very ancient fossils;—it is accompanied by rauchwacke; contains sometimes fetid limestone, and is found frequently intermixed with gypsum; its total thickness may be reckoned at 1500 feet."

M. Risso also informed me, that near the source of the Var this same elder Alpine limestone contains gypsum, associated with sulphur and salt springs.

I did not examine the gypsum of Vinagrié and Requiez, on the east of Nice, which Mr. De la Beche considers as connected with the Jura or younger Alpine limestone; and, at the gypsum quarry of Cimiez, a little north of the town, I could find no decisive junction. But I think it remains to be determined, by the analogies of other districts, whether the gypsum at these three localities is protruded to the surface by the elevations and contortions that occur in this neighbourhood, and occupies the usual place of gypsum below the Jurassic and in connection with the elder Alpine limestone; or, whether it offers the novel phenomenon of massive gypsum, coëval with the Jura or younger Alpine limestone, a formation in which, thin beds of fibrous gypsum, and selenites dispersed through beds of clay, are the only forms of sulphate of lime which have, till lately, been noticed. The recent observations of M. Brongniart, M. Dufrénoy, and M. Elie de Beaumont, in the South-east and South of France, favour the opinion of Mr. De la Beche, that the gypsum at Nice belongs to the Jura limestone formation. It may, however, be stated, that Mr. De la Beche's section *, is not inconsistent with the other hypothesis: for the dip of the Castle Rock is towards and beneath the gypsum of Cimiez; and if this Castle Rock be referred to the dolomite of the new red sandstone formation, it will occupy its usual place subjacent to the gypsum. It may be observed still further, that should the Castle Rock belong to the Jura limestone, its dip towards the gypsum of Cimiez may still be explained, by imagining a fault to cross the plain of Nice between Cimiez and the castle.

The usual association of the members of the new red sandstone formation may be seen also in the South-east of France, along nearly the whole line of road from Toulon to Frejus and the base of the Estrelles. From beneath the mountains of limestone that stretch north-east from Toulon, the new red sandstone emerges, and presents nearly all the ordinary associations of red marl and red sand, with gypsum, granular dolomite, rauchwacke, and red conglomerate, which are so familiar to us in Central Germany. Near the base of the Estrelles, this conglomerate is loaded with pebbles of reddish porphyry, derivative from these mountains, and much resembling the porphyritic pebbles

* Plate 23. fig. 1.

of the red conglomerate at Exeter, and of the rothe-todte-liegende at the base of the Hartz.

Mr. De la Beche has pointed out, in the neighbourhood of Nice, details which confirm the statement made in my paper on the Alps above alluded to; namely, that limestones of all formations occasionally become dolomitic, and that the occasional presence of dolomite will of itself enable us to infer nothing as to the age of the strata in which it may occur. Still I think it will be found that in formations more recent than the new red sandstone, it assumes only an accidental place and subordinate character amongst beds whose greater mass still retains the condition of common carbonate of lime; whilst, in the new red sandstone formation, the calcareous beds are almost exclusively dolomitic, and the dolomite is of a most strongly marked and decided character. Moreover, I cannot entirely acquiesce with him in the theory of M. Von Buch, which attributes the origin of the magnesia in the great dolomitic mountains of the Tyrol and other localities to the agency of subjacent pyroxenic rocks. I have long been aware that at their point of contact with beds and dykes of trap, limestones of all ages are occasionally impregnated with magnesia, and become dolomitic to a small distance only from the pyroxenic rocks: but I see no reason from hence to argue that strata of many hundred feet in thickness, and at the distance of many miles from any known pyroxenic rocks, have derived their magnesia from subjacent igneous rocks, where we have no proof of their existence. Nor do I see how, on this hypothesis, we could ever find strata of carbonate of lime alternating with beds of dolomite; for, how in cases of such alternations could the superior beds have derived their magnesia from beneath, without the inferior calcareous beds also being equally, or in a greater degree, converted into dolomite? and yet examples of these alternations occur abundantly in all formations, and present an objection which it behoves the supporters of the theory of Von Buch upon this subject to explain.

IX.—*On the Geology of a Portion of Bundelcund, Boghelcund, and the Districts of Saugor and Jubulpore.*

BY CAPTAIN JAMES FRANKLIN, OF THE BENGAL ARMY. F.G.S. F.R.S.

[Read June 20th, 1828.]

HAVING had an opportunity of examining the geological features of a portion of the provinces of Bundelcund and Boghelcund, and of the districts of Saugor and Jubulpore, I have the honour to submit the result of my observations, together with a map and section, to the Geological Society of London: and I beg more particularly to offer to their attention the limestone formation which is found on the summit of the second range of hills, as it appears to correspond in every particular with the lias of England; nor am I aware that this formation has heretofore been shown to exist in India.

The tract which has fallen under my observation, is a portion of the lowest northern steps of the Virídáya mountains. The ranges of hills have separate names, which serve for local distinction; but, viewed as parts of the general geology of India, they all merge in the common denomination of the great zone which they contribute to form.

I commenced my route at Mirzapore, a place of considerable traffic on the river Ganges, and ascended the first range of hills at the pass of Tara. The tract between these two places is not very interesting in a geological point of view, being composed of alluvium reposing upon beds of "canker," or intimately intermixed therewith; and, near the hills, it has been found, from the excavation of wells, to rest on sandstone.

The first range of hills is composed of sandstone, horizontally stratified, and consisting of fine grains of quartz cemented by clay, which is more or less coloured by red oxyd of iron. The sandstone is saliferous, as is evident from the plains below being saturated with salt; and there are, I understand, salt-works on the banks of the Tonse river. In many parts it has sufficient cohesion for architectural purposes, to which it is applied; and it is likewise quarried for pavement slabs, hand-millstones, &c.: in every point of view, indeed, it appears to correspond with the central portion of the new red sandstone of England.

From the crest of the Tara Pass to the foot of the second range of hills near Kuttra, the whole tract is a platform varying from a perfect level only by occasional protrusions of the rock above the surface; and it increases in elevation in a south-west direction. In the part where I passed, except immediately on the crest of the hill, the platform is covered with "canker," either intermixed with the alluvium, or in beds, as in the Scroti river near Buroundu, where it reposes on sandstone. This part of the range is not rich in minerals or metals; but another portion of it is remarkable for containing the diamond mines of Punnah, and the extensive iron mines of Kutola.

I ascended the second range of hills at the pass of Kuttra, and found near the top of it a thin stratum of red clay and sandstone, interstratified in thin laminæ, and surmounted at the summit by friable and variegated sandstone. These beds resembled the red marl of England, and they reposed on a friable slaty marl, which was also in thin laminæ, and coloured by chlorite. The slaty marl rested upon massive beds of a rock horizontally stratified, and resembling grauwacke.

The summit of the second range is a platform like the former, and varies from a perfect level only by the same description of undulation. In order to examine its composition, I visited all the water-falls between the Kuttra Pass and the Tonse river.

The first of these cataracts is near the village of Billohi, about twelve miles west of the pass of Kuttra. The fall of water is 398 feet, and the escarpment nearly perpendicular. At the bottom I found fragments of chlorite-slate; but the lowest bed *in situ* was a thin stratum of fine argillaceous sandstone, tinged deeply by red oxyd of iron, and containing mica disseminated in small particles. Upon it reposed a bed of siliceous sandstone. These strata were compact and hard. They were covered by a thick bed of variegated sandstone which continued to the surface.

From the cataract of Billohi, I proceeded to that of Bowttee, ten miles further west. This is a stupendous chasm, and highly picturesque, not so much from the fall of water, which is 400 feet, as from the extent of the *cirque,* the perpendicular height of which is 420 feet. At the bottom was a greenish white, arenaceous sandstone, not quite so compact as that of Billohi, though perhaps a continuation of the same; and upon it, commencing at the depth of 300 feet below the surface, was a variegated or mottled stratum; to this succeeded another of red, purple, or salmon-colour, which extended to the surface.

The cataract of Kewti, twenty-four miles west from Bowttee, and those of

Cachye and the Tonse river, present the same varieties of sandstone as occur at the falls of Bowttee.

From the cataract of the Tonse river, I proceeded by Birsingpore, Hathee, Sohawel, and Nagound, to Lohargaon, and met with no rock but sandstone, sometimes ferruginous, and sometimes slaty with mica, until I arrived at Hathee, where it changed to argillaceous limestone.

At Birsingpore, in the bed of a small river which runs near the town, was a stratum of red marl or sandstone, containing laminæ of calcareous spar distinctly interstratified. At Sohawel, red marl underlay the limestone above mentioned. At Nagound, in the bed of the Omeron river, the lower and central portions of the limestone were exposed to view, and contained fragments of fossil wood, stems of fern, and the gryphite shell which is peculiar to this formation. At Murhur, near the tank of the old village, it reposed on red marl in conformable stratification; and at Lohargaon, the wells of the cantonments exhibited its upper or marly beds reposing upon grey limestone.

From Lohargaon I proceeded to Saugor. The first part of the route, or to the bed of the Cane river near Tigra, exhibited, alternately, limestone lowlands and sandstone hillocks. In the bed of the river itself was red marl and sandstone. From that locality the same alternation extended to Hutta, where the limestone reposed on red marl in the banks of the Sonar river. The same order of superposition occurred at Nursinghagarh, in a small ravine north of the Fort; but there the marl was tinged by green earth or chlorite. At Pureriah the limestone was exhibited in contact with trap rocks, and was thereby changed both in appearance and nature. Those portions which contained most silex were converted into chert; and, in some specimens, one half consisted of chert, and the other half retained the property of effervescing with acid.

The aspect of this limestone is dull and earthy; its stratification horizontal, or nearly so, and always conformable to that of the red marl on which it reposes;—its lower beds are thin and separated by argillaceous partings, and, for the greater part, sufficiently compact for lithographic purposes;—its middle beds are massive, usually of a dark smoke-grey colour, always exhale a strong argillaceous odour when breathed upon, and contain fragments of petrified wood, the stems of ferns, and a gryphite*. This variety burns into a strong lime, which has the property of hardening under water. The yellow variety

* It is very much to be regretted that no specimens of the fossils above mentioned reached the Society. The rock specimens have certainly all the characters of lias; and some of them can hardly be distinguished from the white lias of Bath, and a variety of lias-conglomerate from the neighbourhood of Shepton Mallet.—W.J.B.

is always compact, usually dendritic, and presents frequently on its surface irregularities which represent the interlacings of ivy.

This limestone extends over the platform of the second range of hills, and covers it with a thin stratum, the continuity of which is interrupted only by the occasional protrusion of the red marl or sandstone on which it reposes.

After passing the town of Pureriah, I came upon the overlying rocks which I designate by the general term of trap. The hills on the left of the road are composed of these rocks, and after ascending the pass of Pureriah I met with no other description of rock between it and Saugor.

The upper part of the trap of Pureriah, like that of Saugor, is generally composed of boulders imbedded in friable wacke, and vary in size from that of an egg to that of a large bomb-shell. They are formed of concentric layers, which are sometimes very thin and often numerous.

Under the stratum of boulders, which occupies the highest parts, is a bed of indurated wacke that passes into basalt, and is occasionally vesicular. Beneath it is a stratum of earthy limestone.

I have termed this rock earthy limestone, because I know not what other name to give it. Its principal component is carbonate of lime; and next to that is alumine; it also contains silex, and, when this earth abounds, the rock is converted into chert; on the other hand, when ferruginous clay abounds, it passes into jasper. It occasionally assumes the texture of highly indurated clay, and sometimes, though very rarely, the hardness of clinkstone, but, generally speaking, it is friable. On the borders of the trap where it is always found, if the trap reposes on sandstone, it contains nodules of sandstone imbedded in it.

Below the limestone is a stratum of amygdaloïd, containing calcareous spar and occasionally zeolites. Sometimes it resembles the toadstone of England; and it has been ascertained, by the excavation of wells, that it reposes on sandstone at Saugor. I have not met with it *in situ* in any other part, except some indistinct vestiges near Iysinghanugur.

From Saugor I proceeded southward by Iysinghanugur to Tendukaira, and met with no rock except trap, which contained abundance of chalcedony, semi-opal, mealy zeolite, cacholong, agates, jaspers, and heliotrope, until I descended the range of hills which forms the northern barrier of the valley of the Nermada river.

This great valley is favourable for throwing light on the primitive rocks of the central chain, as the overlying beds appear to have been removed, and the older strata exposed to view. The whole mass of overlying rocks which had been previously passed, reposes on red marl or sandstone; as is apparent in the bed of the Barama river, about one mile north-east of Tendukaira, and all along the foot of the hills in that direction.

Its associate, the earthy limestone, here becomes a friable rock; but its property of effervescing with acid is not destroyed, except in a few instances, where it becomes highly indurated; and in such cases I presume it contains felspar. It fuses readily with a moderate heat, and operates as a flux when mixed with clay: it contains likewise fragments of sandstone, which are more or less changed by its contact.

After descending the hills, and advancing about three miles into the valley of the Nermada river, a new field opens. The older rocks are laid bare; but, instead of exhibiting horizontal stratification, they are highly inclined, sometimes perpendicular, and altogether unconformable to those which I had previously passed. I shall not here mention the iron mines of Tendukaira, because a satisfactory account of them would swell this paper too much; but I will observe one circumstance. The conical hill about one mile and a half westward of Tendukaira, is composed of trap, and its summit was once crowned with a cluster of basaltic columns; but some powerful operation of nature has dislocated them.

From Tendukaira I made a detour to Garha Kota, and my route thither enabled me to lay down the eastern boundary of the trap formation. A reference to the map* will explain the result of this part of my route. I found the trap always in intimate association with earthy limestone, and the whole series reposing on red marl or sandstone.

From Garha Kota I returned to Great Deori, and proceeded across the Bandain hills to Jubulpore.

After quitting Deori, trap prevailed for about three miles, and then commenced the sandstone of the Bandain hills, which continued uninterruptedly until I descended the escarpment of these hills, and again entered the valley of the Normada river.

The sandstone of the Bandain Hills is mottled red and white; its stratification is horizontal, as far as the eye can judge; and it appears to be correspondent with the bunter sandstein of Werner, and consequently with the new red sandstone of England. The same hills are composed of sandstone opposite to Nagound, Lohargaon, Tigra, and Gurreah or Ghysabad; and there can be no doubt that the whole is a mass of sandstone.

After proceeding about three miles into the valley, I came upon the ridge of the Kymur range of hills, which in this part is composed of quartz rock varying to siliceous grit, and its strata are nearly perpendicular; but to the

* Plate XXV.

south-west of this point, near Hirapore, the rock is compact; and still further west, opposite Googri, it is intermixed with clay-slate and schistose limestone, which last contains mica, and perhaps serpentine.

Between this range and Jubulpore is a broad valley, covered by a thick stratum of alluvium, which required more minute investigation than my hurried route enabled me to bestow.

The town of Jubulpore is situated at the foot of a range of hills consisting of syenitic granite. The composition of the rock is flesh-coloured felspar, smoky quartz, black mica, and hornblende. I have traced the formation for thirty miles, in which distance it dips beneath, and rises above the surface several times, and becomes well-defined granite.

Every rock connected commonly with granite, is to be found in this neighbourhood:—gneiss, containing hornblende and partially decomposed, appears in the bed of the Normada river at Tilwara Ghat: gneiss, resembling mica-schist at Rammegur, and along the low range of hills which extends thence towards Lamaita: hornblende-schist in the hills between Bhowra and Parneri; and talcose and argillaceous schists between Bhowra and Murroud. In the bed of the river between Lamaita and Beragurh, a series of strata are exposed to view which exhibit a regular gradation from gneiss to roofing-slate, massive schist, schistose limestone, quartz rock, and beautifully snow-white dolomite.

The last rock, which appears near the water-fall, varies considerably in its characters in different localities. A few miles further west, near the village of Bograi, it effervesces freely, contains crystals of tremolite, and is so friable that it almost crumbles beneath the fingers. At Beragurh it is intimately associated with quartz; and the snow-white variety which resembles alabaster seems to be an aggregate of dolomite and pure quartz. This variety scarcely effervesces without being pulverized; but it takes a fine polish, and is quarried for various purposes. It is traversed in many parts by layers of chlorite schist.

The gneiss, which forms the extremity of the series mentioned above, contains but little felspar. One of the beds is contorted, friable, and of a greenish colour, from a mixture of epidote. The stratum which succeeds to it is also greenish, and contains small garnets and crystals of actinolite; but it is chiefly remarkable for being penetrated by numerous greenstone veins and nodules, which do not occur in either of the adjoining strata. The greenstone has a large granular structure, and the nodules inclose garnets.

The beds which follow these strata graduate into fine grauwacke, or micaceo-argillaceous schist of a soft and silky texture, still, however, preserving the green tinge. Upon them reposes a stratum of roofing-slate, and its superincumbent associate is massive schist. The slate might be used for architectural purposes, though not particularly fine. Its colour is dark lead, approaching to black. After the slates follow the schistose limestone, quartz rock, and dolomite. The former limestone, as well as the latter, contains magnesia.

From Jubulpore I returned to Tendukaira by another route, along the metalliferous range which it was my business to examine: but I shall refrain from giving any account of its mines, for the same reason which I have alleged in my description of Tendukaira. I must also defer sending a map of this portion, which I have constructed on a large scale, in order to show the position of the mines, until a future opportunity. In the mean time I may observe, that a part of the southern barrier of the valley of the Nermada river is composed like its northern opposite Tendukaira, Sermou, &c. of trap rocks, the contour of which I have laid down to the extent of eighty miles; and I trust that a future opportunity will enable me to complete the whole.

The result of my inquiries respecting this eastern deposit of overlying rocks is, that it extends southward as far as Chuparah, and thence eastward towards Mandela, Omercuntuc, and Sohagpore; but whether it unites with the great central mass, I could not learn. It is somewhat harder than the trap of Saugor, but does not essentially differ from it in character, though it differs greatly in its substratum, which is here granite or gneiss.

In the re-entering angles of the trap-hills, the occasional appearance of the primitive formations may be traced; and, in a cluster of such hills, about one mile south of Bograi, the rock is composed of mica, quartz, compact felspar, and chlorite, intimately intermixed in fine grains, and is somewhat friable. In the same hills also occurs a conglomerate composed of rounded pebbles of primary rocks; but it contains no fragments of greenstone or basalt, although the hills in question are nearly surrounded by trap.

After passing Bograi the valley expanded, and was covered by a thick deposit of alluvium, through which the dolomite occasionally cropped-out for a short distance; but, with these exceptions, no rocks appeared above the surface until I arrived at Keerpani, where the hills were composed of stratified quartz rock, sometimes granular, but more frequently compact, and containing felspar. The strata were highly inclined, and sometimes perpendicular; and there was no rock, except quartz, between Keerpani and the sandstone hills of Arrijerro, which are on the boundary of the sandstone and trap formations of the Saugor district.

To this enumeration of rocks may be added a very curious calcareous conglomerate, which is found in the bed of rivers whose source or whose channel is in trap districts. I have observed it in the bed of the Sonar river, north of

Reilli, and in other places: it occurs also plentifully in the Nermada river in various parts; but the largest mass I have seen of it is near the Janni Ghat.

It is composed of rounded fragments of wacke, basalt, sandstone, and occasionally of other rocks, varying from the size of a pea to that of an ordinary grain of sand, and cemented by calcareous matter. When the particles are fine, the rock in some respects resembles calcareous sandstone, and has sufficient cohesion for architectural purposes. Its stratification is always horizontal, the coarsest parts being the lowest; and, as it reposes on all the other rocks, it is evidently the latest formation. At Beragurh it may be seen in the high banks of the river resting on the primitive strata, and is itself covered to the depth of thirty feet only by alluvium.

Having thus given a description of my route, and a brief compendium of my observations, as they were made on the spot, I will now venture a few general remarks on the conclusions I have drawn from them.

The late Dr. Voysey observed that, "he had reason to believe, partly from personal observation, and partly from specimens obtained from other sources, that the basis of the whole peninsula of India is granite. He had traced it along the coast of Coromandel, lying under iron-clay; also in the bed of the Godaveri river, from Rajamandri to Nandair; and he had specimens from the base of the Seetabaldi Hills of Naypore, from Travancore, Tinnivelli, Salem, and Belhari*." To this may be added Mr. Sterling's account in his memoir on Cuttack, where he says, "The granite where my specimens were principally collected, appears to burst through an immense bed of 'laterite' (iron-clay) rising abruptly at a considerable angle†."

These are recorded facts on the southern side of the central chain; and on the northern side it may be observed that Neridar, Narhat, Hirapore, Adjygarh, and Callinger, all of them points in the same belt of sandstone, attest that granite is the basis of those hills; and a series of specimens from the latter place may be seen in the Benares Museum. The sandstone indeed becomes thicker to the eastward of Callinger, and the granite is not seen for a considerable distance; but the cataract of Billohi, and the pass of Kuttra, exhibit strong indications of its being at no great depth below; and, accordingly, it again re-appears, and eventually becomes the prevailing rock in the district of Ramgarh.

Though I am convinced that granite is very near the surface in many parts of the tract which has fallen under my observation, yet there is a series of primary stratified rocks intervening between the granite and the secondary

* See note, Asiatic Researches, vol. xv. p. 123. Art. "Diamond Mines of Southern India."

† Asiatic Researches, vol. xv. p. 178. Art. "Orissa Proper, or Cuttack."

formations, as in other countries; but there is reason to think that it is thin, and very often wanting; and my motive for thinking that it is thin, is, that its strata have no breadth, as in other countries:—as an instance, I refer to the series which is laid bare in the bed of the Nermada river, between Lamaita and Beragarh. The strata are there not intermixed like those of the Kymur Hills, but present a series of beds from gneiss upwards, each in its place, graduating imperceptibly into the next, and all preserving the same dip, direction, and parallelism; and yet this series is comprised within the space of two miles, without any evident reason for its being so confined.

The Kymur Hills undoubtedly pass under the sandstone of the Bandain Hills, and perhaps repose on granite; but I have no proof that they do so: and I mention it as one of those circumstances which may be better applied hereafter than at present.

The sandstone formation is the next which attracts notice. Its thickness is of course variable. At the Bouti cataract it exceeds 420 feet, and there can be no doubt that it is thicker near Chachye and the Tonse cascade;—at the Bandain Hills the thickness must be still greater. It appears to comprise most of the varieties of Dr. MacCulloch's lowest and superior sandstones, but the general parallelism of its strata to the horizon better identifies it with the new red sandstone of England.

The limestone formation is exceedingly curious. It constitutes a mere plastering over the surface of red marl or sandstone, and I should doubt whether it ever attains the thickness of one hundred feet; perhaps fifty may be a fair average. I have not met with it in any other place than on the summit of the second range of hills; and it may there be seen in the low lands and beds of small rivulets; but the larger rivers have their channel in the subjacent sandstone, and, perhaps, in some cases in the primitive strata.

The overlying rocks are not only the most extensive, but, considered as geological phænomena, the most important in India. The thickness of this formation is constantly variable. In the centre of India it occupies the summit of the highest mountains, and at Bombay it descends to the level of the sea. It reposes indiscriminately upon every rock, from granite upwards; and all that can be done, therefore, with respect to it, is, to find out the rock on which it reposes, and the level of its inferior limit in the tract under examination: thus at Saugor it reposes on sandstone, and its inferior limit in that district is about 1350 feet above the sea.

There are two kinds of basaltic rocks in the district of Jubulpore, which are clearly distinct formations. The oldest variety is that which penetrates the grauwacke stratum in the bed of the Nermada river, near the village of

Lamaita. This stratum, though not above fifty yards thick, is intersected by innumerable greenstone veins and nodules, always running in the direction of the strata; and as they do not occur in any of the adjoining formations, they must, I presume, be at least as old as that rock. The other basalt is an overlying rock like that of Saugor; but it reposes on granite or gneiss, and appears to contain a greater proportion of augite and olivine.

The calcareous conglomerate must be classed, at least in point of time, with the tufas and concretionary formations so prevalent in India.

X.—*A Tabular Arrangement of the Organic Remains of the County of Sussex.*

BY GIDEON MANTELL, ESQ., F.G.S. F.R.S. &c.

[Read June 6th, 1828.]

ALLUVIAL DEPOSITS.

			References.*	*Localites.*
Subterranean Forests.			Geol. Suss. 288, 289	Felpham near Bognor. Pevensey Levels.
PEAT.				
(*a*) Consisting of the remains of fresh-water and marsh plants, trunks and branches of trees, hazle-nuts, &c.			Ibid. 287–290	Lewes and Arundel Levels. The Wish near Eastbourne. Little Horsted, Isfield.
(*b*) Consisting of the remains of marine plants, confervæ, fuci, &c.			. . . .	Pevensey Levels.
BLUE CLAY or Silt.			Ibid. 286	Lewes Levels.
FRESH-WATER.				
Class.	*Genus.*	*Species.*		
Insecta.	Phryganea[a].		. . . .	Ibid.
Conchifera.	Cyclas	cornea.	Ibid. 287[b].	Ibid.
Mollusca.	Succinea	amphibia.		
———	Planorbis	carinatus.		
———	———	corneus.		
———	Limnea	stagnalis.		
———	———	palustris.		
———	———	limosa.		
———	Valvata	piscinalis.		
———	Paludina	impura.		
MARINE.				
Conchifera.	Lutraria	compressa.	Ibid. 287[c]	Ibid.
———	Tellina	solidula.		
———	Cardium	edule.		
Mollusca	Turbo	Ulvæ.		
Mammalia.	Cervus.		Cuv. Oss. Foss. iv. Pl. 3. f. 16	In sand several feet beneath the bed of the Ouse, Lewes Levels; probably in diluvium.[d]
———	Monodon	Monoceros.	. . . .	Lewes Levels[e]
———	Delphinus	Phocœna.	. . . .	Mouth of the Cuckmere[f]. Beeding Levels.[g]

* The fossils which are not in the possession of the author and those not examined by him are marked by an asterisk.

[a] The indusia or cases of the larvæ of this genus of insects, with minute shells of the genera Planorbis, Limnea, &c. adhering to them, are very abundant in the silt or blue clay.

[b] Still inhabit the rivers and ditches.

[c] Exist in the neighbouring ocean.

[d] The entire skeleton. A species allied to the Canadian, figured by Cuvier.

[e] Portion of the skull.

[f] The skull eighteen inches long; dug up at a depth of ten feet in blue clay.

[g] Human skeletons in coffins of very rude workmanship have been found in the silt at the depth of several feet; the bones and teeth were of a deep chocolate colour like those of the deer, &c. above mentioned.

Diluvium

No vegetable remains have been noticed in these deposits.
Testacea very rare.

Class.	*Genus.*	*Species.*	*References.*	*Localities.*
Conchifera.	Mytilus.		Geol. Suss. 277	Cliff between Brighton and Rottingdean.[a]
Mollusca.	Trochus.			
Mammalia.	Balæna.		. . . .	Base of the cliff near Kemp-town, Brighton.[b]
———	Bos.		. . . .	Brighton cliffs.[c]
———	Cervus.		. . . .	Ibid. Copperas Gap.[d]
———	Equus.		Ibid. 278	Ibid.[e]
———	Elephas	primigenius.	Ibid. 203	Peppering near Arundel.[f]
			Ibid. 278	Brighton cliffs. Brick-yard near Hove.[g]

Tertiary Formations. *Térrains de sédiment supérieurs.*

London Clay. *Calcaire Grossier. Prémier Térrain Marine.*

1. *Blue Clay of Bracklesham.* Geology of Sussex, p. 268.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*Localities.*
Annelides.	Dentalium[h].		. . . .	Bracklesham Bay.
Conchifera.	Crassatella	sulcata.	Min. Con. Tab. 345. f. 1	Ibid.
———	———	compressa.	Lam. Coq. Foss. Env. de Paris, Pl. 18. f. 1.	
———	Corbula.			
———	Sanguinolaria	Hollowaysii.	Min. Con. Tab. 159.	
———	Cytherea	nitidula.	Lam. Coq. Foss. Env. de Paris, Pl. 21. f. 1. 2.	
———	Venericardia	planicosta.	Min. Con. Tab. 50.	
———	———	acuticosta.	Lam. Coq. Foss. Env. de Paris, Pl. 20. f. 2.	
———	Cardium	semigranulatum.	Min. Con. Tab. 144.	
———	Pectunculus	pulvinatus.	Lam. Coq. Foss. Env. de Paris, Pl. 16. f. 9.	
———	Chama	squamosa.	Min. Con. Tab. 348.	
———	Ostrea	Flabellula.	Ibid. Tab. 253. Chama plicata, Brander Foss. Hant. f. 84. 85.	
———	———	undetermined.		
Mollusca.	Melania	sulcata.	Min. Con. Tab. 39.	
———	———	costellata?	Lam. Coq. Foss. Env. de Paris, Pl. 12. f. 2.	
———	Ampullaria	patula.	Min. Con. Tab. 284. (Two middle figures.)	
———	———	sigaretina.	Ibid. Tab. 284. (Two lower figures.)	
———	Natica	similis.	Ibid. Tab. 5. (Two middle figures.)	
———	Scalaria	acuta.	Ibid. Tab. 16. f. 4. 5. (Two lower figures.)	
———	Solarium	canaliculatum.	Brander Foss. Hant. f. 7. 8.	
———	Trochus	agglutinans.	Min. Con. Tab. 98. f. 1. (Two smaller figures.)	
———	Turritella	multisulcata.	Lam. Hist. Nat. Anim. sans Vert. vii. 562.	
———	———	conoidea.	Min. Con. Tab. 51. f. 1. 4.	
———	———	brevis.	Ibid. Tab. 51. f. 3.	
———	———	elongata.	Ibid. Tab. 51. f. 2.	
———	Cerithium	Cornucopiæ.	Ibid. Tab. 188. f. 1. 3. 4.	
———	Pleurotoma[i].			
———	Fusus	longævus.	Ibid. Tab. 63.	

[a] In a confused mass in the shingle bed.
[b] Portion of a rib (12 feet long, 32 inches in circumference) in the sand beneath the shingle bed and resting on the chalk: when entire it must have exceeded 30 feet in length.
[c] Teeth. [d] Jaw, teeth, and bones. [e] Bones and teeth. [f] The skeleton.
[g] Bones and teeth. [h] Resembles D. entale. [i] Too imperfect to determine the species.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*Localities.*
Mollusca.	Pyrula	bulbiformis?	Fusus bulbif. Min. Con. Tab. 291. Murex Pyrus, Brander Foss. Hant. f. 52. 53.	
———	———	lævigata.	Lam. Coq. Foss. Env. de Paris, Pl. 4. f. 7.	
———	Murex	argutus.	Brander Foss. Hant. f. 13.	
———	Voluta	Luctator.	Min. Con. Tab. 115. f. 1.	
———	———	Bicorona.	Lam. Hist. Nat. Anim. sans Vert. vii. 351.	
———	Ancilla	aveniformis.	Min. Con. Tab. 99. f. 1. 2. (Middle figures.)	
———	———	Turritella.	Ibid. Tab. 99. f. 3. 4. (Larger figures.)	
———	———	canalifera.	Lam. Coq. Foss. Env. de Paris, Pl. 2. f. 6.	
———	Conus	Dormitor.	Min. Con. Tab. 301.	
———	Nummularia	lævigata.[a]	Ibid. Tab. 538. f. 1.	
Pisces.	Raia[b].		Brander Foss. Hant. f. 117.	
			Ibid. f. 109.[c]	

2. *Arenaceous Limestone or Sandstone of Bognor.*[d]

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*Localities.*
Polypi.[e]			. . . .	The rocks on the Coast, near [Bognor.
Annelides.	Dentalium	planum.	Min. Con. Tab. 79. f. 1.	
———	Serpula.		Geol. Trans. 1st series, ii. 205.	
———	Vermetus	Bognoriensis.	Geol. Suss. 272. Hist. Suss. vol. iii. Pl. 1. f. 3. Min. Con. Tab. 596. f. 1. 2. 3.	
Conchifera.	Fistulana	personata.	Lam. Coq. Foss. Env. de Paris, Pl. 24. f. 6. 7. 7 *a*. 7 *b*. Teredo antenautæ, Min. Con. Tab. 102.	
———	Pholadomya	margaritacea.	Min. Con. Tab. 297. f. 1. 2. 3.	
———	Panopæa	intermedia.	Ibid. Tab. 76. f. 1. and Tab. 419. f. 2.	
———	Lutraria?	oblata.	Ibid. Tab. 534. f. 3.	
———	Venericardia	Brongniarti.[f]	Not figured.	
———	Cardium?			
———	Pectunculus	brevirostris.	Min. Con. Tab. 472. f. 1.	
———	———	decussatus.[g]	Ibid. Tab. 27. f. 1.	
———	Modiola	elegans.	Ibid. Tab. 9. f. 5.	
———	Pinna	affinis.	Ibid. Tab. 313. f. 2.	
———	*Ostrea	edulis?	Webster, Geol. Trans. 1st series, ii. 205.	
———	Anomia	lineata.	A. striata, Min. Con. Tab. 425.	
———	Lingula	tenuis.	Min. Con. Tab. 19. f. 3.	
Mollusca.	Calyptræa	trochiformis.	Trochus apertus, Brander Foss. Hant. f. 1. 2.	
———	Ampullaria	patula.	Min. Con. Tab. 284. (Two middle figures.)	
———	———	sigaretina.	Ibid. Tab. 284. (Two lower figures.)	
———	Natica	similis.	Ibid. Tab. 5. (Two middle figures.)	
———	Pyrula.		Brander, Foss. Hant. f. 52. 53.	
———	Murex	Smithii.	Min. Con. Tab. 578. f. 1. 2. 3.	
———	Rostellaria	Sowerbii.[h]	R. Parkinsoni, Min. Con. Tab. 349. f. 1. 3. 4.	
———	Voluta	Luctator.	Min. Con. Tab. 115. f. 1.	
———	Conus.			
———	Nautilus	imperialis.	Ibid. Tab. 1.	
Pisces.	Squalus?[i]			

[a] The young shell, of the size of a millet-seed, occurs in immense quantities. [b] Palates.
[c] Vertebræ. [d] Dicotyledonous wood perforated by Fistulana personata occurs occasionally in large masses.
[e] A ramose zoophyte, genus undetermined. [f] The specific name in honour of M. Alex. Brongniart.
[g] As it differs from the recent P. decussatus, (see Turton's Brit. Bivalves, 173,) a different specific name should be imposed.
[h] This Rostellaria was figured and described by the late Mr. Sowerby as R. Parkinsoni of the Geol. of Sussex; it is however perfectly distinct, and it becomes necessary to adopt a different specific name; that of Sowerbii is here given as a tribute of respect to the present scientific editor of the Mineral Conchology of Great Britain. The R. Sowerbii occurs in the tertiary formations only; R. Parkinsoni in the chalk marl, and Shanklin sand.
[i] A small tricuspid tooth.

3. *Sand on Emsworth Common.*

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*Localities.*
Annelides.	Dentalium	cylindricum.	Min. Con. Tab. 79.	
Mollusca.	*Nummularia	elegans.	Ibid. Tab. 538. f. 2.	

Plastic Clay. *Argile Plastique. Prémier Térrain d'eau douce.* Castle Hill, Newhaven.

Leaves; remains and impressions. Geol. Suss. Tab. 8. f. 1. 2. 3. 4. Brit. Min. Tab. 500. These are supposed by Mr. Sowerby to resemble the larger foliage of Platanus orientalis, Geol. Suss. p. 262.
"Fruit of a species of Palm?" Webster, Geol. Trans. 1st series, vol. ii. p. 191.
Wood; dicotyledonous. Occurs in small fragments in the reddish brown sandy-marl. Geol. Suss. p. 257. No. 7.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*Localities.*
Conchifera.	Cyclas.[a]		Brit. Min. Tab. 500. iv. 185	Castle Hill, near Newhaven.
———	Cyrena.		Geol. Suss. 264.	
———	Cytherea	convexa.	Ibid. Pl. 25. f. 2. Desc. Geol. Env. de Paris, Pl. 8. f. 7. p. 282. (Edit. 1822.)	
———	Unio.		Brit. Min. Tab. 500.	
———	Avicula	media.	Min. Con. Tab. 2. f. 2.	
———	Ostrea.		Geol. Suss. 264.	
Mollusca.	Helix	lævis.[b]	Ibid. Tab. 18. f. 19. 20. H. lævis, Fleming Brit. Anim. 265.	
———	Cerithium	funatum.	Geol. Suss. Tab. 14. f. 4. Min. Con. Tab. 128.	
———	———	politum.[c]	C. melanoides, Geol. Suss. Tab. 18. f. 3. Min. Con. Tab. 147.	
Pisces.	Mustelus?[d]		Geol. Suss. 264.	

Chalk Formation.

1. *Chalk with Flints.* 2. *Chalk without Flints.* (Craie blanche.)

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Agamia.	Confervites	fasciculata[e].	Ad. Brong. Hist. Veg. Foss. Pl. 1. f. 1 . .	Lewes. Steyn-[ing.	Isle de Bon-[holm.
———	———	undetermined.	Geol. Suss. Pl. 9. f. 12	Ibid.	
———	Fucoides	Brongniarti[f].	Ibid. Pl. 9. f. 1	Ibid.	
———	———	undetermined.	. . . .	Ibid.	
Phanerogamia (Dicotyledonous)[g].			Geol. Suss. 157	Ibid.	
Polypi.	Flustra	utricularis[h].	Lam. Hist. Nat. Anim. sans Vert. ii. 224. König. Icon. Foss. Sect. f. 61.	Ibid.	
———	———	undetermined.			
———	Orbitolites	lenticulata.	Geol. Suss. Tab. 16. f. 22–24. Desc. Geol. Env. de Paris, Pl. 9. f. 4. (Edit. 1822.) .	Ibid.	
———	Caryophyllia	centralis.	Madrepora centralis, Geol. Suss. Tab. 16. f. 2. 4.	Ibid.	Heytesbury.
———	Madrepora.		Geol. Suss. 160.	Brighton.	

[a] Very rarely perfect. [b] Bath is named by Dr. Fleming as its locality, evidently by mistake.
[c] In Min. Con. vol. iv. p. 48, Mr. Sowerby expresses a doubt whether these shells should not be referred to Potamides: Dr. Fleming however retains them in Cerithium, see Brit. Anim. p. 358.
[d] Teeth resembling those of this species.
[e] In flint and chalk: very rare. Craie tufeau, Isle de Bonholm.
[f] Specific name in honour of M. Adolphe Brongniart, author of the Hist. Veget. Foss.
[g] Sometimes in flint nodules and perforated by Fistulanæ or Teredines: in chalk, in the state of a brown friable mass: rare.
[h] Attached to Echini. Ventriculites quadrangularis, Geol. Suss. Tab. 15. fig. 6. probably belongs to this genus. There are also several undetermined species.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Polypi.	Spongia	ramosa.[a]	Geol. Suss. Tab. 16. f. 11	Lewes.	Warminster.
———	———	lobata.	Parkin. Org. Rem. ii. Pl. 7. f. 6. Fleming Brit. Anim. 526	Ibid.	
———	———	several species undetermined.[b]	. . . .	South Downs.	Ibid.
———	Spongus	Townsendi.[c]	Geol. Suss. Tab. 15. f. 9	Lewes.	Ibid.
———	———	labyrinthicus.	Ibid. Tab. 15. f. 7. S. hemisphærica, Flem. Brit. Anim. 526	Ibid.	Heytesbury.
———	Siphonia.[d]		Parkin. Introd. Org. Rem. 52	Ibid.	
———	Alcyonium.		Geol. Suss. Tab. 15. f. 4. 5. Tab. 16. f. 17. 18.	Ibid.	
———	Choanites	subrotundus.	Ibid. Tab. 15. f. 2	Ibid.	
———	———	Königi.[e]	Ibid. Tab. 16. f. 19–21	Ibid.	Warminster.
———	———	flexuosus.[f]	Ibid. Tab. 15. f. 1	Ibid.	
———	Ventriculites	radiatus.[g]	Ibid. Tab. 10. 11. 12. 13. Linn. Trans. vol. xi. Mantellia radiata, Parkin. Introd. Org. Rem. 53	Ibid.	
———	———	alcyonoides.	Geol. Suss. 176. Smith's Strata, Tab. 3. f. 1. Ocellaria König, Icon. Foss. Sect. f. 98. 99.	Ibid.	Ibid.
———	———	Benettiæ.	Geol. Suss. Tab. 15. f. 3	Ibid.	
Radiaria.	Apiocrinites	ellipticus.	Miller, Hist. Crin. p. 34. Bottle Encrinite, Parkin. Org. Rem. ii. Pl. 13. f. 31. 34. 75 .	Ibid.	Northfleet.
———	Pentacrinites.[h]				
———	Marsupites	Milleri.[i]	Geol. Suss. Tab. 16. f. 6. Mill. Hist. Crinoid. 133	Brighton.	Ibid.
———	Pentagonaster	semilunatus.[k]	Parkin. Org. Rem. iii. Pl. 1. f. 1	Lewes.	
———	———		. . . .	Ibid.[l]	
———	Cidaris	cretosa.[m]	Ibid. iii. Pl. 4. f. 3. Pl. 1. f. 11	Ibid.	Ibid.
———	———	variolaris.	Desc. Geol. Env. de Paris, Pl. 5. f. 9 . .	Ibid.	
———	———	corollaris.	Geol. Suss. Tab. 17. f. 2. Parkin. Org. Rem. iii. Pl. 1. f. 7	Ibid.	
———	Echinus	saxatilis.	Parkin. Org. Rem. iii. Pl. 3. f. 1 . . .	Ibid.	
———	———	Königi.	Geol. Suss. 189. Parkin. Org. Rem. iii. Pl. 1. f. 10	Ibid.	
———	———	Spines belonging to four or more species.	Ibid. Tab. 17. f. 12–14. Parkin. Org. Rem. ii. Pl. 4. f. 19. 20	Ibid.	
———	Spatangus	cor anguinum.	Desc. Geol. Env. de Paris, Pl. 4. f. 11. Parkin. Org. Rem. iii. Pl. 3. f. 11	Ibid.	Meudon.
———	———	rostratus.	Geol. Suss. Tab. 17. f. 10. 17	Brighton.	
———	———	planus.	Ibid. Tab. 17. f. 9. 21	Lewes.	
———	———	Prunella?	Ibid. Tab. 17. f. 22. 23	Brighton.	
———	Conulus	Albogalerus.	Ibid. Tab. 17. f. 8. 20. Galerites albogalerus, Desc. Geol. Env. de Paris, Pl. 4. f. 12.	Lewes.	Dieppe.
———	———	vulgaris.[n]	Parkin. Org. Rem. iii. Pl. 2. f. 3	South Downs.	
———	———	subrotundus.	Geol. Suss. Tab. 17. f. 15. 18	Lewes.	
———	Echino-corys	scutatus.	Parkin. Org. Rem. iii. Pl. 2. f. 4. Ananchytes, Lamarck	Ibid.	Meudon.
———	———	ovatus.	Desc. Geol. Env. de Paris, Pl. 5. f. 7. Ananchytes ovata, Lamarck	Ibid.	Ibid.
———	———	hemisphæricus.	Desc. Geol. Env. de Paris, Pl. 5. f. 8 . .	South Downs.	Toigny.
Crustacea.	Astacus	Leachii.	Geol. Suss. Tab. 29. 30. 31	Lewes.	
———	———	Sussexiensis.	Ibid. Tab. 30. f. 3	Ibid.	

[a] Common in flints. [b] Vast numbers of the flints derive their forms from the sponges they inclose.
[c] This species is probably distinct from the Pewsey cup-corals. [d] Common in flints.
[e] Radiated spicula are observable in some specimens. [f] In flints.
[g] Immense quantities of flints owe their forms to this genus of Polypi.
[h] Portion of a stem resembling that of P. Caput-Medusæ. Mill. Hist. Crinoid. p. 46. possibly distinct.
[i] Tortoise Encrinite of Parkinson.
[k] Very rare. [l] Detached Ossiculæ too imperfect to admit of determination.
[m] It differs essentially from C. papillata of the oolites. [n] Quere if specifically distinct.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Crustacea.	Pagurus	Faujasii?	Geol. Suss. Tab. 29. f. 3. Brongniart, Hist. Crust. Foss. Pl. 11. f. 2	Lewes.	Mæstricht.
———	Scyllarus	Mantelli.	Brongniart, Hist. Crust. Foss. 130 . . .	Ibid.	
———	Eryon.[a]		Ibid. 128. Geol. Suss. Tab. 29. f. 2 . .	Steyning.	
Annelides.	Serpula	ampullacea.	Geol. Suss. 196. Min. Con. Tab. 596. f. 1.	Lewes.	
———	———	Plexus.	Ibid. 196. Min. Con. Tab. 598. f. 1 . .	Ibid.	
———	Spirorbis.		Desc. Geol. Env. de Paris, 251	Ibid.	Meudon.
Cirripeda.	Pollicipes	sulcatus.	Min. Con. Tab. 606. f. 7. Geol. Suss. Tab. 33. f. 11	Ibid.	Norwich.
Conchifera.	Fistulana	personata.	Geol. Suss. Tab. 18. f. 23. Lamarck. Coq. Foss. Env. de Paris, Pl. 24. f. 6. 7. 7 *a*. 7 *b*. Teredo antenautæ, Min. Con. Tab. 102 .	Ibid.	
———	Inoceramus	Cuvieri.	Geol. Suss. Tab. 27. f. 4. Catillus C., Desc. Geol. Env. de Paris, Pl. 4. f. 10 (Edit. 1822).	Ibid.	Meudon.
———	———	Brongniarti.	Geol. Suss. Tab. 27. f. 8	Ibid.	Warminster.
———	———	Lamarckii.	Ibid. Tab. 27. f. 1. Geol. Trans. 1st series, v. Pl. 1. f. 3	Ibid.	Dover.
———	———	mytiloides.	Geol. Suss. Tab. 28. f. 2. Mytaloides labiatus, Desc. Geol. Env. de Paris, Pl. 3. f. 4. (Edit. 1822)	Ibid.	Bougival.
———	———	cordiformis.	Min. Con. Tab. 440.	Ibid.	Gravesend.
———	———	latus.	Geol. Suss. Tab. 27. f. 10. Min. Con. Tab. 582. f. 1	Ibid.	Norfolk.
———	———	Websteri.	Geol. Suss. Tab. 27. f. 21	Ibid.	
———	———	striatus.	Ibid. Tab. 27. f. 5. Min. Con. Tab. 582. f. 2.	Ibid.	Heytesbury.
———	———	undulatus.	Ibid. Tab. 27. f. 6	Ibid.	Ibid.
———	———	involutus.	Min. Con. Tab. 583	Ibid.	
———	Plagiostoma	spinosum[b].	Geol. Suss. Tab. 26. f. 10. Min. Con. Tab. 83.	Ibid.	Meudon, Rouen.
———	———	Hoperi.	Ibid. Tab. 26. f. 2. 3. 15. P. Mantelli, Desc. Geol. Env. de Paris, Pl. 4. f. 3. (Edit. 1822)	Ibid.	Rouen.
———	———	Brightoniensis[c].	Geol. Suss. Tab. 26. f. 15	Brighton.	
———	Pecten	quinquecostatus.	Ibid. Tab. 26. f. 14. 20. Min. Con. Tab. 56. f. 4. 8	Lewes.	Meudon.
———	———	nitidus.[d]	Geol. Suss. Tab. 26. f. 4. 9	Ibid.	Dieppe.
———	———	undetermined.	Ibid. Tab. 25. f. 4	Ibid.	
———	Dianchora	lata.[e]	Ibid. Tab. 26. f. 21. Podopsis, Desc. Geol. Env. de Paris, (Edit. 1822)	Ibid.	Le Hâvre.
———	———	obliqua.	Geol. Suss. Tab. 25. f. 1. Tab. 26. f. 12 .	Brighton.	Ibid.
———	Ostrea	vesicularis.[f]	Desc. Geol. Env. de Paris, Pl. 3. f. 5. (Edit. 1822.) Gryphæa globosa, Min. Con. Tab. 392.	Lewes.	Meudon.
———	———	semiplana.	Geol. Suss. Tab. 25. f. 4. Min. Con. Tab. 489. f. 3	Ibid.	
———	———	canaliculata.	Min. Con. Tab. 135. f. 1	Ibid.	Cromer.
———	Crania	Parisiensis.	Ibid. Tab. 409. f. 1. Desc. Geol. Env. de Paris, Pl. 3. f. 2. (Edit. 1822.)	Brighton.	Meudon.
———	Terebratula	subrotunda.[g]	Min. Con. Tab. 15. f. 1. 2	Lewes.	
———	———	carnea.	Desc. Geol. Env. de Paris, Pl. 4. f. 7 . .	Ibid.	Ibid.
———	———	ovata.	Min. Con. Tab. 15. f. 3	Ibid.	Rouen.
———	———	undata.[h]	Ibid. Tab. 15. f. 7. 8. 9	Ibid.	Meudon.
———	———	elongata.	Ibid. Tab. 435. f. 1. 2	Ibid.	Norwich.
———	———	plicatilis.[i]	Ibid. Tab. 118. f. 1. 2. Tab. 83. f. 6 . .	Ibid.	Dieppe.

[a] Too imperfect for the species to be ascertained. [b] One of the most characteristic shells of the chalk.

[c] Very rare. [d] P. cretosus, Min. Con. Tab. 394; and P. arachnoides Desc. Geol. Env. de Paris, Pl. 3. f. 8. (Edit. 1822) are but varieties of this species. [e] Podopsis striata, Desc. Geol. Env. de Paris, Pl. 4. f. 2. A. B. p. 83. (Edit. 1822), is probably a distinct species.

[f] A characteristic fossil of the chalk; very common. [g] Very common.

[h] T. undata, T. subundata, T. intermedia, T. semiglobosa of Min. Con. are included, being considered as varieties only.

[i] T. plicatilis, T. octoplicata, T. concinna of Min. Con.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Conchifera.	Terebratula	subplicata.	Geol. Suss. Tab. 26. f. 5. 6. 11	Offham.	
Mollusca.	Trochus	Basteroti.[a]	Desc. Geol. Env. de Paris, Pl. 3. f. 3 . .	Lewes.	Meudon.
———	Cirrus	depressus.	Geol.Suss.Tab.18.f.18.22.Min.Con.Tab.428.	Ibid. *et pass.*	Warminster.
———	———	perspectivus.	Ibid. Tab. 18. f. 21. 12. Min. Con. Tab. 428.	Ibid.	Ibid.
———	———	granulatus.[b]	Ibid. 195	Southerham, [near Lewes.	
———	Dolium	nodosum.	Ibid. 196. Min. Con. Tab. 426	Clayton, near [Hurst.	
———	Belemnites	mucronatus.[c]	Ibid. Tab. 16. f. 1. Desc. Geol. Env. de Paris, Pl. 3. f. 1. (Edit. 1822.) B. Allani, Fleming, Brit. Anim. 240. Min. Con. Tab. 600. f. 1	Brighton.	Meudon. Scandinavia. Near Giant's Causeway, Ireland.
———	———	granulatus.	Min. Con. Tab. 600. f. 3. 5	Lewes.	Mæstricht.
———	———	lanceolatus.	Ibid. Tab. 600. f. 8. 9	Steyning.	
———	Baculites	Faujasii.	Ibid. Tab. 592. f. 1	Lewes.	Ibid.
———	Nautilus	elegans.[d]	Geol. Suss. Tab. 20	Ibid.	
———	Ammonites	varians.[e]	Ibid. Tab. 21. f. 2. 5. 7	Ibid.	
———	———	Woollgari.[f]	Ibid. Tab. 21. f. 16. Tab. 22. f. 7. Min. Con. Tab. 587	Ibid.	
———	———	navicularis.	Geol.Suss.Tab.22.f.5.Min.Con.Tab.555.f.2.	Offham.	Guildford.
———	———	catinus.	Ibid. Tab. 22. f. 10	Southerham.	
———	———	Lewesiensis.	Ibid. Tab. 22. f. 2. Min. Con. Tab. 358. Hist. Mont St. Pierre, Pl. 31?	Lewes.	Mæstricht.
———	———	peramplus.	Geol. Suss. 200. Min. Con. Tab. 357 . .	Ibid.	
———	———	rusticus.	Min. Con. Tab. 177	Ibid.	
———	———	undatus.[g]	Ibid. Tab. 569. f. 2	Ibid.	
———	Scaphites	striatus.[h]	Geol. Suss. Tab. 22. f. 3. 4	Brighton.	
———	Hamites	armatus.[i]	Ibid. Tab. 23	Lewes.	
Pisces.[k]	Murœna	Lewesiensis.	Ibid. Tab. 39. f. 11. Tab. 40. f. 2 . . .	Ibid.	
———	Zeus	Lewesiensis.	Ibid. Tab. 35. 36	Ibid.	Gravesend.
———	Salmo?	Lewesiensis.	Ibid. Tab. 33. 40	Ibid.	
———	Esox	Lewesiensis.	Ibid. Tab. 41. f. 1. 2. Tab. 25. f. 13 . .	Ibid.	
———	Amia?	Lewesiensis.	Ibid. Tab. 37. 38	Ibid.	
———	Squalus.[l]		Ibid. Tab. 32. f. 1. Sq. Cornubicus . . .	Ibid.	
			Ibid. Tab. 32. f. 2. 3. 6. Sq. Mustelus . .	Ibid.	
			Ibid. Tab. 32. f. 4. 7. 8. Sq. Zygœna . .	Ibid.	
			Ibid. Tab. 32. f. 12. 14. 15. Sq. Galeus .	Ibid.	
			Ibid. Tab. 33. f. 10	Ibid.[m]	
———	Balistes[n]?		Ibid. Tab. 33. f. 5. 6	Ibid.	
———	Diodon[o]?		Ibid. Tab. 32. f. 18. 20	Ibid.	
			Ibid. Tab. 39. 40. 41	Ibid.[p]	
			Ibid. Tab. 42. Hist. Mont St. Pierre, Tab. 29	Ibid.[q]	Mæstricht.
Reptiles.[r]	Mososaurus	Hoffmannii.[s]	Ibid. Tab. 33. 41. Hist. Mont. St. Pierre .	Ibid.	Ibid.
Iuloidocopros.[t]			Ibid. Pl. 9. f. 3. 6. 9. 10	Ibid.	Ibid.

[a] Occurs in the form of casts only. [b] Lower chalk.

[c] A beak or mandible has lately been discovered which probably belonged to some species of Belemnites or Nautilus.

[d] Rare in the white chalk. [e] Very rare. [f] Lower chalk. [g] Upper chalk : unique.

[h] Very rare. [i] Exceedingly rare. [k] This arrangement and nomenclature of the fishes of the chalk must be considered only as temporary; the greater part will require the establishment of new genera for their reception. [l] Teeth resembling those of several recent species. [m] Vertebræ.

[n] Defence of. [o] The palates resemble those of Diodon Histrix; but from the numbers often found grouped together, the mouth of the original appears to have been paved with them.

[p] Radii or fin bones of unknown fishes allied to Balistes. These radii are entirely distinct from those of the Lias, and belong to three or more species. [q] Jaw with teeth and bones of an unknown fish.

[r] Bones, teeth, portions of the mandibles, &c. of several reptiles and fishes too imperfect to be determined.

[s] Dorsal and caudal vertebræ. [t] The name given to these bodies by Dr. Buckland, who supposes them to be fœcal remains. See the Professor's paper on Coprolites.

3. *Chalk Marl.*

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Agamia.	Confervites	fasciculata.	Ad. Brongn. Hist. Veget. Foss. Pl. 1. f. 1	Hamsey.	
Phanerogamia† (Dicotyledonous).			. . . .	Ibid.	
Polypi.	Flustra.[a]		. . . .	Ibid.	
———	Millepora	Fittoni[b].	Geol. Suss. Tab. 15. f. 10	Ibid.	
———	Spongia	several undetermined.[c]	Ibid. 107	Ibid.	
———	Alcyonium?	pyriformis.	Ibid. 105	Ibid.	
Radiariæ.	Cidaris	claviger.	König.	Ibid.	
———	Echinus	saxatilis?	Geol. Suss. Tab. 17. f. 1	Ibid.	
———	Spatangus	cordiformis.	Ibid. 108	Middleham.	
———	Conulus	Hawkinsii[d].	. . . .	Hamsey.	Guildford.
	Spines of several species.				
Crustacea.	Astacus	Sussexiensis.[e]	Ibid. Tab. 30. f. 3	Southerham.	
Annelides.	Serpula	Plexus.[f]	Min. Con. Tab. 598. f. 1	Hamsey.	
———	Vermicularia	umbonata.	Geol. Suss. Tab. 18. f. 24. Min. Con. Tab. 57.	Ibid.	
———	———	Sowerbii.	Ibid. Tab. 18. f. 14. 15	Ibid.	
Conchifera.	Venus	Ringmeriensis.	Ibid. Tab. 25. f. 5	Middleham.	
———	Astarte?		Ibid. 126	Ibid.	
———	Venericardia.		Ibid. 126. Min. Con. Tab. 259	Ibid.	
———	Cardium	decussatum.	Ibid. Tab. 25. f. 3. Min. Con. Tab. 552. f. 1	Hamsey.	
———	Cucullæa.[g]		. . . .	Middleham.	
———	Arca	2 or 3 species undetermined.	. . . .	Ringmer.	
———	Chama.[h]		. . . .	Hamsey.	
———	Avicula	2 species undetermined.[i]	. . . .	Ibid.	
———	Inoceramus	tenuis.	Geol. Suss. 132. No. 65	Ibid.	
———	———	Cripsii.	Ibid. Tab. 27. f. 11	Ibid.	
———	Plagiostoma	elongatum.	Ibid. Tab. 19. f. 1. Min. Con. Tab. 559. f. 2	Ibid.	Folkstone.
———	———	asper.	Ibid. Tab. 26. f. 18	Ibid.	
———	Pecten	Beaveri.	Ibid. Tab. 25. f. 11. Min. Con. Tab. 158	Ibid.	
———	———	triplicatus.	Ibid. Tab. 25. f. 9	Ibid.	
———	———	quinquecostatus[k].	Ibid. Tab. 25. f. 10	Ibid.	
———	———	orbicularis.	P. laminosus, Geol. Suss. Tab. 26. f. 8. Min. Con. Tab. 186	Ibid.	
———	Plicatula	inflata.	P. spinosa Geol. Suss. Tab. 26. f. 13. 16. 17. Min. Con. Tab. 409. f. 2	Ibid.	
———	———	pectinoides[l].	Min. Con. Tab. 409. f. 1	Ibid.	
———	Terebratula	subrotunda.[m]	Ibid. Tab. 15. f. 1. 2	Ibid.	
———	———	undata.	Ibid. Tab. 15. f. 7	Eastbourne.	
———	———	striatula.	Ibid. Tab. 536. Geol. Suss. Tab. 25. f. 7. 8. 12. T. Defrancii, Desc. Geol. Env. de Paris, Pl. 3. f. 6. (Edit. 1822.)	Hamsey.	
———	———	Mantelliana.	Min. Con. Tab. 537. f. 5. T. sulcata, Geol. Suss. 130	Ibid.	
———	———	Martini.	T. Pisum, Min. Con. Tab. 536. f. 6. 7. Geol. Suss. 131	Ibid.	
———	———	rostrata.	Min. Con. Tab. 537. f. 1. 2	Ibid.	

† In the state of a brown friable mass.

[a] There are probably several species. [b] The specific name is in honour of Dr. Fitton, P.G.S.

[c] A flexuose species in masses of an oval form is very common. [d] A remarkable species found in the chalk marl only, hitherto neither figured nor described. Diameter of the base two inches and a half, height two inches; base nearly circular, flat; vent placed in the base two-thirds from the mouth, and one-third from the margin. Specific name in honour of John Hawkins, Esq. F.G.S. of Bignor Park. [e] Rare. [f] Two small masses, very rare.

[g] M. Brongniart sent me a similar cast from Rouen. [h] A subglobose shell, not uncommon.

[i] The shells very thin and fragile. [k] Probably a distinct species. [l] Cambridgeshire, in galt. [m] Rare.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Conchifera.	Terebratula	squamosa.[a]	Geol. Suss. 132. No. 64	Hamsey.	
Mollusca.	Auricula	incrassata.	Ibid. Tab. 19. f. 2. 3. 34. Min. Con. Tab. 163	Stoneham.	Blackdown, [Devon.
———	Ampullaria?		Ibid. Tab. 18. f. 11	Hamsey.	
———	Trochus	linearis.	Ibid. Tab. 18. f. 17	Ibid.	
———	———	agglutinans?[b]	Ibid. Tab. 18. f. 7	Ibid.	
———	Rostellaria	Parkinsoni.	Ibid. Tab. 18. f. 1. 2. 4. Min. Con. Tab. 558. f. 3	Ibid.	Ibid. in Shank- [lin sand.
———	Cassis	avellana.[c]	Desc. Geol. Env. de Paris, Pl. 6. f. 10. (Edit. 1822.)	Ringmer.	Rouen.
———	Eburna?		Geol. Suss. Tab. 18. f. 13	Hamsey.	
———	Voluta	ambigua?[d]	Ibid. Tab. 18. f. 8	Ibid.	
———	Baculites	Faujasii.	Min. Con. Tab. 592. f. 1	Ibid.	
———	———	obliquatus.	Ibid. Tab. 592. f. 2. 3. Hamites baculoides, Geol. Suss. Tab. 23. f. 6. 7	Glynd.	Ibid.[e]
———	Nautilus	elegans.	Geol. Suss. Tab. 20. f. 1. Tab. 21. f. 5. Min. Con. Tab. 116	Hamsey.	
———	———	expansus.	Min. Con. Tab. 458. f. 1 "N. elegans in a young state." Geol. Suss. Tab. 21. f. 1. 4 .	Middleham.	
———	Ammonites	Mantelli.	Geol. Suss. Tab. 22. f. 1. Min. Con. Tab. 55	Ibid.	
———	———	Sussexiensis.	Ibid. Tab. 20. f. 2. Tab. 21. f. 10. A. Rhotomagensis, Desc. Geol. Env. de Paris, Tab. 6. f. 2. (Edit. 1822.) Min. Con. Tab. 515	Hamsey.	Ibid.
———	———	varians.	Geol. Suss. Tab. 21. f. 2. 7. Min. Con. Tab. 176	Ibid.	Ibid.
———	———	cinctus.	Ibid. 116. Min. Con. Tab. 564. f. 1 . .	Middleham.	
———	———	falcatus.	Ibid. Tab. 21. f. 6. 12. Min. Con. 579. f. 1	Ibid.	
———	———	curvatus.	Ibid. Tab. 21. f. 18. Min. Con. Tab. 579. f. 2	Hamsey.	
———	———	complanatus.	Ibid. 118. Min. Con. Tab. 569. f. 1 . .	Ibid.	
———	———	rostratus.	Min. Con. Tab. 173	Southerham.	
———	———	tetrammata.	Ibid. Tab. 587. f. 2	Hamsey.	
———	Scaphites	striatus.	Geol. Suss. Tab. 22. f. 3. 4. 9. 11. S. obliquus, Min. Con. Tab. 18. f. 4–7 . . .	Ibid.	Ibid.
———	———	costatus.	Geol. Suss. Tab. 22. f. 8. 12. Parkin. Org. Rem. iii. Pl. 10. f. 10	Ibid.	
———	Hamites	armatus.	Geol. Suss. Tab. 23. f. 3. 4. Min. Con. Tab. 168	Ibid.	
———	———	plicatilis.	Ibid. Tab. 23. f. 1. 2. Min. Con. Tab. 234. f. 1	Ibid.	
———	———	alternatus.	Ibid. Tab. 23. f. 10. 11	Ringmer.	
———	———	ellipticus.	Ibid. Tab. 23. f. 9	Ibid.	
———	———	attenuatus.	Ibid. Tab. 23. f. 8. 13. Min. Con. Tab. 61. f. 4. 5	Hamsey.	Folkstone.
———	Turrilites	costatus.	Ibid. Tab. 23. f. 15. Tab. 24. f. 1. 4. 5. Min. Con. Tab. 36	Ibid.	Rouen.
———	———	undulatus.	Geol. Suss. Tab. 24. f. 8. Tab. 23. f. 14. 16. Min. Con. Tab. 75. f. 1. 2. 3	Ibid.	
———	———	tuberculatus.	Geol. Suss. Tab. 24. f. 2. 3. 6. 7. Min. Con. Tab. 74	Middleham.	Ibid.
Pisces.	Squalus	Mustelus.[f]	Ibid. Tab. 32. f. 2. 3. 5. 6. 9. 11	Hamsey.	
———	———	Galeus.[f]	Ibid. Tab. 32. f. 12. 14. 15. 16	Ibid.	
			Ibid. Tab. 34. f. 10	Ibid.	

Scales, &c. and Coprolites[g]. (Iulo-eido-coprolites, Dr. Buckland, see p. 232–234 of this volume.) Geol. Suss. Pl. 9. f. 4. 5. 7. 8. 11.

[a] This species has not been figured.

[b] Cast of the base of the shell.

[c] Query if not a variety of Auricula incrassata?

[d] This shell is closely allied to, if not identical with, V. ambigua of Hordwell Cliffs. It is attached to an Ammonite.

[e] Craie chloritée.

[f] Teeth resembling those of the recent species are occasionally found.

[g] These substances have been known since the time of Woodward by the name of "*Iuli of Cherry Hinton*," and were supposed to be the amenta or cones of a species of fir. Their animal origin was first suggested by Mr. König, see Geol. of Suss. p. 104. Dr. Buckland has lately investigated the subject with his usual acumen and success; and the analysis of Dr. Prout having proved their animal nature beyond all doubt, Dr. B. proposes to distinguish these fossils by the term *Coprolite*, and supposes them to be the fæcal remains of fishes or of sepiæ. I have one of these bodies in an Amia? lying on the air-bladder.

4. *Firestone or Upper Green Sand.* (Craie chloritée ou Glauconie crayeuse.)

This division contains so many of the fossils common to the marl, that in the following list those organic remains alone are enumerated which have been noticed exclusively in the Firestone. Among the fossils abundant in both deposits are, Pecten orbicularis, Plicatula inflata, Terebratulæ, Nautilus expansus, Ammonites varians, A. Mantelli, wood, scales of fishes, &c.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Agamia.	Fucoides	Targionii.[a]	Ad. Brong. Hist. Veget. Foss. Pl. 4. f. 2. 6. Geol. Suss. 98	Bignor.	Near Florence.
Polypi.	Millepora	Gilberti.	Geol. Suss. 106. No. 8	Southbourn.	
———	Siphonia	Websteri.	Parkin. Introd. Org. Rem. 50. Tulip alcyonium, Webster, Geol. Trans. 1st series, ii. Pl. 28	Ibid.	Isle of Wight.
———	Spongia.[b]		. . . .	Ibid.[c]	
Radiaria.	Spatangus	Murchisonianus.	König. Icon. Sect. Foss. Cent. 2	Ibid.	
Conchifera.	Cardita?[d]		. . . .	Ibid.	
———	Arca	carinata.	Min. Con. Tab. 44. (Lower figures) . .	Ibid.	Devizes.
———	Plagiostoma.[e]		. . . .	Ibid.	
———	Gryphæa	vesiculosa.	Ibid. Tab. 369	Hamsey.	
———	Ostrea	carinata.	Ibid. Tab. 365. White, Nat. Hist. Selbourne. Desc. Geol. Env. de Paris, Pl. 3. f. 11. (Edit. 1822.)	Southbourn.	Le Hâvre.
———	Terebratula	biplicata.	Min. Con. Tab. 90	Ibid.	Cambridge.
Mollusca.	Trochus	Rhodani.	Desc. Geol. Env. de Paris, Pl. 9. f. 8. (Edit. 1822.)	Ibid.	Lignerolle au [dessus d'Arbe.
———	———	bicarinatus?	Min. Con. Tab. 221. f. 2	Ibid.	
———	Ammonites	planulatus.	Ibid. Tab. 570. f. 5	Ibid.	
———	———	Catillus.	Ibid. Tab. 564. f. 2	Ibid.	

5. *Galt or Folkstone Marl.*

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Agamia.	Fucoides.[f]		Geol. Suss. 83	Norlington.	Bletchingley, [Surrey.
Phanerogamia (Dicotyledonous).[g]			. . . .	Near Willingdon.	Folkstone.
Polypi.	Turbinolia	Königi.[h]	Ibid. Tab. 19. f. 22. 24	Ringmer.	Bletchingley.
Radiaria.	Spatangus.[i]		. . . .	Ibid.	Ibid.
Crustacea.	Arcania.[k]		Ibid. Tab. 29. f. 7. 8. 14	Ibid.	Near Cam- [bridge.
———	———[l]		Ibid. Tab. 29. f. 9. 10	Ibid.	
———	Etyæa.		Ibid. Tab. 29. f. 11. 12	Ibid.	
———	Corystes.		Ibid. Tab. 29. f. 13. 15. 16	Ibid.	
———	Astacus.[m]		Ibid. 98	Ibid.	
Annelides.	Dentalium	striatum.	Ibid. Tab. 19. f. 4. Min. Con. Tab. 70. f. 4	Ibid.	Folkstone.
———	———	ellipticum.	Ibid. Tab. 19. f. 21. 25. Min. Con. Tab. 70. f. 6. 7	Ibid.	Ibid.
———	———	decussatum.	Min. Con. Tab. 70. f. 5	Newtimber.	

[a] Occurs in vast quantities near Bignor. At the same locality was also found the culm or stem of an undetermined plant.

[b] Several species undetermined; common in the rocks near the sea-houses.

[c] The inferior bed of marl which is in contact with the firestone at Southbourn, is almost entirely composed of ramose zoophytes, probably Milleporites, Madreporites, &c. so as to form a reef of corals. In this bed was found a long cylindrical zoophyte, partly composed of chert, of the same kind as those which occur in the vale of Pewsey in Wiltshire.

[d] Much compressed; possibly a Pholadomya.

[e] A small species undescribed; it occurs also in the malm at Amberly.

[f] In layers of indurated red marl.

[g] Rolled fragments probably of a species of fir or pine, and generally perforated by Fistulanæ.

[h] Hitherto observed in galt only.

[i] A fragment only.

[k] The thorax.

[l] Unknown, but belonging to the family Corystidæ

[m] Remains of the abdominal covering of two unknown species.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Conchifera.	Fistulana	pyriformis.[a]	Geol. Suss. 76	Willingdon.	
———	Arca.[b]		. . . .	Ringmer.	
———	Nucula	pectinata.	Ibid. Tab. 19. f. 5. 6. 9. Min. Con. Tab. 192. f. 6. 7	Ibid.	Folkstone.
———	———	ovata.	Geol. Suss. Tab. 19. f. 26. 27	Ibid.	Ibid.
———	Pecten	orbicularis.[c]	Min. Con. Tab. 106	Ibid.	
———	Inoceramus	concentricus.	Geol. Suss. Tab. 19. f. 19. Min. Con. Tab. 305. Desc. Geol. Env. de Paris, Pl. 6. f. 11 .	Ibid.	Blackdown, [Rouen.
———	———	sulcatus.	Geol. Suss. Tab. 19. f. 16. Min. Con. Tab. 306. Desc. Geol. Env. de Paris, Pl. 6. f. 12 .	Ibid.	Perte du [Rhone.
———	———	gryphæoides.	Min. Con. Tab. 584. f. 1	Ibid.	
Mollusca.	Ampullaria	canaliculata.	Geol. Suss. Tab. 19. f. 13	Ibid.	Bletchingley.
———	Natica.		Ibid. Tab. 19. f. 31. 32	Ibid.	Folkstone.
———	Cirrus	plicatus.	Min. Con. Tab. 141. f. 3	Norlington.	Ibid.
———	Rostellaria	carinata.	Geol. Suss. Tab. 19. f. 10–14	Ringmer.	Bletchingley.
———	Belemnites	Listeri.	Ibid. Tab. 19. f. 18. B. minimus, Lister Hist.	Ibid.	Ibid.
———	———	attenuatus.	Ibid. Tab. 19. f. 17. 23. Min. Con. Tab. 589. f. 2	Ibid.	Folkstone.
———	Nautilus	inæqualis.	Ibid. Tab. 21. f. 14. 15. Min. Con. Tab. 40. (Lower figure)	Ibid.	Ibid.
———	Ammonites	splendens.	Ibid. Tab. 21. f. 13. 17. Min. Con. Tab. 103	Norlington.	Ibid.
———	———	auritus.	Min. Con. Tab. 134	Ringmer.	Ibid.
———	———	planus.	Geol. Suss. Tab. 21. f. 3. (var. of A. varians?)	Ibid.	Ibid.
———	———	lautus.	Ibid. Tab. 21. f. 11. Min. Con. Tab. 309 .	Ibid.	Ibid.
———	———	biplicatus.	Ibid. Tab. 22. f. 6. A. Deluci? Geol. Min. Pl. 6. f. 4	Ibid.	Le Hâvre.
———	———	tuberculatus.	Min. Con. Tab. 310. f. 1. 2. 3. Geol. Suss. p. 92	Ibid.	Folkstone.
———	———	lævigatus.	Ibid. Tab. 549. f. 1	Ibid.	Ibid.
———	Hamites	attenuatus.	Ibid. Tab. 61. f. 4. 5. Geol. Suss. Tab. 19. f. 29. 30	Ibid.	Ibid.
———	———	maximus.	Ibid. Tab. 62. f. 1	Ibid.	Ibid.
———	———	intermedius.	Ibid. Tab. 62. f. 2. 3. Geol. Suss. Tab. 23. f. 12	Ibid.	Ibid.
———	———	tenuis.	Ibid. Tab. 61. f. 1	Ibid.	Ibid.
———	———	rotundus.	Ibid. Tab. 61. f. 2. 3	Ibid.	Ibid.
———	———	compressus.	Ibid. Tab. 61. f. 7. 8	Ibid.	Ibid.
Pisces.	Squalus	Mustelus ?[d]	. . . .	Norlington. Ringmer.[e]	

6. *Shanklin Sand.* (Lower Green Sand.)

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Phanerogamia (Dicotyledonous).[f]			Geol. Suss. 76	Willingdon n[r] Folkstone.	
Radiaria.	Spatangus.[g]		. . . .	Parham.	
Crustacea.			*Martin Geol. Mem. West Suss. 32 . . .	Bignor Common.[h]	
Annelides.	Dentalium	one or more.	Geol. Suss. 72	Parham.	
———	*Vermicularia	concava.	Min. Con. Tab. 57. f. 1–5	Pulborough.	
Conchifera.	Mya	plicata var.?	Ibid. Tab. 419. f. 3. M. intermedia, Geol. Suss. 74	Parham, near [Margate.	
———	———	*Mandibula.	Martin Geol. Mem. West Suss. 33. Min. Con. Tab. 43	Pulborough.	Devizes
———	*Pholadomya.		. . . .	Ibid.	
———	Corbula	Striatula.	Min. Con. Tab. 572. f. 2. 3	Parham.	
———	Tellina	æqualis.	Not figured	Ibid.	
———	———	inæqualis.	Min. Con. Tab. 456. f. 2	Ibid.	Blackdown.
———	Venus	parva.	Ibid. Tab. 518. f. 4. 5. 6	Ibid.	Shanklin.

[a] At the junction of the galt and Shanklin sand, imbedded in wood. [b] A very imperfect cast. [c] One example only. [d] Teeth. [e] Scales and vertebræ; very rare. [f] Rolled fragments of wood at the junction of the sand with the galt. [g] Fragment of a species too imperfect to be determined. [h] "Crustaceous fossil like a shrimp."—Martin.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Conchifera.	Venus	angulata.[a]	Min. Con. Tab. 65	Parham.	Blackdown.
———	———	Faba.	Ibid. Tab. 567. f. 3	Ibid.	Shanklin.
———	———	ovalis.	Ibid. Tab. 567. f. 1. 2	Ibid.	Feversham.
———	Thetis	minor.	Ibid. Tab. 513. f. 5. 6	Ibid.	Shankl[n] Chine.
———	Cucullæa	decussata.	Ibid. Tab. 206. f. 3. 4	Ibid.	Feversham.
———	Nucula	impressa.	Ibid. Tab. 475. f. 3	Ibid.	Blackdown.
———	*Modiola	æqualis.	Ibid. Tab. 210. f. 2	Ibid.	
———	———	bipartita.	Ibid. Tab. 210. f. 3. 4	Ibid.	Osmington.
———	Mytilus	lanceolatus.	Ibid. Tab. 439. f. 2	Ibid.	
———	*Pinna.		Martin Geol. Mem. West Suss. 32 . . .	Pulborough.	
———	*Trigonia	Dædalea.	Min. Con. Tab. 88. T. clavellata, Geol. Suss. 73	Parham.	Blackdown.
———	———	alæformis.	Ibid. Tab. 215. f. 2	Ibid.	Ashford, Kent.
———	———	*spinosa.	Ibid. Tab. 86. Martin Geol. Mem. West Suss. 33	Pulborough.	
———	Gervillia	aviculoides.	Ibid. Tab. 511. Geol. Suss. 74	Parham.	
———	———	solenoides.	Ibid. Tab. 510. f. 1–4. Geol. Suss. 74 . .	Ibid.	
———	———	acuta.[b]	Ibid. Tab. 510. f. 5	Ibid.	
———	*Inoceramus.[c]		Martin Geol. Mem. West Suss. 33 . . .	Pulborough.	
———	Pecten	quadricostatus.	Min. Con. Tab. 56. f. 1. 2. (3?)	Parham.	Exeter.
———	———	obliquus.	Ibid. Tab. 370. f. 2	Ibid.	
———	———	orbicularis.[d]	Ibid. Tab. 186. Martin Geol. Mem. West Suss. 33	Pulborough. Parham.[e]	
———	*Orbicula.[f]		Martin Geol. Mem. West Suss. 32 . . .	Pulborough.	
———	Terebratula	ovata.	Min. Con. Tab. 15. f. 3	Parham.	
———	———	lata.	Ibid. Tab. 502. f. 1	Ibid.	Devizes.
———	*Lenia.		Martin Geol. Mem. West Suss. 32 . . .	Pulborough.	
Mollusca.	Patella.[g]		. . . .	Parham.	
———	Pileopsis.[h]		. . . .	Ibid.	
———	*Auricula.		Martin Geol. Mem. West Suss. 31 . . .	Pulborough.	
———	Natica	canrena.	Parkin. Org. Rem. iii. Pl. 6. f. 2	Parham.	Ibid.
———	*Turbo.		Martin Geol. Mem. West Suss. 31 . . .	Pulborough.	
———	Rostellaria	Parkinsoni.[i]	. . . .	Parham.	Blackdown.
———	———	calcarata.	Min. Con. Tab. 349. f. 6. 7	Ibid.	Ibid.
———	———	with 2 processes.[k]	. . . .	Ibid.	Broughton, Kent.
———	Nautilus.[l]		Martin Geol. Mem. West Suss. 31 . . .	Near Pulborough.	
———	Ammonites	Goodhalli.[m]	. . . .	Willingdon.	Blackdown.

Hastings Deposits.

1. *Weald Clay.* (Upper Division.)

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Crustacea.	Cypris	Faba.[n]	Min. Con. Tab. 485	Cooksbridge.	
Conchifera.	Cyclas	membranacea.[o]	Ibid. Tab. 527. f. 3. "Tilgate Fossils," 26	Shipley.	
———	———	media.[p]	Ibid. Tab. 527. f. 2	Cooksbridge.	
Mollusca.	Paludina	vivipara.[q]	Lamarck Hist. Nat. Anim. sans Vert. Vivipara fluviorum, Min. Con. Tab. 31. f. 1 .	Laughton, near Lewes.	Near Tilbuster Hill, Surrey.

[a] Casts four inches and a half wide sometimes occur. [b] Avicula? [c] Lower beds.
[d] "Lower beds of green-sand." [e] Upper valve? A flat shell with numerous striæ. [f] Unlike O. reflexa, Min. Con. Tab. 506. f. 1. [g] Oval, conical, depressed; longest diameter one inch and a half, transverse one inch.
[h] Of the size of Patella Unguis, Min. Con. Tab. 139. f. 7. [i] Probably a variety of the chalk marl species, Geol. Suss. Tab. 18. f. 1. [k] Resembles very closely R. Pes Pelicani.
[l] Species not particularized. [m] Mr. Martin mentions three species of Ammonites; neither particularized.
[n] In limestone, septaria, and shale. [o] In blue clay. [p] In septaria and shale.
[q] The remains of this species, associated with those of Cypris Faba, form extensive beds of limestone, known by the name of Sussex marble.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Mollusca.	Paludina	elongata.[a]	Min. Con. Tab. 509. Tilgate Fossils, 26 .	Near Cooks- [bridge.	Compton-Grange, Isle of Wight.
———	———	carinifera.[b]	Ibid. Tab. 509. f. 3	Resting-Oak- [Hill.	
———	Potamides or Cerithium.[c]		Tilgate Fossils, 25	Shipley, near West Grinstead.	
Pisces.[d]			. . . .	Cooksbridge.	
Reptilia.[e]			Martin Geol. Mem. West Suss. 41 . . .	Resting-Oak- [Hill.	

2. *Tilgate Beds* (Middle Division),

including the Horsted sand, Tilgate sand, grits, and clays, and the Worth sandstone.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Cryptogamia (Vascularia).	Calamites.[f]		. . . .	Near Tun- [bridge Wells.	
———	Sphenopteris	Mantelli.	Ad. Brongn. Prodr. Hist. Veget. Foss. 50. Hymenopteris psilotoides, Geol. Trans. 2d series, i. 424. Tilgate Foss. Pl. 1. f. 3. *a. b.* Pl. 3. f. 6. 7. Pl. 20. f. 1. 2	Tilgate Forest. [Hastings. [Worth.	
———	Lonchopteris	Mantelli.	Ad. Brongn. Prodr. Hist. Veget. Foss. 60. Pecopteris reticulata, Tilgate Foss. Pl. 3. f. 5. Geol. Trans. 2d series, i. 423 . .	Hastings.	Env. de Beauvais. Eridge Park.
———	Lycopodites ?[g]		. . . .	Chiddingly.	
Phanerogamia (Monocotyledonous.)	Clathraria	Lyellii.	Tilg. Foss. Pl. 1. f. 1. 2. 7. Pl. 2. f. 1. 2. 3. Geol. Trans. 2d series, i. 423	Tilgate Forest.	
———	Carpolithus	Mantelli.[h]	Tilg. Foss. Pl. 3. f. 1. 2. Geol. Trans. 2d series, i. 423. Ad. Brong. Prodr. Hist. Veget. 127	Ibid.	
(families uncertain.)	Endogenites	erosa.	Tilg. Foss. Pl. 3. f. 1. 2. Geol. Trans. 2d series, i. 423	Ibid. Hastings.	
(Dicotyledonous: families not determined.[i])			. . . .	Ibid. Hast- [ings, &c.	
Crustacea.	Cypris	Faba.[k]	Min. Con. Tab. 485	Ibid.	
Conchifera.	Cyclas	media.	Ibid. Tab. 527. f. 2	Tilgate Forest. [Hastings.	
———	———	cornea ?[l]	. . . .	Tilgate Forest.	
———	———	membranacea.[m]	Ibid. Tab. 527. f. 3	Hastings.	

[a] In septaria, clay, and shale.

[b] Associated with the other species. Some of the smaller specimens of the last two species closely resemble Paludina tentaculata.

[c] A small delicate species, always in a mutilated state.

[d] Scales, bones, &c.

[e] Bones of saurian animals (very rarely) with Paludinæ and Cyclades.

[f] A compressed culm; nearly an inch in circumference, five joints in the length of four inches. In blue shale.

[g] A small delicate plant, carbonized; related to the recent Lycopodia? leaves of several species of Ferns, and other remains too imperfect to be determined.

[h] This fossil M. Brongniart supposes to be the seed-vessel of Clathraria Lyellii.

[i] Carbonized wood in small masses; doubtful if dicotyledonous; and lignite disseminated in sand, clay, grit, &c.

[k] With Cyclades, &c.

[l] A small species closely resembling Cyclas cornea, abundant in the calciferous grit.

[m] In shale, &c.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*	*Elsewhere.*
Conchifera.	Unio	porrectus.[a]	Min. Con. Tab. 594. f. 1	Tilgate Forest.	
———	———	compressus.[a]	Ibid. Tab. 594. f. 2	Ibid.	
———	———	antiquus.[a]	Ibid. Tab. 594. f. 3. 4. 5	Ibid. Hastings.	
———	———	aduncus.[a]	Ibid. Tab. 595. f. 2. Tilg. Foss. Pl. 10. f. 11	Linfield. Bolney.	
———	———	cordiformis.[a]	Ibid. Tab. 595. f. 1	Tilgate Forest.	
Mollusca.	Succinea ?[b]		. . . .	Ibid. [Wells.	
———	Paludina	vivipara.	Tilg. Foss. Pl. 10. f. 8. 9	Ibid. Tunbridge	
———	———	elongata.[c]	Ibid. Pl. 10. f. 7	Tilgate Forest.	
Pisces.	Lepisosteus.[d]		Lacèpede, Tilg. Foss. Pl. 5. f. 4. 15. Martin	[Hastings.	
			Geol. Mem. West Suss. 48	Billinghurst.	
				TilgateForest.	
			Specimen with pectoral fin	Heathfield.	
———	Silurus.[e]		Tilg. Foss. Pl. 10. f. 4. 6	Tilgate Forest.	
			Ibid. Pl. 5. f. 14. Pl. 15. f. 2. 6	Ibid.[f]	
				Ibid.[g]	
				Ibid.[h] [Wells.[i]	
			Ibid. Pl. 10. f. 2	Ibid. Tunbridge	
				Hastings.[k]	
Reptilia.	Trionyx.		Ibid. Pl. 6. f. 1. 3. 4. 5. 8. Pl. 7. f. 4. 7. p. 60	Tilgate Forest.	[of Soleure.
———	Emys.[l]		Ibid. Pl. 6. f. 6. 7. Pl. 7. f. 3. Oss. Foss. v. 232	Ibid.	Jura limestone
———	Chelonia.[m]		Ibid. Pl. 6. f. 2. Pl. 7. f. 1. 2. 5. 8. Oss. Foss. v. 239	Ibid.	Mæstricht.
———	Plesiosaurus.[n]		Ibid. Pl. 5. f. 11. Pl. 9. f. 4. 5	Ibid.	
———	Crocodilus	priscus.	Ibid. Pl. 10. f. 5. Oss. Foss. v. Pl. 6. f. 1 .	Ibid.	
———	Leptorhynchus.[o]		Ibid. Pl. 7. f. 5. 6. 8. Cuv. Oss. Foss. v. 127	Ibid.	Caen.
			Ibid. Pl. 5. f. 1. 2. 7. 10. 12. Cuv. Oss. Foss. v. 142 .	Ibid.[p]	
			Ibid. Pl. 8. f. 8	Ibid.[q]	
			Ibid. Pl. 8. f. 9	Ibid.[r]	
———	Megalosaurus.[s]		Ibid. Pl. 9. f. 2. 3. 6. Pl. 18. f. 2. Pl. 19. f. 1. 2. 8. 12. 14. 15. 16. Geol. Trans. 2d series, i. Pl. 40. 41	Ibid.	Stonesfield, n[r]
———	Iguanodon.[t]		Tilg. Foss. Pl. 4. Pl. 10. f. 12. Pl. 12. f. 1. 2. 3. 4. Pl. 16. f. 1. Pl. 18. f. 1. Oss. Foss. v. 351. Phil. Trans. 1825	Ibid.	[Oxford. Swanage, Isle
			Tilg. Foss. Pl. 15. f. 3. 4	Ibid.[u]	[of Purbeck.
				Ibid.[x]	
———	Pterodactylus ?		Ibid. Pl. 8. f. 1. 2. 3. 10. 11. 18	Ibid.	Hastings.
Aves.[y]			Ibid.	Ibid.	Ibid.

Sauro-coprus of Dr. Buckland. Small obscurely spiral masses, supposed to be fæcal.

[a] Casts of these species occur in abundance in the grits and sandstones of the Forest, in many instances constituting entire layers of considerable extent and thickness, like the muscle band of the coal measures, formed by a species of the same freshwater bivalve. See Pet. Derb. Pl. 27. 28. [b] A small species related to S. amphibia, in limestone with a group of Paludina elongata. [c] Abundant in the grit. [d] A genus allied to Esox. A fragment of the fore part of the body with the gills; nine inches long, seven inches broad, five inches thick, covered with rhomboidal scales. Detached scales are common in every bed of the Hastings formation. In the Museum of the College of Surgeons in London, there is a portion of the skin of a fish covered with scales of a similar character, from the Brazils, which Mr. Clift supposed to belong to a fresh-water genus allied to Esox. [e] Radii or fin bones; three or more species.

[f] Teeth tricuspid, striated. They resemble some from the Stonesfield slate.

[g] Teeth tricuspid, smooth. They differ from the tricuspid teeth of Squali.

[h] Palates or dentes tritores, resembling some from Stonesfield, Oxfordshire.

[i] Jaws with hemispherical teeth. [k] Scales, vertebræ, &c., of a small species too mutilated to admit of determination. In the argillaceous partings of the strata. [l] A remarkably flat species.

[m] Related to the fossil turtle of Mæstricht. [n] Bones, teeth, &c. [o] The fossil species of Caen.

[p] The fossil species of the Jura limestone. [q] A very small species resembling that figured in the Oss. Foss. vol. iii. Pl. 76. f. 8. [r] A small species. [s] Teeth, vertebræ, and other bones.

[t] Horn, teeth, vertebræ, phalanges, femur, tibia, fibula, clavicles, coracoid bone, ribs, &c.

[u] Teeth of an unknown saurian. Dr. Jäegar of Stuttgard has discovered teeth very much resembling these, in the neighbourhood of that city; together with the teeth and jaws of two other phytivorous saurians.

[x] Bones of other undetermined saurian animals. [y] Bones referable to Birds or to a flying reptile. Some appear to be decidedly the tibiæ of a wading bird.

3. *Ashburnham Beds.* (Lower Division of the Hastings Deposits.)

Argillaceous limestone alternating with schistose marls.

Class.	*Genus.*	*Species.*	*References and Synonyms.*	*In Sussex.*
Cryptogamia.				
(Vascularia.)	Sphenopteris	Mantelli.[a]	. . . .	Pounceford.
Conchifera.	Cyclas	media.[b]	Min. Con. Tab. 527. f. 2	Ibid.
———	———	membranacea.[c]	Ibid. Tab. 527. f. 3	Ibid. Ashburnham.
———	———	cornea.[d]	. . . .	Maresfield. West Hothly. Ashburnham. Hastings. Framfield.
———	Unio	antiquus.[e]	. . . .	West Hothly.
Mollusca.	Paludina	elongata.[f]	. . . .	Barnett's Wood, near Framfield.
———	———	vivipara.[g]	. . . .	Ibid.
Pisces.[h]			. . . .	Darvel's Wood, near Battel.
Reptilia.	Megalosaurus.[i]		. . . .	Pounceford.
———	Crocodilus.[k]		. . . .	Darvel's Wood.

[a] Lignite and imperfect traces of carbonized vegetables.

[b] Forms beds of limestone.

[c] Constitutes the principal portion of the argillaceous beds in some localities.

[d] This species resembles C. corneus of Lamarck, vol. vi. Entire beds of limestone are formed of it, associated with shells of the genus Unio. It occurs also in vast quantities in the grit.

[e] Two or more species in limestone with Cyclades.

[f] In limestone.

[g] In limestone and shale.

[h] Scales detached, small vertebræ, very imperfect remains in shale.

[i] Vertebræ; uncertain if from grit or shale.

[k] Vertebræ from the clay between the limestone, on the authority of Dr. Fitton.

⁂ This Catalogue was begun at the suggestion of Dr. Fitton, and intended as a supplement to his Memoir on the South-east of England, read before the Geological Society on the 15th of June 1827, and about to be published in a subsequent part of these Transactions. A paper by Dr. Fitton, first establishing the subdivision of the green and ferruginous sands, appeared in the Annals of Philosophy for November 1824.

Results.

There have been discovered in the strata of Sussex (exclusively of the organic contents of the comparatively modern alluvial deposits) the fossilized remains of nearly four hundred species of animals and vegetables, of which the following arrangement exhibits a condensed view.

Vertebral Animals.

Mammalia.	Pachydermata,	4 species	belonging to as many genera.
	Cetacea,	1 ———	——— 1 genus.
Aves.	Of the tribe Grallæ,	1 or more species	——— 1 ———
Reptilia	Testudinata,	3 ———	——— 3 or more genera.
	Sauria,	9 ———	——— 5 ———
	Pterodactylus?		
Pisces.		24 ———	——— 18 ———

Invertebral Animals.

Mollusca.	Multilocular	(Nautilidæ)†,	58 species	belonging to 8 genera.
	Simple,	(5 species freshwater)	63 ———	——— 29 ———
Conchifera.		(12 species freshwater)	125 ———	——— 40 ———
Annelides.			14 ———	——— 4 ———
Crustacea.			12 or more species	——— 10 ———
Radiaria.	Echinidæ,		24 species	——— 5 ———
	Asteriadæ,		2 or more species	——— 1 genus.
	Crinoidæ,		3 ———	——— 3 or more genera.
Polypi.			27 species	——— 10 ———

Vegetables.

Acotyledonous	10 or more species belonging to	6 or more genera.
Monocotyledonous	4 ———	3 ———
Dicotyledonous	2 ———	2 ———

Total—Mammalia 5 species; Aves 1 or 2; Reptilia 12; Pisces 24; Mollusca 121, of which 5 are freshwater; Conchifera 125, of which 12 are freshwater; Annelides 14; Crustacea 12; Radiaria 29; Polypi 27; Plantæ 16.

The geological distribution of the species above enumerated is shown in the following Table, and the zoological characters of the respective formations are thus established, so far as the present imperfect state of our knowledge will permit.

† Under this term the ancient multilocular genera are included. See Fleming Brit. Anim. 226.

A Tabular View of the Geological distribution of the Fossils of Sussex, exhibiting the zoological characters of the Strata.

[The strata are grouped according to their zoological characters, the Shanklin Sand being included in the Chalk Formation. The Purbeck would of course rank with the Hastings Deposits.]

Organic Remains.		Tertiary Form[n].			Chalk Formation.						Hastings Deposits.			
The contents of the alluvial beds, as belonging to the modern epoch, are not enumerated.	Diluvium.	London Clay.	Plastic Clay.	Total.	Chalk.	Chalk Marl.	Firestone.	Galt.	Shanklin Sand.	Total.	Weald Clay.	Tilgate Strata.	Ashburnham Bed.	Total.
Mammalia[a]	5	—	—	—	—	—	—	—	—	—	—	—	—	—
Aves[b]	—	—	—	—	—	—	—	—	—	—	—	2?	—	2?
Reptilia — Testudinata — Marine	—	—	—	—	—	—	—	—	—	—	—	1	—	1
Reptilia — Testudinata — Freshwater	—	—	—	—	—	—	—	—	—	—	—	2	—	2
Reptilia — Sauri[c]	—	—	—	—	1	—	—	—	—	1	1	7	2	10
Reptilia — Enalio-Sauri[d]	—	—	—	—	—	—	—	—	—	—	—	1	—	1
Reptilia — Pterodactylus?	—	—	—	—	—	—	—	—	—	—	—	?	—	—
Pisces[e]	—	3	1	4	14	3	1	2	—	20	2	7	1	10
Mollusca — Multilocular[f]	—	3	—	3	15	23	2	16	4	60	—	—	—	—
Mollusca — Simple — Freshwater[g]	—	—	3	3	—	—	—	—	—	—	4	3	2	9
Mollusca — Simple — Marine	1	34	—	34	5	11	2	5	8	31	—	—	—	—
Conchifera — Freshwater[h]	—	—	4	4	—	—	—	—	—	—	2	8	4	14
Conchifera — Marine	1	25	3	28	31	26	6	8	32	103	—	—	—	—
Annelides	—	5	—	5	3	3	—	3	2	11	—	—	—	—
Crustacea[i]	—	—	—	—	6	1	—	5	1	13	1	1	—	2
Radiaria — Echinidæ	—	—	—	—	17	4	1	1	1	24	—	—	—	—
Radiaria — Asteriadæ	—	—	—	—	2	—	—	—	—	2	—	—	—	—
Radiaria — Crinoidæ[k]	—	—	—	—	3	—	—	—	—	3	—	—	—	—
Polypi	—	1	—	1	18	4	3	1	0	26	—	—	—	—
Plantæ — Terrestrial[l]	—	1	3	4	1?	1?	2	1	1	6	—	8	1	9
Plantæ — Marine	—	—	—	—	4	1	1	1	—	7	—	—	—	—
Number of Species	7	72	14	86	120	77	18	43	49	307	10	40	10	60[m]
Character of the Formations[n]		London Clay, Mar., Plastic Clay, F. W.			Marine.						Freshwater.			

[a] Teeth, bones, &c. [b] Detached bones only. Some of those supposed to belong to birds may probably be referred to Pterodactylus. [c] Three of the genera extinct. [d] Genus extinct.

[e] The remains too imperfect, in most instances, to admit of positive conclusions as to their marine or freshwater habitats.

[f] Not a vestige in the Hastings beds; seven genera extinct. [g] Although the species are but few, these shells occur in vast numbers. [h] In immense quantities.

[i] Cypris Faba; very abundant in the upper beds. [k] Two genera extinct.

[l] The vegetables are probably much more numerous, their characters being in many instances too imperfectly displayed to admit of accurate determination. [m] As, in a few instances, the same species occur in more than one subdivision of the same formation, the total amount here given rather exceeds the number of distinct species.

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[n] Diluvium.—Bones of Pachydermata and Cetacea.

London Clay.—Seventy-two species, of which sixty-two are marine shells; a large proportion of simple univalves.

Plastic Clay.—Fourteen species, of which ten are either terrestrial or freshwater.

Chalk.—Nearly three hundred species, which, with scarcely any exceptions, are marine. Fifty-eight species of multilocular Mollusca, and twenty-four of Echinidæ.

Hastings Beds.—About sixty species, which, with but few exceptions, are either terrestrial or fluviatile: Reptiles, Testacea, and Vegetables. Neither the Echinidæ, Zoophyta, nor Marine Mollusca, occur in these deposits.

*** P. 204, note [g], and p. 208, note †, the word "Wood" is omitted at the beginning of the two sentences here referred to.

XI.—*On the Discovery of a New Species of Pterodactyle in the Lias at Lyme Regis.*

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[Read Feb. 6th, 1829.]

IN the same blue lias formation at Lyme Regis, in which so many specimens of Ichthyosaurus and Plesiosaurus have been discovered by Miss Mary Anning, she has recently found the skeleton of an unknown species of that most rare and curious of all reptiles, the Pterodactyle, an extinct genus, which has yet been recognized only in the upper Jura limestone beds of Aichstedt and Solenhofen, in the lithographic stone, which is nearly coëval with the chalk of England.

The history of the only two perfect specimens that have yet been found of this most anomalous genus of extinct reptiles, is familiar to all geologists from the minute and detailed descriptions which Cuvier has given of them: and the *Pterodactylus longirostris* and *Pterodactylus brevirostris* are pronounced by him to be incontestably the most extraordinary of all the extinct animals which have come under his consideration; and such as, if we saw them restored to life, would appear most strange and most dissimilar to any thing that now exists. "Ce sont de tous les êtres dont ce livre nous révèle l'ancienne existence, les plus extraordinaires, et ceux qui, si on les voyait vivans, paroîtroient les plus étrangers à toute la nature actuelle*."

In size and general form and in the disposition and character of its wings, this fossil genus, according to Cuvier, somewhat resembled our modern bats and vampyres, but had its beak elongated like the bill of a woodcock, and armed with teeth like the snout of a crocodile; its vertebræ, ribs, pelvis, legs, and feet, resembled those of a lizard; its three anterior fingers terminated in long hooked claws like that on the fore-finger of the bat; and over its body was a covering, neither composed of feathers as in the bird, nor of hair as in the bat, but of scaly armour like that of an Iguana;—in short, a monster resem-

* Cuv. vol. v. Part II. p. 379.

bling nothing that has ever been seen or heard-of upon earth, excepting the dragons of romance and heraldry. Moreover, it was probably noctivagous and insectivorous, and in both these points resembled the bat; but differed from it, in having the most important bones in its body constructed after the manner of those of reptiles. With flocks of such-like creatures flying in the air, and shoals of no less monstrous Ichthyosauri and Plesiosauri swarming in the ocean, and gigantic crocodiles and tortoises crawling on the shores of the primæval lakes and rivers,—air, sea, and land must have been strangely tenanted in these early periods of our infant world.

As the most obvious point of difference between our new species of Pterodactyle and those described by Cuvier, consists in the greater length of the claws, I propose to designate it by the name of *Pterodactylus macronyx*, and for the peculiarities of its structure, refer to my subjoined description of the details of its skeleton, and to Plate XXVII. lithographed from the specimen, and from a drawing which Mr. Clift kindly prepared to accompany this paper.

The individual we possess must have been nearly of the size of a raven:—the head is wanting, but much of the skeleton, though dislocated, is nearly entire; part of the neck is also lost. Mr. Clift and Mr. Broderip have discovered that the remaining cervical vertebræ are surrounded with small cylindrical bony tendons of the size of a thread*. These run parallel to the vertebræ, like the tendons that surround the tails of rats, and resemble the bony tendons that run along the back of the Pygmy Musk (*Moschus Pygmæus*), and of many birds, and are familiar to us in the leg of the common Turkey: these bony tendons must have materially added to the power of the neck and head of the Pterodactyle. Of the vertebræ of the back and the ribs but few remain: the sternum is much crushed, but appears to have been large; the pelvis also is large and well preserved. Three vertebræ of the tail remain, and show by their size that it was large and powerful: the legs are longer and stronger than in any of the bats or vampyres, and terminate in a long foot;—the lower extremities being thus altogether more adapted for standing and moving on the ground, after the manner of birds.

The scapulæ and coracoids are remarkably perfect, and much resemble those of birds: the wings when unfolded must have reached nearly four feet from tip to tip; their membrane was expanded by an elongation of the phalanges of the fourth finger, aided by the legs, and probably by the tail. The three anterior fingers are of unequal length; the first having two phalanges, the second three, and the third four, as in the foot of crocodiles and lizards. In all three fingers the penultimal phalanges, next the ungual bone, are the

* Plate XXVII. fig. 1[a].

longest; and in the second and third fingers the antepenultimal is the shortest. This is precisely the arrangement pointed out by Cuvier in the *Pterodactylus longirostris.* These three fingers, terminating in claws so long that I have chosen them to characterize the species by the name *macronyx*, must have formed a powerful paw, wherewith the animal was enabled to creep, or climb, or suspend itself from trees:—thus, like Milton's fiend, all-qualified for all services and all elements, the creature was a fit companion for the kindred reptiles that swarmed in the seas or crawled on the shores of a turbulent planet.

——————— "The Fiend,
O'er bog, or steep, through straight, rough, dense, or rare,
With head, hands, wings, or feet, pursues his way,
And swims*, or sinks, or wades, or creeps, or flies."

Paradise Lost, Book II. line 947.

I had for some time past suspected the existence of the Pterodactyle in the lias at Lyme; partly from having heard, about twenty years ago, that in the collection of Mr. Rowe, then made at Charmouth, there was the skeleton of a fossil bird, which I never saw, but imagine may have been a Pterodactyle; and partly from having found, four years ago at Lyme, in the collection of Miss Philpots, some bones of a wing and toe, which I could refer to no other animal, and of which a drawing was then made for me. More recently, I have discovered in the cabinet of Miss Philpots a thin elongated fragment of flat bone, which appears to be the jaw of a Pterodactyle; it is set with very minute, flat, lancet-shaped teeth, bearing the character of a lacertine animal—A drawing of it is annexed†.

Having thus established the existence of this genus at so early a period in the secondary formations as that of the lias, I revert to an opinion expressed to me in 1823 by Mr. I. S. Miller of Bristol,—that many of the bones in the Oxford Museum, from the oolitic slate of Stonesfield, which have generally been considered as the bones of birds, ought rather to be referred to the Pterodactyle. At that time I saw much reason to adopt his opinion with respect to many specimens; and I now, on further examination, am disposed to think that they may all be referred to a flying reptile rather than a bird; and it is

* In the Zoological Journal, No. XVI. p. 458, is a paper by G. Tradescant Lay, Esq. on the *Pteropus Pselaphon*, or Vampyre Bat, of the Island of Bonin, which shows that animal, in case of need, to possess the power of swimming. "One of them being placed by the sailors on a raft thrown into the sea, and having for some time laboured in vain to find a convenient place to suspend itself, abandoned the raft, and swam pertinaciously after the boat."

† Plate XXVII. fig. 3.

remarkable that the elytra of coleopterous insects, on which this reptile might have fed, occur at Stonesfield in the same stratum with its bones. Here then we have another new and important locality of the genus Pterodactyle, nearly in the middle region of the oolite formation, in a place intermediate between the lias and the lithographic limestone: and from its occurrence at the two extremes, and nearly in the centre of the series of the successive deposits which are grouped together under the name of Jura limestone, we may with probability infer, that its existence extended through the entire long period of this great formation from lias to chalk. Within this period are included all the strata of Tilgate Forest: and it deserves inquiry whether many of the bones discovered therein, which Mr. Mantell has referred to birds, may not on more careful examination prove to belong also to the Pterodactyle; and whether there be any certain evidence of the existence of fossil birds in strata more ancient than the tertiary.

I now proceed to my description of the details of the skeleton of *Pterodactylus macronyx**.

As many of the bones are moved from their natural place, they will be recognized more easily by reference to Plate XXVII. fig. 2, where the extremities are restored.

In my description, I shall follow, as nearly as possible, the order and illustrations adopted by Cuvier in his admirable account of the *Pterodactylus longirostris*.

Head.—The head is entirely wanting:—the fragment of a jaw† found in the same lias at Lyme Regis, and now in the collection of Miss Philpots, is probably that of our Pterodactyle; the teeth are simple, and like one another —flat, and shaped at the point like a lancet‡: the jaw bone is very thin.

Neck.—The anterior part is lost, and the remainder much obscured by pyrites; one vertebra only at *a*, is distinctly seen to be three quarters of an inch in length; thus corresponding with the cervical vertebræ of *Pterodactylus longirostris*. Around this long vertebra, and extending from it in both directions towards the head and back, are small cylindrical bony tendons, resembling the soft tendons that run parallel to the vertebræ in the tails of rats. They seem to terminate in the first dorsal vertebra, but the specimen is too imperfect to show this with certainty.

Vertebræ.—The vertebræ are much dislocated, and many of them lost; the bodies of four are seen near *a'*; two also are visible beneath the neck, at *b*; and one dorsal vertebra, at *b'*, retains the spinous process, and one transverse

* Plate XXVII.

† Plate XXVII. fig. 3.

‡ See magnified view of them at fig. 3.

process with the head of the articulating rib in contact with it. C is the body of a vertebra showing a convex articulating surface, as in the crocodile, with a cast of the medullary cavity at 2; the annular portion is lost. Traces of the spinous processes of another vertebra are seen at C 1.

d. Vertebra, probably lumbar, showing its concave articulating surface, one transverse process, and two anterior spinous processes. Behind this we see the body and large transverse process of another vertebra, probably sacral.

e. Ribs dislocated; impressions of other ribs appear on the stone.

K. Tail.—Three caudal vertebræ, much larger in proportion than those of *P. longirostris;* the legs also are larger and longer: and the tail was probably longer, and may have cooperated with the legs in expanding the membrane for flight:—a long and powerful tail is in strict uniformity with the character of a lizard.

9. 9. Omoplates;—long and narrow as in crocodiles, but still more nearly resembling those of birds.

X.X. Coracoid bones;—large as in birds for support to the wings in flight.

Clavicle;—none apparent.

18. Sternum—is much broken, and its form indistinct, but was large and broad for the attachment of pectoral muscles.

1. 1. Humeri;—lower extremities.

1″. 1″. Humeri;—upper extremities having the anterior tuberosity salient as in birds, but partly broken off; the right humerus and right scapula are much displaced; the left humerus and other bones of the left wing are nearly in their natural juxta-position, 1. 2. 3. 4. 5.

2. 2. Fore-arms;—showing no traces of any ulna. The right fore-arm is imperfect.

Carpus.—In the left carpus four bones are distinctly visible, *f. g. h. i.* Three of these are in contact with the radius, and the fourth (*i*) is in contact with the largest metacarpal bone: the bones of the right carpus are all dislocated and dispersed, *j. k. l. m.*

3. First, second, and third metacarpal bones of the right hand;—the under surface placed upwards.

3′. First, second, and third metacarpal bones of the left hand.

3″. Metacarpal bone supporting the fourth or wing-finger of left hand.

3‴. Metacarpal bone supporting the fourth finger of right hand.

S. Three fingers of the left hand terminating in long claws;—there are two phalanges in the first finger, three in the second, and four in the third finger, as in crocodiles and lizards.

S′. The right hand;—all the bones of the first and third fingers are present, and but little disturbed; but the ungual and anterior part of the second bone of the second finger are hid by the humerus.

4. First bone of the fourth or wing-finger.—This finger had probably four phalanges; parts of the two first, and an impression of part of the third, are all that remain*. There is no vestige of a fifth finger. The proportions of the phalanges of the first three fingers are as follows: The penultimal of each is the longest; and of the phalanges of the second and third finger, the antepenultimal is the shortest: the form of all the claws is that of a half-crescent compressed, and sharp at the point.

Pelvis.—The three bones of the right side of the pelvis are very distinct, and nearly in place. M. Ilium. L. Ischium. Y. Pubis.

N. left femur. N′. right femur displaced.

O. right tibia. O′. left tibia compressed so as to give the false appearance of a fibula, but there is no trace of a fibula near the right tibia.

T. Tarsus.—The bones of the tarsus are too much covered with pyrites to be made out: portions of two only are visible.

P. Four bones of metatarsus of the left foot distinct and undisturbed, their lower side being uppermost; the metatarsus of the right foot is concealed.

R. Phalanges of the left toes; all the ungual bones are wanting.

In the first toe, there remains a fragment of the first phalangal;—in the second toe, a fragment of the first and of the second phalangal;—in the third toe, the first phalangal entire, and portions of the second and third;—in the fourth toe, four bones remain, the ungual only being lost; of these the penultimal is the longest, and the second and third shortest, as in the ***P. longirostris*** and in lizards: these second and third bones of the fourth toe, and the second bone of the third toe, are depressed and partly covered by a fragment of the second phalangal bone of the wing, which I have taken off and replaced.

R′. Toes of the right foot much dislocated; one claw alone remains at R″; it is smaller than the smallest claw of the first finger at S.

The length of the foot and of the tibia and femur shows that the animal must have stood firmly on the ground, where, with its wings folded, it probably moved after the manner of birds. It could perhaps also perch on trees, and lay hold of their branches with its foot and toes, like birds and lizards.

* Plate XXVII. 4. 5. 6.

XII.—*On the Discovery of Coprolites, or Fossil Fæces, in the Lias at Lyme Regis, and in other Formations.*

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[Read Feb. 6th, 1829.]

1. *Coprolites in Lias.*

IT has long been known to the collectors of fossils at Lyme Regis, that among the many curious remains in the lias of that shore, there are numerous bodies which have been called Bezoar stones, from their external resemblance to the concretions in the gall-bladder of the Bezoar goat, once so celebrated in medicine: I used to imagine them to be recent concretions of clay, such as are continually formed by the waves from clay on the present beach; but I have now before me sufficient evidence to show that they are coëval with the lias, and afford another example of the same curious and unexpected class of fossils with the album græcum, which I first discovered in 1822 in the cave of Kirkdale, being the petrified fæces of Saurian animals, whose bones are so numerous in the same strata with themselves*. The Coprolites, which I shall first describe, have yet been noticed chiefly at Lyme Regis; but I think it probable that they exist wherever the remains of Ichthyosauri are abundant; the most likely place to afford them is the extensive coast near Whitby, where, as at Lyme, the lias is exposed to continual destruction by the sea, and abounds in bones of Saurians†. A great number of these so-called Bezoars at Lyme,

* The chemical evidence for this conclusion rests on the high authorities of Dr. Wollaston and Dr. Prout. In Dec. 1825, I submitted to Dr. Wollaston a specimen from Lyme Regis (Plate XXVIII. fig. 12.) and also one from Tilgate Forest (Plate XXXI. fig. 18.); and he then informed me that both these specimens contain much phosphate of lime, and that his analysis appeared to confirm my conjecture as to their fæcal origin.

In the present year Dr. Prout has kindly occupied himself with this subject, and has analysed all the varieties of fæcal substance that are mentioned in this paper.—See his Letter subjoined (p. 237).

† Since this paper was read, I have recognized a Coprolite from Whitby, in the collection of R. I. Murchison, Esq.; it forms the nucleus of a small Septarium. At Bath and Barrow-on-Soar, where large quarries of lias are laid open, and bones of Ichthyosauri are frequently dug up, we shall probably also soon find Coprolites.

occur as loose pebbles upon the shore, having been washed out of the lias; but many are also found dispersed, like Septaria, in the lias shale, and sometimes in the stone lias. Occasionally they form the nuclei of small Septaria, or have selenites or crystals of sulphate of barytes adhering to, and radiating from, their surface. These imbedded specimens have undergone no process of rolling, but retain their natural form, as if they had fallen from the animal into soft mud, and there been preserved undisturbed until it was consolidated to the state of lias and lias shale.

The certainty of the origin I am now assigning to these Coprolites, is established by their frequent presence in the abdominal region of the numerous small skeletons of Ichthyosauri, which, together with many large skeletons of Ichthyosauri and Plesiosauri, have been found in the cliffs at Lyme, and supplied to various collectors by the skill and industry of Miss Mary Anning. I have two of these skeletons, in each of which the Coprolites are very apparent, but flattened; and Miss Anning informs me that since her attention has been directed to these bodies, she has found them within the ribs or near the pelvis of almost every perfect skeleton of Ichthyosaurus which she has discovered. She further informs me, that whereas in the entire thickness of the lias formation there are certain strata that abound in bones, whilst in others they are comparatively rare; so also the so-called Bezoars are most abundant in those parts of the formation in which the bones of Ichthyosauri and Plesiosauri are most numerous.

I propose to assign the name of Ichthyosauro-coprus to the fossil fæces which are thus evidently derived from Ichthyosauri*.

In variety of size and external form the Coprolites at Lyme Regis resemble oblong pebbles or kidney-potatoes. They, for the most part, vary from two to four inches in length, and from one to two inches in diameter. Some few are much larger, and bear a due proportion to the gigantic calibre of the

* We are as yet without direct evidence to show which of the Coprolites are derived from Plesiosauri; the discovery of a skeleton containing them within it, will probably ere long decide the question: from the smaller size of their jaws, it should seem the Plesiosauri were less voracious, or at least less qualified to swallow large animals, than their neighbours the Ichthyosauri;—still they were carnivorous and swallowed their prey entire, and must have contributed their due proportion to the stores of Coprolites that lie buried with them in the lias. There is sufficient variety in these Coprolites to allow them to be referred to more than one genus, and to many species of Saurians. At present we can with safety apply the term Ichthyosauro-coprus to those only which are found within the skeletons of Ichthyosauri, and to specimens like those engraved at Plate XXIX. figs. 2. & 5. which contain bones of animals too large to have been swallowed entire by a creature having so small a mouth as the *Plesiosaurus dolichodeirus*. There is no third genus of animals in the lias to which we can refer these largest Coprolites.

largest Ichthyosauri*; others are small, and bear a similar ratio to the more infantine individuals of the same species, and to small fishes†: some are flat and amorphous, as if the substance had been voided in a semifluid state‡; others are flattened by pressure of the shale. Their usual colour is ash-grey, sometimes interspersed with black, and sometimes wholly black. Their substance is of a compact earthy texture, resembling indurated clay, and having a conchoidal and glossy fracture. Their general appearance will be best understood by referring to the figures given of them in Plates XXVIII. XXIX. & XXX. The structure of the Coprolites at Lyme Regis is, in most cases, tortuous, but the number of coils is very unequal; the most common number is three: the greatest I have seen is six§: these variations may depend on the various species of animals from which they are derived: I find analogous variations in the tortuous intestines of modern skates, and sharks, and dog-fish‖. Some Coprolites, especially the small ones, show no traces at all of contortion or any other structure¶.

The sections of these fæcal balls show their interior to be arranged in a folded plate, wrapped spirally round from the centre outwards, somewhat like the whorls of a turbinated shell**; their exterior also retains the corrugations and minute impressions, which, in their plastic state, they may have received from the intestines of the living animals††. Dispersed irregularly and abundantly throughout these petrified fæces are the scales, and occasionally the teeth and bones, of fishes, that seem to have passed undigested through the bodies of the Saurians, just as the enamel of teeth and sometimes fragments of bone are found undigested both in the recent and fossil album græcum of hyænas. These scales are the hard bright scales of the *Dapedium politum*, and other fishes which abound in the lias, and which thus appear to have formed no small portion of the food of the Saurians. The bones are chiefly vertebræ of fishes and of small Ichthyosauri; the latter are less frequent than the bones of fishes, but still are sufficiently numerous to show that these monsters of the ancient deep, like many of their successors in our modern oceans, may have devoured the small and weaker individuals of their own species. One large Coprolite‡‡ contains a vertebra, more than an inch in diameter, of an Ichthyosaurus that must have been at least four feet in length: and the jaws of large Ichthyosauri in the collection of the Geological Society, show how competent they were to swallow animals even of much greater size

* Plate XXIX. figs. 1. 2. & 4.
† Plate XXX. fig. 6—12.
‡ Plate XXX. fig. 5.
§ Plate XXVIII. figs. 3. 5. 11. 12′.
‖ Plate XXXI. figs. 19. 20. 21. 22.
¶ Plate XXX. fig. 4. & fig. 6—12.
** Plate XXVIII. figs. 3. 4. 10. 11. & 12′.
†† Plate XXVIII. figs. 6. 7. 8. 9.
‡‡ Plate XXIX. fig. 2.

than this*. It appears moreover, probable, that the remains of cuttle-fish occur in these fæcal balls at Lyme Regis. I had requested Dr. Prout to ascertain the cause of the bright jet black colour that pervades some of them : his reply after examination was, that their analysis is very similar to that of the fossil ink from the lias which I had also submitted to him, and to ask me if it was possible that Ichthyosauri could have eaten sepiæ : Mr. Gray also, whilst examining my specimens of the fossil pens and fossil ink-bags from the lias, asked if I ever found the semi-osseous or horny rings of the suckers of Cephalopodes : I replied that many of the fæcal balls are interspersed with small black circles, which seem to correspond in shape and substance with the horny rings he was inquiring for †, and to confirm the conjecture of Dr. Prout that sepiæ formed part of the food of the Saurians. Though containing much animal matter and but little lime, these rings, like the scales of fishes that have travelled with them through the intestines of the reptiles, seem to have resisted the destruction which awaited most of the bones that were submitted to this digestive process ‡.

Nearly half of all the Coprolites in the lias at Lyme Regis contain these rings, which, if they are derived, as I imagine them to be, from the suckers of the Loligo or other Cephalopodes, show that the Saurians fed largely on the Cephalopodes of the ancient seas §. I think it, however, right to mention two facts that seem unfavourable to my opinion as to these rings. 1st. That none of them are so large as the largest cup-rings of the modern Loligo. 2nd. That the lias contains the remains of a small fish whose vertebræ are nearly of the same size and shape as the rings in question : it is also possible that the rings in Plate XXX. figs. 2 A. & 3 A. may be sections of a large tuberculated scale or bone.

* Crocodiles in the Ganges, whose jaws are not one half the size of the fossil jaws I allude to, are often found to contain a human body in their stomachs. I possess vertebræ of Ichthyosauri nearly seven inches in diameter.

† Plate XXX. figs. 1. 2. & 3.

‡ It is a question that deserves attention, as connected with animal and mineral chemistry, Why fossil scales are preserved more perfectly than the bones of the fishes to which they belonged, though containing much less lime, and much more animal matter? The substance of the rings in the suckers of the recent Loligo and other Cephalopodes, much resembles the semi-transparent and horn-like substance of recent fish scales. In the case of our Coprolites, both rings of Loligo and scales of fishes appear to have been indestructible; and in the same lias with them at Lyme Regis, the beaks, and horny pens and ink-bags of a fossil Loligo, and other Cephalopodes, occur in high preservation: these will be described in the next Part of the Geol. Trans.

§ A strong *a priori* probability that the Cephalopodes of the lias period would have been devoured abundantly by the Saurians, arises from the fact mentioned in Loudon's Mag. Nat. Hist.

I now proceed to compare with the Sauro-coprolites of Lyme Regis some similar substances which have long been known to exist at Westbury, Aust Passage, and Watchet, on the banks of the Severn, and which now also prove to be fæcal balls of digested bone: they mostly occur in a thin bed of sandy micaceous lias, so full of the bones and teeth and spines of reptiles and fishes, as to form a bony breccia known to geologists by the name of the bone-bed, and occupying the lowest place at the bottom of the lias formation. The bones are chiefly of unknown small reptiles, but those of Ichthyosaurus and Plesiosaurus also occur; they are for the most part broken, though not much rolled, and both bones and teeth are separated from the part to which in life they belonged. Mr. Conybeare and myself have described these Coprolites as irregular bodies of various form, usually cylindrical, with rounded ends, some having a black and glossy surface and fracture, others being of a dull brown colour; and have conjectured them to be rolled palates, or rolled fragments of very solid bone: at that time no one suspected that they were bone reduced to the state of fæces *. More recently, Mr. Dillwyn has applied to them the name of nigrum græcum, from their resemblance in form to the album græcum of the cave of Kirkdale.

Mr. J. S. Miller of Bristol possesses an extensive collection of these bodies, and has also for some time suspected them to be fæcal. He has kindly lent me those which I have engraved at Plate XXX. figs. 13. 14. 16: a few only of these Coprolites from the Severn district resemble those of the lias at Lyme Regis; most of them are much smaller, and differ in the absence of spiral structure, and the rare occurrence of scales or bones in them. Externally they are of a bright glossy black, internally of a dark brown colour; their substance is compact, their fracture splintery, and sometimes conchoidal; their surface often smooth as if they had been polished †. They vary in size from that of

No. 7. p. 153., that the most valuable bait at the Newfoundland fisheries is the *Loligo vulgaris*; with this animal nearly one half of all the codfish there taken is caught. The Loligo appears there in throngs about the beginning of August, and it begins to retire from the coast in September. Cuttle-fish are also used as a favourite bait by fishermen on our own coasts. Mr. Clift informs me that he recollects having seen a large shark dissected near Poole, in the stomach of which was found nothing but a mass of beaks of Sepiæ. He also informs me that ambergris is often much contaminated by an admixture of the beaks of Sepiæ. Since, then, our modern whales and sharks and larger fishes are so voracious of modern Cephalopodes, it is probable that the Cephalopodes of the ancient seas were an equally favourite food to their contemporary Saurians: the discovery of the beak of a Sepia within a Coprolite would decide this question in the affirmative.

* Geol. Trans. Second Series, vol. i. p. 302, and Plate XXXVII.

† It is probable their smoothness and form are entirely due to the action of the intestines in which they were moulded; but, as the bones and teeth that are found with them have the same black colour and glossy surface, these common characters may have resulted from agents to which

a small potatoe to a hemp seed: in shape, many of them resemble the subangular concretions found in the human gall-bladder, and in the cavities of a diseased kidney; others are spherical, like sheep's dung, or cylindrical, like that of rats and mice, with various intermediate varieties of size and form; some are flat like a bean, others polygonal*.

There is no direct evidence to show from what animals the smaller varieties of these Coprolites have been derived. Many may probably be referred to the small reptiles, and others to the fishes, whose broken and scattered bones, teeth, palates, and spines, are so frequent in the same breccia with themselves: others may possibly be derived from the inhabitants of the Nautili, Ammonites, Belemnites, and other Cephalopodes which abounded at the period of the lias formation†.

The extent and quantity of this coprolitic breccia near the estuary of the Severn is very remarkable. My friend, R. Anstice, Esq. of Bridgwater‡, has sent me masses of lias, which he found in 1823 at the east extremity of Blue-Anchor Bay, near Watchet, full of these black pupa-shaped fæcal bodies, which he says he never could understand; they are here also mixt with numerous teeth and scattered scales of fishes, and with teeth and bones of small unknown Saurians: he also informs me that Mr. Baker of Bridgwater has recently found the same breccia in the bed of the Parrot, five miles below that town at Combwich, where the lias crosses the river near low-water-mark. In the specimens he has sent me from thence, the fæcal remains and bones are rare, but scales of fishes are very abundant; similar scales occur in the lias at Bawdrip, on the east of Bridgwater, as also in the lias at St. Hilary near Cowbridge, and at Gold Cliff in Glamorganshire, and at Wickwar in Gloucestershire: in all these cases, as in the breccia of Westbury and Aust, the scales are dispersed and dislocated, and seem derived from fishes that died and fell to pieces, and whose scattered bones, scales, and teeth, became mixt with the remains of reptiles and of other inhabitants of those ancient seas. I have

they were all equally exposed, whilst they lay together loose at the bottom of the sea, or since they have been buried together in the lias; the polish in neither case is the effect of rolling; and the cause of the bright jet black colour is probably carbonization; the entire substance of the bones is often black, but the surface only is black in most of the Coprolites; their interior is usually brown.

* Plate XXX. fig. 13—29 inclusive.

† On dissecting a *Sepia officinalis*, I have found the stomach filled with small bones of fishes mixt with fragments of shells of small Solens, and with small bivalves.

‡ We owe to Mr. Anstice our knowledge of the existence of the head of *Plesiosaurus dolichodeirus*, described by Mr. Conybeare in Geol. Trans. Second Series, vol. i. p. 119, as having been found by Mr. Clarke, who presented it to Mr. Anstice.

yet seen no Coprolite in specimens of the bony breccia from these four last localities. The late Rev. J. J. Conybeare gave me specimens of the same breccia from the lias in a shaft dug in the year 1808 at Bath Easton, in fruitless pursuit of coal; in these specimens I now recognize Coprolites; and in a mass of lias breccia, which I collected a long time since at the base of Broadway Hill near Evesham, I find the brecciated character is due also to an accumulation of Coprolites.

This remarkable phænomenon of a stratum of stone many miles in extent, and many inches in thickness, and in which sometimes one fourth part of the whole substance is made up of balls of Coprolite, seems explicable only by its position in the lowest region of the great formation of the lias, a position which must for a long time have been the bottom of an ancient sea, and the receptacle of the fæces and bones of its inhabitants, the cloaca maxima, as it were, of primæval Gloucestershire. This period must have occupied the interval between the termination of the red marl, and the beginning of the deposit of the lias formation, and the earthy sediments then deposited must have been inconsiderable in the districts we are now speaking of. In the sediments which next succeeded, and of which the great mass of the lias formation is composed, there is no such abundant accumulation of Coprolites in any single thin stratum, but they occur insulated and dispersed in the slaty clay and stone, or included within the skeletons of the Ichthyosauri*. The fact of so many of these skeletons being those of young animals, proves that they did not die in the course of nature from infirmity or age; and the entire condition both of young and old skeletons shows that they perished suddenly, and were buried immediately after their death; they would otherwise have fallen to pieces, and been dispersed like the bones in the breccia at Westbury and

* Among the strata at Lyme that most abound in bones, is a bed of marl about three feet thick, in which Sauro-coprolites are chiefly found, but even in this bed they are far and widely dispersed; in one case only Miss Anning has found two Coprolites together, and these were close to the skeleton of an Ichthyosaurus, as if they had been voided by it in the struggles of death. In the cliff a quarter of a mile west of the Port of Lyme in the lias marl, above the strata that most abound in the remains of Saurians, I found one bed of stone-lias about 6 inches thick, in which was a congeries of small Coprolites, irregular and subangular, like those in the bone-bed of the Severn district, and so different from those which are associated with the large Saurians in the lower parts of the lias, that I imagine them to be derived from fishes or Cephalopodes, or some other unknown animals; they are, however, important, as affording a geological chronometer whereby we mark at least one short interval in the deposition of the lias marls, during which they must have been accumulated at the bottom of the then existing seas. I found no remains of fishes or Saurians with them, nor any pebbles or other indications of a long period such as seems to have been occupied in the formation of the coprolitic bone-bed at Westbury and Watchet. Nearly the same conclusion as to short intervals between the deposition of the component parts

Aust: moreover, it seems not improbable that the cause of the death of so many animals of every age and condition, may have been the sudden influx of the mud, which has since been indurated to the state of lias and lias shale*. The same inference as to sudden death and immediate burial may be drawn from the generally perfect condition of the fishes in this formation; had they not been speedily enveloped in the sediment of the nascent lias, they would have been devoured by Ichthyosauri, or by other fishes, or by smaller animals, and the bones and scales would have either been involved in Sauro-coprolites, or have been dispersed. A still stronger inference of the same kind arises from the frequent and perfect preservation of fossil ink-bags in contact with the horny pens and other remains of a fossil Loligo and other Cephalopodes: had these soft animals not been entombed very speedily after death, the decomposition of their bodies would have separated for ever these parts which we find in contact; moreover, the ink-bags would very speedily have perished, and their contents have been dispersed. The sudden entombment of the animals also in the lias at Lyme Regis, is further shown by a fossil fish in the collection of Miss Philpots retaining a fæcal ball within its body; this individual must have been buried in mud before even the soft parts of its abdomen had undergone displacement or decay. Dr. Prout has analysed this ball; and I would propose to distinguish it, and all similar substances that can be referred to fishes of unknown species, by the name of Ichthyocoprus.

Should any question be raised as to the antecedent probability of excrementitious substances being preserved in a fossil state, nearly the same argument may be applied as in the case of the fossil album græcum of the hyænas;

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of the lias may be drawn from the very rare occurrence of parasitic shells on the bones of the Ichthyosauri and Plesiosauri at Lyme Regis. Had these bones remained long exposed to water at the bottom of the sea, parasites would have attached themselves similar to those we so often find on fossil bones in other strata, showing that a period at least sufficient for the growth of these parasites elapsed between the deposition of the bones and their complete interment in mud or sand. The absence of such parasites, added to the smooth and uninjured state of the surfaces of the bones, shows how immediately after death the animals must have been covered with the mud that is now consolidated into shale and stone: one bone of a Plesiosaurus in the collection of Miss Philpots is the only specimen I recollect from the lias at Lyme that has a parasitic shell adhering to it; this one, however, is sufficient to show one short interval in the deposition of the five hundred feet of marl and argillaceous limestones that here compose the lias formation; probably there were many such short intervals; the coprolitic bed on the west of the Port of Lyme is another.

* There may also have been an influx of the bitumen which is so abundant in the lias shale, or a sudden alteration in the temperature of the waters, or a chemical and fatal change in their composition.

in that case it was argued by Dr. Wollaston, *a priori,* that if the hyænas had eaten bones, we might expect to find album græcum preserved, together with the fragments of bones that remained not devoured in their antediluvian dens; and my immediate discovery of this substance fully verified Dr. Wollaston's conjecture: the same argument extends to the case of other fossil animals that swallowed bones; the main condition is, that the osseous fæces shall have been deposited in such places, and under such circumstances as would guard them from destruction till they were imbedded in some protecting matrix; this done, their chemical ingredients are as indestructible as the undigested bones which are preserved in the same strata with themselves. If such perishable impressions on sand as the footsteps of tortoises and other animals, have been retained and moulded on the surfaces of the strata of new red sandstone at Corncockle Muir near Dumfries*, and if such fragile bodies as the eggs of aquatic birds have been preserved in the lacustrine limestones of Cournon in Auvergne†, why should not the indurated and semi-calcareous fæces of Ichthyosauri and other voracious animals have fallen uninjured to the bottom of the sea, and there becoming imbedded in mud or sand, or nascent stone, have remained undisturbed and perfect unto the present hour?

II. *Coprolites in Mountain Limestone.*

The specimens engraved at Plate XXX. fig. 31—41. are the only ones I have seen from strata of older formation than the lias; for my knowledge of them I am indebted exclusively to Mr. J. S. Miller, who has collected a series of them from the bottom of the mountain limestone at Clifton near Bristol. They occur in one bed of limestone nine inches thick, between the black rock limestone and the old red sandstone, and are mixed with small bones and teeth of fishes, palates of at least ten kinds, spines of Balistes, and teeth of sharks, and fragments of old red sandstone, and offer a case apparently analogous to that of the bone-bed at the bottom of the lias; each respectively seems to indicate a period anterior to the deposition of the two great formations of the mountain limestone and the lias, during which the bottom of the then existing oceans received little accession of mineral matter, but was the receptacle both of the indurated fæces of its voracious inhabitants, and of the bones of those individuals among them that escaped violent death and consequent reduction to the state of fæcal balls in the stomachs of one another.

These most ancient Coprolites in the mountain limestone are all small, and are probably varieties of Ichthyocoprus.

* See Dr. Duncan's account of footmarks, &c. Trans. Royal Soc. Edinburgh, 1828.

† See Croizet and Jobert's *Récherches sur les Fossiles du Puy de Dôme*, *Disc. Prél.* p. 27.

III. *Coprolites in Oolite.*

I have very recently discovered Coprolites in limestone of the Oxford oolite formation at Osmington Mill on the coast of Dorset, about four miles east of Weymouth; and Mr. Jelly has found them in the Kimmeridge clay at the base of Shotover Hill near Oxford: they are small, the largest is of the size of a filbert; others are of irregular shape, like those in the lias at Westbury and Watchet; the character, however, of these Coprolites from the oolite and Kimmeridge clay is somewhat obscure.

IV. *Coprolites in Hastings Sand.*

About four years ago, in the collection of Mr. Mantell, I found a specimen from the Hastings sandstone of Tilgate Forest, which I suspected to be fæcal, and of which I then prepared a drawing*, and obtained an analysis from Dr. Wollaston, and subsequently from Dr. Prout, as before stated: it contains much phosphate of lime, and has fish-scales imbedded in it like the Coprolites at Lyme; like them it has also a spiral structure, but differs in the circumstance of the coiled substance being rather cylindrical, whereas in the lime Coprolites it is nearly flat. I know not to which of the many reptiles Mr. Mantell has discovered at Tilgate this Coprolite may be referred. He has lately found other specimens of this same unknown species of Coprolite.

V. *Coprolites in Green-sand.*

To the Rev. B. Richardson of Farley Castle I am indebted for a specimen of Coprolite in green-sand from Wiltshire;—it is nearly of the size of a filbert, and very stony. Dr. Prout's analysis shows it to contain a considerable proportion of siliceous matter; it effervesced moderately in dilute muriatic acid, emitting faintly the peculiar smell usually given off by Coprolites; and the portion dissolved consisted essentially of phosphate and carbonate of lime; it is engraved at Plate XXXI. fig. 17. Miss Anning has recently found similar small Coprolites in the green sand near Lyme.

VI. *Coprolites in Chalk.*

Whilst I was examining and drawing the specimens from the lias that are represented at Plate XXVIII. figs. 3. 4. 5. 10. 11. 12. 12′., their structure so much reminded me of the fossil Iuli of the chalk and chalk marl which have been described by Woodward, Parkinson, and other writers, as fir cones of the larch†, that it occurred to me these so-called Iuli must also be of fæcal

* Plate XXXI. fig. 18.

† See Woodward's Catalogue, Part II. p. 22. 6. 72., and Parkinson's Organic Remains, vol. i. p. 447. and Plate VI. figs. 16. 17.—Mantell's Geology of Sussex, p. 103. et seq.

origin *: this conjecture was soon verified by examination of the specimens in question: like the Coprolites at Lyme, I found them to be composed of a flat plate of digested bone reduced to a plastic state resembling putty, and coiled up spirally like a tape-worm twisted round itself.

This plate is much thinner, and its coils are more numerous than in the Sauro-coprolites from the lias: imbedded in the substance of this plate, I found many scales of fishes †, and around its exterior, corrugations or impressions derived from the membrane of the intestine wherein it was formed ‡.

The analysis of Dr. Prout consummates the evidence of their fæcal origin, showing them to be composed chiefly of phosphate of lime: they vary from one to two inches in length, and from half an inch to an inch in diameter. On comparing the analysis of a fossil vertebra of fish from the chalk near Lewes with that of an Iulus, Dr. Prout found the difference to be scarcely perceptible; its colour and appearance before analysis was also similar §.

Until we can ascertain the animal from which they have been derived, I propose to designate these bodies by the name of Iulo-eido-coprolites. It is obvious, from their form and structure, they cannot be referred to the same animals as the Coprolites at Lyme; indeed the bones of Saurians of any kind are rarely found along with them; probably they may have been produced by some of the sharks, rays, diodons, balistes, or other fishes whose teeth, and palates, and spines, are so common in the chalk formation; the tortuous structure of the intestine of the existing shark, making thirty-four turns in a

* Plate XXXI. fig. 1—11. † Plate XXXI. fig. 6.

‡ Plate XXXI. figs. 1. 4. 5. 6. 9. 11. compare them with the recent specimens (figs. 20. & 21.) of the same plate.

§ The following accurate description by Mr. Mantell (Geol. of Sussex, p. 104.) shows how nearly he approached the discovery of the origin I am now assigning to these Iuli; although he modestly states that, after examining more than fifty specimens, he can add but little to what is known concerning them.

"The remains in question are of a reddish brown colour, from 0.5 inch to two inches long, of a cylindrical form, and generally tapering towards the apex, which is obtuse. They are more or less compressed, and have a scaly, corrugated surface. Their constituent substance is precisely of the same nature as that of the vertebræ and other bones found in the chalk formation; some examples have scales of fishes attached to them. In structure, they differ most essentially from any strobilus or cone; for, instead of an imbricated surface formed by scales containing seed, and proceeding from one common axis, as in the Iuli of the Larch, their scaly appearance is produced by the undulating margin of the substance of which they are composed, the latter being irregularly coiled in a spiral manner round an oval cavity or receptacle."

Mr. König also had long suspected their animal nature from the offensive odour they emit on being submitted to muriatic acid.—See Mantell's Geology of Sussex, pp. 103. 104. 158. and tab. ix.

length of ten inches, offers an analogy which may explain the spiral form of these Iulo-eido-coprolites, and also of the Sauro-coprolites from Lyme Regis*.

I have just learnt from Mr. Millar, that Colonel Houlton of Farley Castle possesses specimens from the mountain of St. Peter near Maestricht, which are identical with these Iulo-eido-coprolites of the English chalk. The Colonel has favoured me with the loan of these specimens†.

The specimen represented in Mr. Mantell's Plate IX. fig. 3. as an unknown body from the chalk at Lewes, has also been ascertained by Dr. Prout to be of a fæcal nature‡; its external form and surface favour this opinion, but as it has no internal spiral coils, it must have been derived from some other animal than those which produced the Iulo-eido-coprolites. Mr. Mantell has just sent me a smaller specimen from the chalk near Lewes§, in which an uncontorted substance of a similar form and colour, and giving a similar analysis, lies within the body of a fossil fish (*Amia Lewesiensis*), and in immediate contact with its air-bladder‖. Both these specimens from Lewes are probably varieties of Ichthyocoprus, and the smaller one may safely be called *Amia-coprus*. These uncontorted specimens prevail in the lower chalk, where alone the Amia is found, and seldom occur in the chalk marl where the spiral Iulo-eido-coprolites are so common.

VII. *Coprolites in Tertiary Strata.*

Mr. Burtin in his *Oryctographie de Bruxelles*¶ figures a specimen as a "fruit, ou noyau de fruit inconnu," which seems evidently to be a Coprolite. Mr. Mantell** has referred to it as resembling the Iuli of the chalk; and I have copied it in Plate XXXI. fig. 11*a*. Also in a collection I recently purchased of fossil fruits from the London clay of Sheppy, there is a Coprolite†† which in form resembles some of those from the lias on the Severn‡‡.

* An examination of the form and composition of the fæces of living fishes, particularly of the shark and ray and sturgeon tribes, throws much light on the present inquiry. I have recently dissected some rays and dog-fishes, and found in them a short spiral intestine coiled round internally like a screw-pump or winding staircase; injecting these intestines with Roman cement, I have made artificial Coprolites that in form are exactly similar to many of our fossil specimens. Plate XXXI. figs. 19. 20. 21. 22. The vascular structure also of the tortuous intestines of certain species of dog-fishes resembles the minute impressions and ramifications on the surface of the Iulo-eido-coprolites. Plate XXXI. figs. 20. 21.

† Plate XXXI. figs. 9. 10. 11.

‡ Plate XXXI. fig. 13.

§ Plate XXXI. fig. 12.

‖ Mantell's Sussex, p. 239. and Plate XXXVIII.

¶ Plate V. F. G.

** Mantell's Sussex, p. 158.

†† Plate XXXI. fig. 14.

‡‡ In the crag at Southwold in Suffolk, Mr. Lyell has found a remarkable body, apparently a Coprolite, of the size and form of an oblong duck's egg, and almost entirely composed of phosphate of lime and oxyd of iron: it is traversed by cracks like a septarium, and the cracks are filled with oxyd of iron; it however exhibits no internal structure, nor organic remains, nor any other circumstantial evidence to prove incontrovertibly that it is of fæcal origin.

VIII. *Coprolites in Fresh-water Formations.*

In a valuable series of specimens recently imported by Mr. Lyell and Mr. Murchison from the fresh-water deposits near Aix in Provence, Mr. Murchison has recognised two distinct species of Coprolite; the one had been collected as a curious concretion from the shale of the fresh-water coal formation at Fuveau*; the other in size and shape resembles a caterpillar, and had been brought home as a fossil insect, being in the laminated fresh-water marl that contains the remarkable deposit of fossil insects above the gypsum formation close to Aix†.—Both these specimens have been examined by Dr. Prout.

IX. *Coprolites in Diluvium.*

I need only refer to the account given in my *Reliquiæ Diluvianæ,* of the fæces of hyænas in the Cave of Kirkdale, and to the large quantities of the same substance that have subsequently been discovered at Torquay and Maidstone, and in the Cave of Lunel, to show how frequent is the occurrence of Hyæno-coprus in diluvial mud and gravel.

Thus, in formations of all ages‡, from the first creation of vertebral animals to the comparatively recent period in which hyænas accumulated album græcum in their antediluvian dens, we find that the fæces of aquatic or terrestrial carnivorous animals have been preserved. We have them in the lowest region of the carboniferous limestone, the lias, the oolite, the Hastings sandstone, the Wiltshire green-sand, the chalk-marl and chalk of Sussex, at Maestricht, at Brussels, in the London clay at Sheppy, in the fresh-water formation at Aix, and in diluvium. In all these various formations our Coprolites form records of warfare, waged by successive generations of inhabitants of our planet on one another: the imperishable phosphate of lime, derived from their digested skeletons, has become embalmed in the substance and foundations of the everlasting hills; and the general law of Nature which bids all to eat and be eaten in their turn, is shown to have been co-extensive with animal existence upon our globe; the *Carnivora* in each period of the world's history fulfilling their destined office,—to check excess in the progress of life, and maintain the balance of creation.

* Plate XXXI. fig. 15.

† Plate XXXI. fig. 16.

‡ It has been stated in a note at p. 229, that Coprolites, wherever they occur, abundantly afford a chronometer which marks affirmatively the lapse of a period of time sufficient for their accumulation; it should be observed on the other hand that their absence, like the absence of organic remains, is a negative fact, from which nothing can be inferred either as to the rapidity or slowness of any formation whatsoever.

APPENDIX.

The facts established in this paper seem connected with the formation of the remarkable substance called *guano* on the coast of Peru, and on many islands adjacent to it. This guano is composed of an accumulation of the dung and urine of sea-birds, and occurs in beds fifty or sixty feet thick. These beds are often covered over with drifted sand, and, during many centuries past, have been extracted for manure.

In Ferussac's *Bulletin* for January 1829, Art. *Chemistry*, p. 84, there is an abstract of a Memoir on the Guano of Paxaro, by Mariano di Rivero, director of the Corps des Mines in Peru and Lima, 1827. He states that it is certainly nothing else than an accumulation of the excrement of sea-birds that have come to pass the night on these spots during a long series of years: he further adds, that certain deposits of it were worked from time immemorial before the conquest. In the time of the Incas, the use of it was under legal regulations, to prevent waste, and during the breeding season of the birds, no one, under penalty of death, was allowed to land on the islands on which it was forming.

Since the time of the Spaniards the preservation of it has been neglected; and its reproduction diminishes as vessels passing more frequently along the coast, frighten away the birds. In modern times, the average consumption of guano for manure has been about 6250 tons per annum, for which the duty paid at the ports has been about 40,000*l.* sterling per annum.

Vauquelin and Fourcroy analysed some specimens of it brought home by Humboldt, and found uric acid partly saturated by ammonia and lime, and oxalic acid partly saturated by ammonia and potash; also phosphoric acid combined with the three same bases, with very small quantities of muriate of ammonia, a little fatty matter, and a little quartzose and ferruginous sand.

We may add this guano to our series of Coprolites, by the name of Ornithocoprus. See also Ure's Chemical Dictionary, Art. *Guano*.

Postscript.

During a recent visit to Lyme Regis, I have ascertained that the lias at that place contains other cylindrical concretions resembling Coprolites, which yet seem not to be of fæcal origin, but simply mineral concretions formed like small septaria in clay, or flints and nodules of pyrites in chalk; they agree chemically with Coprolites in containing much phosphate of lime, but differ from them in their relations to their matrix, in structure, and in the organic remains which they envelop.

I find also that phosphate of lime occurs in other secondary strata, more generally than has hitherto been supposed. Dr. Daubeny has undertaken the analysis of several specimens which I suspect to contain it, and I hope shortly to lay the result before the Geological Society: at present, I deem it right to mention these circumstances by way of caution, as they tend to increase the difficulty of identifying Coprolites wherever they may occur, and render it impossible for chemistry alone to decide affirmatively respecting any specimen that is the subject of our examination. Still the evidence of chemistry is essential; and when it has shown that a specimen contains phosphate of lime, we must further ascertain its relations to the matrix, its external and internal structure, and the character of the organic remains enveloped in it, before we can pronounce whether it be a genuine Coprolite, or a pseudo-coprolitic concretion of phosphate of lime.

XIII.—*Letter from Dr. Prout to Dr. Buckland respecting the Analysis of the Fossil Fæces of Ichthyosaurus and other Animals.*

[Read April 3rd, 1829.]

Dear Sir,

I HAVE examined the different specimens you were kind enough to send me, and found the composition of all of them to be very similar; that is to say, they consist essentially of the phosphate of lime and carbonate of lime, together with minute variable proportions of iron, sulphur, carbon, and occasionally other matters. The relative proportions of the principal ingredients appear to differ somewhat in the different specimens, and even in different parts of the same specimen; hence no formal analysis has been attempted; but the phosphate of lime may perhaps be estimated to constitute from about one-fourth to three-fourths of the whole mass. The iron and sulphur appear to exist in some instances, partly as a sulphuret of iron, and partly in a state of oxidation; and the dark-coloured varieties, in which these principles exist in greatest abundance, appear to owe their colour chiefly to these substances and a little carbonaceous matter.

The above composition seems to prove beyond a doubt the animal origin of these bodies, or, in other words, that their basis is bone. The question is, by what means bone can be made to assume the appearances presented by them. That mere time, and the circumstances to which they have been exposed, are not sufficient to account for these changes, seems to be proved by the fact, that many of the specimens contain fragments of bone possessing its original characteristic structure. We must therefore seek for some other explanation; and your opinion that they are of fæcal origin, or of the nature of album græcum, seems to me to offer a very satisfactory solution, and to account at once for their chemical composition, for their form, and for their mechanical structure, which can hardly be explained on any other supposition.

Nor do I see any serious objection to your opinion, that these substances are the mineralized fæces of carnivorous reptiles of the Saurian and analogous tribes, the fossil remains of which exist so abundantly in the same strata. The proper fæces of existing animals of this kind, consist principally of the phosphate of lime, and often assume the form of album græcum. These animals also pass immense quantities of concrete urine, consisting principally of the lithate of ammonia; but, as this latter is comparatively a destructible substance, it could hardly be expected to be met with in the present instance under circumstances so unfavourable for its preservation*.

The lithic acid, however, is one of the most permanent of animal substances, as is shown by the great length of time that urinary calculi composed of it may be preserved; but more especially by the fact that it exists unchanged in the substance called *guano*, after exposure to the atmosphere, &c. for ages. Hence, perhaps, it is not too much to expect, that under favourable circumstances this principle also may hereafter be found of antediluvian origin.

Sackville-street,
March 14, 1829.

I remain, dear Sir,

Yours very truly,

William Prout.

The Rev. Dr. Buckland.

* I first published many years ago an account of the composition of the urinary excrements of the *Boa constrictor* (see Annals of Philosophy, vol. v. p. 413.); since which time I have examined those of the crocodile and other reptiles, and found them exactly similar. As my attention at that time was not directed to the fæces, though I noticed their composition, I did not publish an account of them; but the late Dr. Marcet, to whom I presented specimens of both kinds of excrement, has given an account of their composition. Of the fæces he says, "This substance I did not find to contain any lithic acid, but *it consisted chiefly of the phosphate of lime*, and appeared to be nothing but the undigested residue of the food of the animal."—*Essay on Calculous Disorders*, p. 140, First Edition.

Supplement to Mr. Sedgwick's Paper on the Magnesian Limestone.

Some parts of the preceding paper on the Magnesian Limestone have been written nearly seven years; and the whole of it was drawn up in the year 1826 very nearly in the form in which it is now printed. The subsequent discoveries of foreign geologists, and my own recent examination of some of the secondary deposits of the Continent, induce me, during the passage of this volume through the press, to add the following supplementary remarks.

The comparison of the magnesian limestone with some of the great calcareous formations of the Alps* I now consider erroneous.

The two vegetable impressions found in the marl-slate were far too imperfect to be identified, but were supposed to be derived from ferns†. This opinion may admit of doubt, especially since the discoveries of M. Voltz, who has found new tribes of plants (*Coniferæ*, &c.) in the formation immediately superior to the magnesian limestone.

The positive identification of the inferior red sandstone with the grès des Vosges may also admit of doubt‡. The two formations in some of their mineral characters closely resemble each other, and they are very nearly in the same part of the secondary series. As, however, the eminent geologists of the Continent are not entirely agreed as to the exact place of the grès des Vosges, it is perhaps premature to refer to that formation in the general comparisons of this paper.

After a personal examination of the secondary formations on the flanks of the Hartz mountains, I see no reason to change any part of the comparison I have made between the contemporaneous formations of England and of central Germany§. The inferior red sandstone is perfectly identical with the rothe-todte-liegende of Mansfeld. I may however remark, that the term rothe-todte-liegende has been used very vaguely, and that, in the neighbourhood of Halle, it is still applied to two systems of red sandstone and conglomerate, which are separated from each other by the coal formation. To the fine development of the bunter sandstein, muschel-kalk, and keuper, and to the great suites of characteristic fossils which are found in each of them, the English strata unfortunately offer very few parallels. But in a general way, the red sandstone

* p. 39. † p. 77. ‡ p. 75. § p. 121, &c.

superior to the magnesian limestone is the equivalent of the bunter sandstein; and a part at least of the variegated marls under our lias may be safely identified with the keuper.

To the opinions which I have advanced respecting the origin of the dolomitic formations of England*, I attribute very little importance. According to the theory of an eminent continental geologist, the dolomitic portions of the Alps have been produced by a peculiar igneous action subsequent to the deposit of the great calcareous formations to which they are subordinate. Whatever may be the evidence for this theory in certain alpine regions, it derives at least no support from the facts stated in the preceding paper. The magnesian earth, whatever may have been its origin, was unquestionably an original constituent of the formations above described; nor is there, I think, any conceivable hypothesis to account for its subsequent introduction.

* p. 123.

London,
October 31, 1829.

XIV. *On the Oolitic District of Bath.*

By WILLIAM LONSDALE, Esq. F.G.S.
(Communicated by Dr. Fitton, P.G.S. &c. &c.)

[Read February 6th, 1829.]

THE following memoir relates to the oolitic district in the neighbourhood of Bath. It was prepared at the suggestion of Dr. Fitton and H. T. De la Beche, Esq., from the notes which a residence near that city had enabled me to make. It is necessary, before I proceed, that I should state the sources from which I have derived information. The vicinity of Bath was the scene of Mr. Smith's earliest investigations; and in following the footsteps of my celebrated precursor, I have to acknowledge the assistance I have received from his Geological Map of Wiltshire, a production which bears ample testimony to his skill as an original and careful observer. From the Map of Messrs. Conybeare and De la Beche of "The country twenty-four miles around Bath," I have also received much valuable information. I am indebted to the "Outlines" of the Rev. William Conybeare and the late Mr. Phillips, for all my directions relative to the "external characters" of the oolitic formations: and lastly, to the Rev. B. Richardson of Farleigh, a gentleman long and extensively known as a diligent and successful cultivator of science, I owe much important matter respecting the neighbourhood in which he resides.

The district which it is purposed to describe, is bounded on the west by the lias, from Wick, near Bath, to Radstock; on the south by the roads connecting Radstock, Frome, and Westbury; on the south-east by the chalk downs bordering Salisbury Plain, and extending from Westbury to Urchfont; on the east by a line passing from the last-mentioned village, through Stert to Devizes, thence along the Wiltshire Downs to Cherhill Hill, and afterwards to Hilmarten and Lynham; and on the north by the roads uniting this hamlet with Christian Malford, Kington St. Michael, Marshfield, and Wick.

The formations included within this circuit are the lias, marlstone of Smith, inferior oolite, fuller's earth, great oolite, Bradford clay, forest marble with Stonesfield slate, cornbrash, Oxford clay, calcareous grit, coral rag, Kimmeridge clay, lower greensand, gault, upper greensand, chalk marl, and lower chalk.

The surface of the country is characterized by three ranges of hills, connected by two plains. Of the former, the most western may be called the range of the great oolite. It rises abruptly from a denudated valley of lias, and attains its greatest elevation at Lansdown, where its summit is 813 feet above the level of the sea. Its general direction is north-east and south-west. In the neighbourhood of Bath it is greatly intersected by deep and sinuous valleys. The escarpment from Toghill near Wick, to the ridge above Wellow, consists of lias, inferior oolite, fuller's earth, and great oolite; but to the southward of that point, the last formation is wanting, and the series is composed of lias, inferior oolite, fuller's earth, and forest marble.

The plain, which joins this range with that of the coral rag, preserves to the north of the road from Bath towards Devizes a tolerably uniform inclination, which nearly coincides with the dip of the strata of cornbrash and Oxford clay composing the surface of the country: but between the road just mentioned and Bradford, a sudden depression takes place, arising, apparently, from an increased dip in the great oolite*. To the south of Bradford the plain recovers its usual features, which it keeps to Beckington, where it is disturbed by an elevated ridge of forest marble, extending transversely from that village nearly to North Bradley.

The second range, which it is proposed to designate by the name of coral rag, rises precipitately from the Oxford clay valley, and has a direction nearly parallel with the range of the great oolite. From Lynham to Bowden Hill and Sandridge, it constitutes a prominent feature in the outline of the country, and maintains an almost uniform elevation. At the latter point the western continuation of the formations composing the ridge has been removed by denudation; but to the south of the Wilts and Berks canal, the surface again rises, and a series of low hills extends from Seend to West Ashton, where they decline to the level of the Oxford clay plain. The escarpment consists, principally, of the Oxford clay, the calcareous grit, and the coral rag; but the Kimmeridge clay and the lower greensand are superimposed at Bowden Hill and Seend.

The plain which unites the second range with the third, or that of the chalk, varies greatly in its breadth. Between Keevil and Earl's Stoke the width exceeds three miles, but between Westbury and Westbury Field it is less than half a mile. From the last-mentioned town to Polshot the surface is a nearly uniform flat, consisting of Kimmeridge clay, but to the north of that village it is diversified by gentle undulations crowned with thin beds of the lower greensand. The eastern boundary of the plain is formed by a narrow band of gault.

* Plate XXXII. Fig. 3.

The range of the chalk hills rises either suddenly from the gault, as between Westbury and Earl's Stoke, and Roundaway Hill and Cherhill; or from a terrace of the upper greensand, as between Earl's Stoke and Devizes. The hills present the usual rounded outline, but are not cut through by any transverse water-courses. The vale of Pewsey, at its entrance, is about 300 feet above the level of the second plain, and its streams flow to the south-east in the direction of Amesbury and Salisbury. The escarpment of the range is composed of the upper greensand, the chalk marl, and the lower chalk.

I now proceed to describe the nature of each formation.

Lias.

In treating of the Lias, I purpose to consider it under two heads, the Lias of Bath, and that of Radstock, as some interesting peculiarities distinguish the formation at the latter locality.

The accompanying Table presents a general type of the lias in the neighbourhood of Bath.

	Descriptions.	Thickness.	Localities.
1. Lias Upper Marl..	Blue clay and marl; which are tough in the lower part of the deposit, but thinly laminated and micaceous in the upper. Irregular beds of stone are interstratified with them	200 feet.	Walcot: Batheaston: Beechen Cliff: the upper part of Bath.
2. Blue Lias	Beds of greyish, argillaceous limestone, varying in thickness from 2 to 18 inches, and separated by others of blue marl which are generally less than 6 inches thick, but sometimes more than 2 feet.	50 to 60 feet.	Weston: Upper Bristol Road: Twerton.
3. White Lias	Thin strata of yellowish white, argillaceous limestone, with partings of pale brownish clay.....	10 feet.	Wick. This division is seldom exposed in the immediate vicinity of Bath.
4. Lias Lower Marl..	Dark grey marl with calcareous concretions	20 feet	Very rarely exposed.

Of these divisions, the 1st and 4th require no further explanation; but as an account of the beds comprising the 2nd and 3rd has not yet been published, the following enumeration is given from a quarry situated on the southern side of the Bristol Upper Road, and about one mile and a half from Bath.

Blue Lias.

Top.	Ft.	In.
Three beds of greyish limestone separated by layers of friable, gritty marl	3	6
"Fire clay," mottled, gritty marl ...	1	6
"White bed," greyish limestone....	1	0
Friable, gritty marl, inclosing nodules of indurated marl................	0	6
"Oaty bed," grey limestone	0	10
Friable, gritty marl................	0	3
"Double bed," grey limestone	1	0

	Ft.	In.
Friable, black marl	0	2
"Pitching bed," greyish limestone	0	6
Friable, black marl	0	4
"Velvet bed," grey limestone	1	6
Friable, black marl	0	5
"Red bed," reddish brown limestone	1	0
Parting of marl	0	0
"Rag bed," a very tough, greyish limestone, 9 to 12 inches	0	10
"Clay burr," nodules of indurated marl	0	3
"Stile bed," grey limestone	0	6
Parting of marl	0	0
"Dun beds," four in number, limestone, brownish on the outside, blue in the centre	1	3
"Well bed," greyish limestone	0	2
Friable, black marl	0	2
"Gutter bed," grey limestone	0	7
Friable, blue marl	0	3
"Gubby or Govey bed," grey limestone	0	7
Parting of marl	0	0
"Double bed," grey limestone	0	8
Blue, friable marl	0	3
Grey limestone	0	2
Blue marl	0	1
Several thin layers of greyish limestone, with partings of marl	6	0
Several layers of nodular, grey limestone, with partings of marl	4	0
Mottled marl	0	3
Grey limestone	0	6
Black marl	0	7
Grey limestone	0	7
Nine layers of nodular, grey limestone, separated by others of blue marl	3	6
Blue marl	2	4
Compact, grey limestone	0	4
"Dirt," blue, friable, sandy marl	0	6
Compact, grey limestone	0	4

	Ft.	In.
Blue marl	0	3
Compact, grey limestone, two strata	0	6
Blue marl with septaria	1	6
Compact, grey limestone	0	4
Blue marl with septaria	2	0
Compact, grey limestone	0	5
Blue marl with septaria	2	6
Compact, grey limestone	0	4
Blue marl	0	6
Six thin beds of grey limestone, with partings of marl	3	6
Blue marl	0	4
Grey limestone	0	10
Dark, slaty marl	0	3
Grey limestone	0	3
Parting of yellowish marl	0	0
Compact, grey limestone	0	8
Dark, slaty marl	0	2
Compact, greyish limestone	0	3
Parting of marl	0	0
Compact, grey limestone	0	6
Parting of marl	0	0
Greyish limestone, with numerous fragments of shells	0	4
Friable, sandy marl, with fragments of shells	0	2
Grey limestone	0	4
Parting of marl	0	0
Grey limestone	0	4
Blue limestone	0	1
Greyish limestone, two strata	0	7
Brownish, sandy marl	0	2
Grey limestone	0	3
Parting of marl	0	0
Brownish limestone	0	6
Grey limestone	0	6
Parting of marl	0	0
Brownish limestone	0	2
Parting of clay	0	0
Greyish limestone	0	2
Indurated, brownish marl	0	9

White Lias.

	Ft.	In.
Thinly laminated, brownish limestone	0	1
"Sun bed" limestone	1	0
"Rotten stone"	0	3
Parting of brownish clay	0	0

	Ft.	In.
Compact limestone	1	0
Brownish clay	0	1
Compact limestone, three beds	1	2
Rotten stone	0	2
Compact limestone, three beds	1	4
Rotten stone	0	2
Compact limestone	0	6
Parting of pale brownish clay	0	1
Compact limestone	0	2
Parting of pale brownish clay	0	0
Compact limestone	0	2
Pale brownish clay	0	1
Compact limestone	0	3
Rubbly limestone	0	1
Compact limestone	0	2
Rubbly limestone	0	4
Compact limestone, the lowest bed which has been worked	0	3

Of these strata, that called the "sun bed" is the most uniform in its characters, and accompanies invariably the white lias. It is an exceedingly fine-grained stone, of a conchoidal fracture, blue in the centre, but pale brown on the exterior. Of the remainder, those to which names have been given are best known. They constitute in general the surface of the country; and the expense of removing the rubbly beds which immediately succeed them, prevents the lower portion of the series from being worked. The "blue lias" consists principally of compact limestone of a dull, earthy aspect, but it sometimes assumes a minutely crystalline structure. The "white lias" is of a compact texture, sometimes of a conchoidal, but more often of a flat or uneven fracture. In some of the strata irregular streaks of clay traverse the stone, and give it a rubbly or rotten nature. Organic remains are more or less abundant in all the beds.

The lias of Radstock is distinguished from that of Bath, by the absence of the marls which are interstratified with the stony beds in the neighbourhood of that city; by the blue lias being in some places wanting, and by one of the strata assuming a granular structure and oolitic appearance. It is called by the peasantry "bastard or inferior oolite." The following section, taken from the memoir on the "South-west coal district of England*," gives the best type of the order of superposition at Radstock.

Top.	Fath.	Ft.	In.
1. Blue clay	1	3	0
2. Gritty lias	0	4	0
3. Blue clay	0	1	6
4. Corn grit (three beds)	0	1	6
5. White lias	2	0	0
6. Knotty claystone	1	0	0
7. Grey or blue marlstone	0	5	0
8. Dark marlstone	0	1	0
9. Black marl	2	0	0

* Geol. Trans. 2nd Series, vol. i. p. 278.

The "blue clay" (1.), which is the "lias upper marl" of the Bath series, is micaceous, and between one and two hundred feet thick. The "gritty lias" (2.) is the "bastard oolite" of the quarrymen. It is a rubbly stone of a more or less granular structure; and from the occasional appearance of minute cells lined with ochreous matter, it might be mistaken for a variety of inferior oolite. *Helicina polites*, *Helicina solaroides*, and *Spirifer Walcottii* are found in this bed. Interposed between the "gritty lias" and the "blue clay" (3.) appears sometimes an irregular bed of dark grey marlstone, abounding with Ammonites, Belemnites, and small concretions of blackish, tough limestone. Between the "blue clay" (3.) and the "corn grit" (4.) in some quarries occur from two to fifteen feet of grey or blueish lias. The "corn grit" is a pale brownish limestone, resting uniformly on the "white lias," and varying in thickness from eighteen inches to three feet. The "white lias" (5.) differs in no respect from that of Bath, and is constantly accompanied by the "sun bed." The strata from (6.) to (9.) are equivalent to the "lias lower marls."

The following sectional lists are given to illustrate the variations which are presented in the quarries around the village. The first is from an opening in the road towards Frome, and near the superior junction of the new and old lines.

	Ft.	In.
"Gritty lias"	6	0
Irregular bed of dark grey marlstone	0	0
"Blue clay," containing concretions of blackish, tough limestone	0	3
Grey lias	3	0
"Corn grit" (three beds)	3	0
"Sun bed"	0	10
White lias	0	0

Quarry in the lane between Tining-farm and Water-side.

"Gritty lias"	0	0
Grey lias	2	0
"Corn grit"	2	0
"Sun bed"	2	6
"White lias"	8	0

Summit of the hill in the Wells Road.

"Gritty lias," in the field above the quarry	0	0
Blue or grey lias	15	0
"Corn grit" (three beds)	3	0
"Sun bed"	1	0
"White lias"	0	0

Lane leading to Clan Down in the descent of Radstock Hill.

	Ft.	In.
"Gritty lias"	6	0
Marlstone	1	0
Grey lias (one bed)	2	0
"Corn grit" (three beds)	3	0
"Sun bed"	1	0

Descent from the Red Posts ($6\frac{1}{2}$ miles from Bath) to Camerton.

	Ft.	In.
Blue clay above	100	0
Gritty lias, Marlstone } No regular separation	4	0
Blue clay	7	6
Grey lias	5	0
Corn grit, Sun bed, White lias } These beds are rarely exposed.		

The superficial extent occupied by the lias in the neighbourhood of Bath, is considerably increased by the deep valleys which intersect the oolitic hills. In the immediate vicinity of the city, this formation composes about one-third of the surrounding heights. To the eastward it gradually declines; and the extreme points of the boundary in that direction may be stated to be Midford, Freshford, and Box. To the west, the north-west, and the south-west, the lias forms an extensive but undulating surface, occasionally overlaid by detached portions of the inferior oolite, and occasionally cut through into the red marl and the coal measures.

The inclination of the lias is affected through the south-west part of the district, under examination, by the irregularities in the subjacent coal field. At Kelston Park the formation inclines gradually towards the south-west. Between Corston and Burnet it forms an elevated ridge, marking the line of a fault. Newton is built on a continuation of this ridge, and in the quarries to the east of the village the dip is south-south-west. In the inclined plains between Farmborough and Burnet, Burnet and the Avon, and Stratton-on-the-Foss and Radstock, the inclination of the strata is towards the north. Along the eastern boundary of the formation the dip is south-east.

Marlstone.

Interposed between the lias and the inferior oolite are several beds of sandy marl, to which Mr. Smith gave the name of marlstone. They effect a gradual passage from the lias into the inferior oolite. The following sectional list was obtained at Box in the summer of 1825.

Top.	Ft.	In.
Micaceous, yellow sand	4	0
Pale brown marlstone, containing numerous fragments of shells	2	0
Chocolate-coloured marl, inclosing nodules of limestone with ferruginous, oolitic particles, and numerous fragments of Ammonites, Belemnites, &c.	0	6
Light-grey marlstone	1	0
Indurated, pale chocolate marl	0	6
Micaceous, sandy, yellowish marl	0	4
Chocolate-coloured marlstone	0	3
Micaceous, yellow sand, containing thin layers of clay, and tabular masses of fissile, micaceous, blue sandstone	3	0

The deposit in some places consists of large masses of micaceous, sandy marlstone, in which are imbedded numerous individuals of a large Pecten with obtuse ribs.

Though the "marlstone" is probably co-extensive with the hills surrounding Bath, yet it is very rarely to be seen. I have noticed it only at Box, Batheaston, and the descent from High Barrow Hill to Pennycuick Bottom near Twerton. Mr. Smith gives Bathhampton and the Coal Canal as two of his localities.

Ammonites Strangwaysii of Sowerby*, the *Ammonites undulatus* of Smith†, abounded at Box.

Inferior Oolite.

This formation consists of nearly equal divisions of limestone and sand. The following section was obtained from Widcombe Hill near Bath.

Fuller's earth	17 feet.
Limestone	60
Sand	70
Lias upper marl	20

The accompanying table exhibits the arrangement of the subordinate beds of the inferior oolite.

Principal divisions.		Subordinate divisions.	Thickness.
1. Limestone.	*a*	Soft freestone more or less oolitic	40 to 50 feet.
	b	Rubbly stone, consisting principally of corals	10
	c	Hard, brown limestone, abounding with casts of shells	6
2. Sand.		Slightly calcareous, and containing irregular courses of concretions of limestone	70

(1 *a.*) The freestone strata consist in the upper part of a distinctly oolitic stone, which cannot be distinguished lithologically from the great oolite. The lower beds contain a greater proportion of sand: they are of a brownish colour, and are scarcely oolitic.

* Min. Con. tab. 256. f. 1. 3. † Stratigraphical System, p. 114: Marlstone-Plate, fig. 3.

(1 *b*.) The rubbly stratum is not of universal occurrence. The masses of crystallized carbonate of lime, of which it is principally composed, present invariably traces of an organic origin. A species of Astrea is the prevailing fossil. The interstices between the crystalline masses are filled with nodules of indurated marl.

(1 *c*.) The hard, brown limestone, which is provincially called the hollow bed, is strongly characterized by its colour, great toughness, and the hollow casts of *Trigonia costata, Lima proboscidea,* and numerous other shells. It yields the greater part of the inferior oolite fossils. This stratum is apparently equivalent with that of Dundry Hill, well known for its organic remains, and for containing minute, globular particles of brown oxide of iron.

(2.) The sand generally possesses only a slight degree of cohesiveness; but in some parts passes into a friable sandstone. The prevailing colour is yellow, and minute spangles of mica are abundantly diffused through it. The calcareous concretions, or "sand burrs," are very tough, and frequently contain in their centre the casts of Ammonites and other organic bodies. This division of the inferior oolite thins out towards the south-west boundary of the formation; and is wanting at Frome, Radstock, and Tunley.

The superficial extent of the inferior oolite in the district to which this memoir belongs, is small. The formation may be described as constituting narrow zones circling around the sides of the hills, and occasionally extending into promontories. Of these the most considerable are Beacon Hill, the ridge advancing from Duncorn Hill to Tunley, and that from Huddock's Hill to Clan Down. The inferior oolite likewise has several outliers; among which may be enumerated, Stantonbury and Winsbury Hills, the Barrow Hills, Priest Barrow, the Sleight, and the ridge to the south of Newton Park. The most favourable point for examining the formation with the exception of the rubbly stratum (1. *b*), is the banks of the canal opposite Limpley Stoke.

The only deviation from the regular dip to the south-east, and not produced by faults, occurs near Kelston, where the inclination is to the south-west. This deflection is owing to the dip of the lias towards the Keynsham valley.

Fuller's Earth.

The inferior oolite is separated from the great oolite by a thick, argillaceous deposit, which has been called the fuller's earth. The peculiar mineral, from which it has derived its appellation, is confined to a particular district; and where it occurs, it constitutes but a very small portion of the thickness of the formation.—The following table exhibits a general type of the fuller's earth.

1.	Blue and yellow clay, with nodules of indurated marl....	30 to 40 feet.
2.	Bad fuller's earth	3 to 5 feet.
3.	Good fuller's earth	$2\frac{1}{2}$ to 3 feet.
4.	Clay containing beds of bad fuller's earth and layers of nodular limestone, and indurated marl	100 feet.

1. The clay or marl which constitutes the upper part of the series is generally of a tough nature, and effervesces with an acid. Masses of that variety of calcareous spar called "cone in cone" are frequently found in it.

2. The bad fuller's earth is of a sandy nature, effervesces strongly, and in general contains numerous fragments of shells.

3. The good fuller's earth is of two kinds, one blue, the other brown. They are irregularly associated, and the latter variety is considered to be of superior quality to the former.

4. The lower clay incloses one or two strata of a tough, rubbly limestone, which is commonly called the "fuller's earth rock." This stone is for the greater part of a very close texture, and bears so considerable a resemblance to cornbrash that it might be mistaken for that formation. The fossils, however, which peculiarly belong to each, afford an almost unerring distinction. The fuller's earth rock is always accompanied by an immense number of Terebratulæ; and *Mya angulifera* and *Isocardia concentrica* are almost invariably found in it. These organic bodies are wanting in the cornbrash, which is characterized by the constant presence of *Avicula echinata*, a shell of very rare occurrence in the older formation. The nodules of indurated marl, which also accompany the lower clay, sometimes agree in colour and texture with blue lias.

The fuller's earth formation describes a zone around the sides of the hills from Tog Hill near Wick, to Green Parlour near Radstock, and occupies the same geological position, between the inferior and great oolites, from the first of those localities to Hinton Field Farm, about one mile from Charter House Hinton; but the great oolite thins out at that point, and for the remainder of the district it is interposed betwixt the inferior oolite and the forest marble.

The good fuller's earth is confined to the brow of Odd Down and the side of Midford Hill.

Great Oolite.

A thorough acquaintance with this important formation illustrates the influence which organic remains have on the external characters of a rock, and prepares the inquirer for examining with greater facility the superior oolitic deposits. When the great oolite is almost entirely free from fossils, it presents an uniform texture and softness, yields easily to the saw, and is admirably adapted for the chisel of the sculptor. In those beds in which fragments of shells abound, the formation acquires the texture of forest marble; and towards the top of the series, where Polyparia exist, the rock assumes the appearance of some varieties of the coral rag.

The whole of the strata composing the great oolite may be arranged under the following heads.

		Subordinate divisions.	Thickness.
1. Upper rags*	a	Coarse, shelly limestones	20 to 55 feet.
	b	Tolerably fine oolites	
	c	Tough, brown, argillaceous limestone	
2. Fine freestones			10 to 30 feet.
3. Lower rags		Coarse, shelly limestones	10 to 40 feet.

1. The subordinate divisions composing the upper rags alternate together several times. The coarse shelly limestones (1. *a*.), the beds to which the term rag is generally confined, possess, for the greater part, an imperfectly oolitic structure; and the oviform spherules are sometimes entirely wanting. The stone yields with difficulty to the saw, and the stratum immediately below the Bradford clay is extremely tough, and loses almost all the characters of an oolite. Some of the beds consist principally of Polyparia, and were identified by Messrs. De Basterot and Desnoyers with the *calcaire à Polypiers* of Lamouroux at Caen in Normandy. The colour of the stone is chiefly yellowish white, but at the junction of the Bradford clay it is blue. The tolerably fine oolites (1. *b*) sometimes possess a beautifully distinct texture, the spherules being perfectly defined. These beds are easily worked, but appear to be of a more perishable nature than the fine freestones (2.). The tough, brown, argillaceous limestone (1. *c*) is of a close, compact structure; it incloses organic remains, and after long exposure to the weather often acquires a cavernous appearance, similar to that which is called rustic work by architects. A bed of clay occurs about the centre of the upper rags. It is of a pale blue colour, and contains a few slabs of a brownish limestone.

2. The fine freestones vary in the number and thickness of their beds. They are principally distinguished from each other by the greater or less decisiveness of the oviform particles, which are occasionally so very obscure that the rock becomes earthy and indistinct in its texture.

3. The lower rags consist partly of shelly limestones, in which the organic remains are sometimes so numerous as to compose almost the entire mass, and partly of coarse freestone, used occasionally for rough walls, and formerly to a considerable extent in building. The bottom bed, which rests immediately

* The word "rag" is applied by the quarrymen to those beds of the great oolite which contain many fragments of shells, and are not easy to work.

upon the fuller's earth, is a fine-grained stone, scarcely oolitic, and crystalline in its structure. On the ridge to the north of Wellow is a peculiar stratum belonging to this division of the great oolite. It is composed of a tough, rubbly rock, containing much argillaceous matter, and in some parts numerous, small, globular grains of oxide of iron. It abounds with Terebratulæ and *Ostrea acuminata.*

For the sake of illustrating the arrangement of the beds of the great oolite and the local variations, a series of sectional lists is subjoined. The first is from Farley Down near Bathford. The upper rags (1.) are partly concealed by vegetation.

		Ft.	In.	
1.	Rubble	8	0	Coarse, shelly oolite.
	Hard rag	2	0	Yellowish, argillaceous limestone, containing many fragments of organic bodies.
	Pale blue, stiff clay	1	0	
	Rubbly stone	3	6	Principally composed of fossils united by indurated marl, but in some parts oolitic.
	Soft rag	11	0	Perishable freestone.
	Hard rag	4	0	This stratum varies greatly; in some parts it is a coarse oolite; in others a brown or yellowish, argillaceous limestone, enveloping large masses of Polyparia, and casts of shells filled with calcareous spar.
2.	Capping	1	6	
	Grey bed	1	8	
	White bed	10	0	
	Hard bed	2	6	
	Red bed	9	0	
3.	Lower rags.			

Ancliff near Bradford.

		Ft.	In.	
1.	Rubble	5	0	Abounding with Polyparia.
	Soft oolite	15	0	This is the bed celebrated for the Ancliff fossils.
	Clay	1	0	Containing small sponges and many fragments of shells.
	Rag	6	6	Very coarsely oolitic.
	Soft oolite	5	0	

Comb Down.

		Ft.	In.	
1.	Ridding	9	0	Many beds of stone differing in characters: some of them are rubbly, and resemble the "crane bed;" others consist of an earthy, brown limestone.
	Crane bed	1	0	Lightly coloured, earthy limestone, with imperfectly formed oolitic particles.
	Clay 3 to 12 inches	0	7	
	Rag beds	7	0	An indistinct oolite, with a few fragments of shells.
	Picking beds	4	0	Soft freestone.
	Cockle bed (in some quarries wanting)	3	0	Earthy, hard limestone, with casts of Polyparia.

		Ft.	In.
2.	Good freestone 25 to 30 feet........	27	0
3.	Lower rags	10	0

Bradford Quarry, between the Trowbridge Road and the Canal.

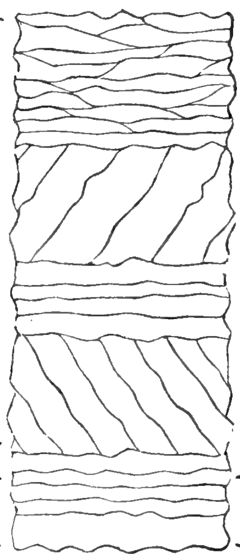
		Ft.	In.	
1.	Bradford clay	0	0	
	Rag	6	0	Hard stone, varying greatly in its character.
	Coarse freestone	4	0	
	Rag	1	6	Coarse oolite, containing many beautiful casts of Polyparia.
	Indifferent freestone ..	6	0	The stratum is divided by lines oblique to the plane of the bed.

Murrel Quarry near Winsley, and about one mile W. from Bradford.

		Ft.	In.
1.	Rubble, partly an oolitic, partly a compact, limestone	12	0
	Rag	2	0
	Clay with laminæ of hard limestone	3	0
	Rag	1	6
	White rag (finely grained freestone)	1	3
2.	Good freestone	7	0
	Soft freestone	3	0
3.	Rag	2	0
	Rag	1	3
	Rag	1	3
	Rag	1	6
	Clay	0	4
	Rag	1	0

		Ft.	In.
3.	Rag	1	0
	Rag	5	0
	Rag	2	0
	Oaty beds, coarse freestone	3	0
	Rag	2	0
	Rag	2	0
	Oolitic clay	1	6
	Iron bed, hard coarse oolite....	4	0
	Rag	3	0
	Coarse freestone	7	0
	Rag	1	6
	Rag	1	0
	Rag	2	0
	Rag	0	8
	Fuller's earth.		

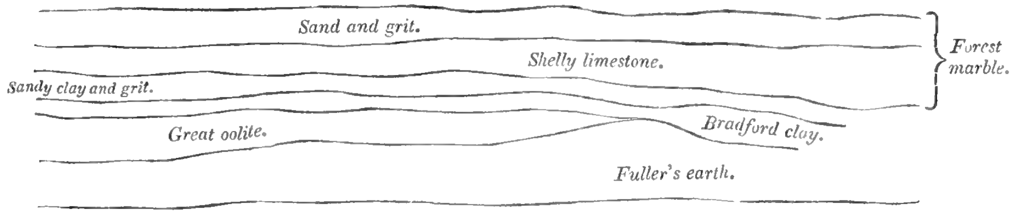
Box Quarries.



		Ft.	In.
1.	Rubble or soft freestone	20	0
	Soft freestone split obliquely into blocks	17	0
	Black rag, White rag, Malmy rag, Red rag — Coarse, shelly oolites 9 to 12 feet ..	10	6
	Corn-grit. Finely grained freestone	17	0
	Rag, 18 inches to 3 feet	2	0
2.	Ground stone, 4 beds. Good freestone........	12	0

The western boundary of the great oolite ranges along the brow of the downs from Tog Hill near Wick, to Huddock's Hill near Dunkerton; but between these localities it is frequently intersected by deep valleys, which occasionally isolate the hills, and then render the oolitic table lands, by which they are surmounted and distinguished, outlying portions. A line drawn nearly east from Huddock's Hill to Hinton Field Farm, about mid-way between Hinton and Norton, would define the southern boundary of the great oolite. At the Farm just mentioned is a small quarry in this formation; and a narrow band, apparently belonging to it, extends around a projecting knowl opposite the quarry. Beyond this point the great oolite cannot be traced. It might however be conceived, that the termination is only a lithological change, and that here, as elsewhere, the great oolite merely assumes the characters of the forest marble. The thin bed of sandy clay and grit which constitutes the bottom of the latter formation, and the Bradford clay, attain under these circumstances a great importance. At Norton, and through the whole of the southern range of the district, either one or the other of those strata, is visible resting on the fuller's earth, and thus proves clearly that the disappearance of the great oolite is not deceptive but real*.

The accompanying diagram will illustrate the relative positions of the three formations, and the thinning out of the intermediate one.



The superior boundary of the great oolite, or that which defines its separation from the Bradford clay and forest marble, extends in an undulating line from Yatton Keynell by Giddy Hall, and the brow of the hills overhanging the Box brook to the Chippenham road, which it crosses to the westward of Pickwick: thence it follows the curvature of the hills, but keeps a little to the east of their escarpment, to Wadswick and the Devizes road, which it passes near Wormwood Farm: from this point it turns westward, and ranges along the descent which bounds Kingsdown and Farleydown on the south, and crosses the Bradford road a little above Monckton Farley: it afterwards de-

* The points most favourable for examining the connection of the lower grit with the fuller's earth, are: the top of the Lane leading from Falkland Knowl to Stoney Littleton; the descent of the road from Frome towards Wells; Buckland Denham; and the brow of the hill above Green Parlour near Radstock.

scribes a line nearly parallel with the heights on the right bank of the Avon to Bradford; and from that town it may be traced by Upper Westwood to Iford Mill and Farleigh Hungerford, where it dips beneath the forest marble.

Bradford Clay.

If it were not for the inconvenience which arises from the change of names, it would be desirable to consider the Bradford clay as a portion of the forest marble. In external characters, the argillaceous deposit we are now describing, cannot be distinguished from the beds of clay which are interstratified with the grits and shelly limestone of that formation. In both instances the clays contain thin layers of limestone and laminæ of grit, which are identical in composition; and *Apiocrinites rotundus*, the fossil to which the Bradford clay has been indebted for its celebrity, is likewise found in the forest marble.

Considered however by itself, this deposit consists of a pale grey clay containing a small proportion of carbonate of lime, and inclosing thin slabs of a tough, brownish limestone, and laminæ of calcareous sandstone or grit.

The greatest thickness of the Bradford clay appears to be in the neighbourhood of Farleigh, where its dimensions are said to be from 40 to 60 feet. It is however frequently wanting.

The Bradford clay appears forming a thin bed in the neighbourhood of Yatton Keynell and Giddy Hall; but between the latter point and Berfield, near Bradford, it is wanting, the forest marble being visible resting on the great oolite at Pickwick and Wormwood. At Berfield the clay re-appears, constituting a thick stratum, which may be traced from that village by Bradford and Upper Westwood to Farleigh. It likewise occurs underlying the forest marble in the ridge to the north of the road from Farleigh to Charter House Hinton; but through the southern part of the district it is difficult to separate the Bradford clay, if it exists, from the fuller's earth.

Forest Marble.

The strata which are interposed between the great oolite and the cornbrash, when exhibited in their simplest manner, admit of the following arrangement.

	Thickness.	
1. Clay, with occasional laminæ of grit ...	15 feet.	Kington St. Michael's, Norton, &c.
2. Sand and grit	40	Ibid. Ibid. Frome, &c.
3. Clay, with thin slabs of stone and laminæ of grit	10	Wormwood, Pipe House Hill near Midford.
4. Shelly limestone or coarse oolite.......	25	Wormwood, Frome, &c.
5. Sand or sandy clay and grit...........	10	Frome, Norton, Baggeridge, &c. &c.
6. Bradford clay.		

1. The top bed of clay is of a pale grey colour, rather smooth to the touch, and effervesces with acids. The laminæ of grit contain a considerable proportion of calcareous matter. At Norton St. Philip it incloses near its upper part a stratum of rubbly, indurated marl, abounding with fragments of a small Ostrea and Terebratulæ.

2. The sand and sandstone appear to be the representative of the Stonesfield slate of Oxfordshire. The sand which sometimes forms the greater part of the bed, but which sometimes is almost wanting, is of a very fine grain, and varies in colour from reddish brown to almost white. It is occasionally mixed with a small quantity of clay or lime, and then becomes a friable sandstone, alternating in thin beds with a calcareous grit. Layers and irregular beds of clay likewise often occur associated with the sand. The sandstone or grit forms, either large spheroidal masses aggregated together and contained in the sand, or tabular strata. The true pot-lid shape is of rare occurrence, and appears to be confined to Ridge near Beckington. The stone possesses a tendency to split into thick flags parallel to its position in the bed, but never into thin tiles. The cross fracture is splintery, and in general exhibits small, shining, parallel facets. The grain of the grit is for the greater part exceedingly fine, though it not unfrequently acquires an oolitic character; and in the same specimen one portion will be a sandy oolite, and the rest a calcareous sandstone. Patches, or small almond-shaped nodules of soft clay are often imbedded in the stone; and on being removed, by exposure to the weather, the emptied cells give it a vesicular appearance. Organic remains are not universally disseminated through the grit, but in some localities they are sufficiently numerous to compose the principal part of the block or stratum, and convert it into an impure, shelly limestone. All the varieties of the grit effervesce very strongly. The prevailing colour is pale brown, but some of the beds are of a deep blue.

3. The clay is of a pale brown colour, is slightly calcareous, and contains patches of a hard, closely grained, shelly limestone slightly oolitic, and laminæ of calcareous sandstone or grit. It is occasionally wanting.

4. The shelly limestone or coarse oolite is the bed to which the term forest marble is peculiarly applied. The prevailing fossil, a small species of Ostrea, is occasionally so abundant as to constitute the greater part of the stone; but it is oftener more sparingly diffused through it. The basis by which the organic bodies are united is frequently composed of crystallized carbonate of lime, though sometimes of a yellowish or bluish marl, and sometimes of a pale, earthy limestone. Oolitic particles are more or less numerous in each variety. Some of the beds are of a close texture, tough and heavy; others are porous,

and yield readily to the hammer. In this state the forest marble approaches in character to the rags of the great oolite. The colour of the stone is generally a pale yellowish brown, but is not unfrequently blue or red, from the presence of oxide of iron. Thin layers of ochreous clay traverse several of the strata, and give them a striped or ribbon-like appearance. The majority of the beds possess a fissile structure, by which they may be cleaved into thin flags obliquely to the plane of stratification. The line of separation is determined either by a layer of organic remains, or the interposition of laminæ of clay. Though this character is prevalent in the forest marble, yet it is not of universal occurrence, the beds being occasionally massive, and dividing only into large irregular blocks. Strata of pale clay or sandy clay, in many localities, separate the beds of shelly limestone, and vary in thickness from an inch to three feet.

5. The lowest division of the forest marble, the sand or sandy clay and grit, does not invariably occur, and when present is often so thin as to escape the notice of a hurried observer. The grit is calcareous, sometimes slightly oolitic, of a pale brown or blue colour, and tolerably hard. It forms either thin layers alternating with sandy clay, or large masses inclosed in loose sand.

The following series of lists is given to illustrate the variations which take place in the different groups of the forest marble.

Right bank of the brook between Lullington and Woolverton, about three miles to the north of Frome.

Group 1.	Clay, with laminæ of grit	8 feet.
2.	Quick sand, with concretions of grit	9 feet.

Quarry between Lullington and the Factory.

Group 1.	Clay, with thin laminæ of grit	8 feet.
2.	Irregular beds of sandstone, parted by layers of sandy clay	10 feet.

Kington Bottom near Kington St. Michael, about three miles to the north of Chippenham.

	Cornbrash.	
Group 1.	Clay	15 feet.
2.	Sand, containing large masses of calcareous grit, some of which are partially oolitic and shelly	9 feet.

Beckington Quarry, in the Lane leading to Carpenter's Mill.

Group 2.	Sand, with large masses of grit containing fragments of wood	18 feet.
	Sandy clay	1 foot.
	Irregular beds of grit, separated by layers of sandy clay	5 feet.

Seventh Milestone from Bath towards Bradford.

Group 2.	Sand, with patches of clay and irregular concretions of grit	$5\frac{1}{2}$ feet.
	Blue clay, containing numerous thin laminæ of grit	18 inches.
	Hard, blue, shelly limestone of irregular thickness	18 inches.
3.	Clay.	

Great Camberwell, about one mile north of Bradford.

Group 3.	Clay, with thin laminæ of stone and grit	10 feet.
4.	Shelly, oolitic limestone................................	3 feet.
	Pale blue clay	$2\frac{1}{2}$ feet.
	Shelly, oolitic limestone................................	3 feet.

Wormwood Quarry, about seven miles from Bath towards Devizes.

Group 3.	Clay, containing irregular patches of stone	6 feet.
4.	Shelly limestone, split into thin layers obliquely to the plane of stratification	10 feet.
Great Oolite.	Four strata of freestone, split into irregular masses	14 feet.

Cross Keys, nine miles and a half from Bath towards Chippenham.

Group 3.	Irregular masses of laminated stone, partly shelly, partly gritty.	2 feet.
	Clay	$8\frac{1}{2}$ feet.
4.	Shelly, oolitic limestone split obliquely, the laminæ often parted by a thin layer of shelly limestone	$2\frac{1}{2}$ feet.
	Clay, sandy in the upper part............................	18 inches.
	Shelly limestone, thinly laminated	6 inches.
Bradford Clay.	Clay abounding with *Terebratula digona* and *T. coarctata*, and inclosing shelly concretions	18 inches.
Great Oolite.	Coarse, oolitic limestone..............................	$3\frac{1}{2}$ feet.
	Clay	3 inches.
	Coarse, oolitic limestone..............................	$3\frac{1}{2}$ feet.
	Coarse, shelly, oolitic limestone	4 feet.

Quarry near the Wells Turnpike, Frome.

Group 4.	Shelly limestone, in irregular beds	15 feet.
5.	Grit, with sand or sandy clay	12 feet.

Quarry at the turning to Hardington from the Frome Road.

Group 5.	Hard, calcareous grit, containing a few shells	8 feet.
	Sand, with large masses of grit	5 feet.

Quarry between Buckland Denham and Lydes-Water.

Group 5.	Irregular beds of grit, separated by layers of sandy clay	20 feet.

Brow of the Hill above Green Parlour near Radstock.

Group 5.	Thin slabs and laminæ of calcareous sandstone, imbedded in sandy clay.	

The western boundary of the forest marble, as far as Norton St. Philip, has been already described, in detailing the superior boundary of the great oolite. From Norton it winds around Baggeridge to Falkland Knowl, Falkland, and the brow of the hill descending to Radstock: there it turns eastwards, and keeps nearly parallel with the main road to Frome. The line which separates the forest marble from the cornbrash being extremely irregular, it is purposed to mention only the leading points through which it passes. From the neighbourhood of Yatton Keynell, where the breadth of the formation is small, the boundary pursues an undulating course by Biddestone to Lower Pickwick, where it takes an eastern direction by Pound Pill, Linleys, Gastard, and Sand Pitt to Potter's Mill; then by Shut-in-Lane, Wick Farm, Chapel Knap, and Whitley to Atford; whence it passes by Cottle's Farm, Flinch Bottom, Upper Wraxhall, New House Farm, Ford Farm, Bradford-Leigh, Wooley, the Folly near Bradford, Westwood, Telisford, Langham Mill, Roade and Shoalford, to Beckington. At this village an elevated ridge of forest marble commences, and extends to Cutteridge. Beyond Beckington the boundary may be traced by St. George's Cross, Oldford Hill, Fromefield, and Stiles Hill to Keyford.

The greatest breadth of the forest marble is from Pert (a small hamlet a little to the south of Norton), to the brow of the hill descending towards Radstock by Green Parlour. The horizontal distance between these points is about four miles, and, but for the denudation around Hardington, would there constitute a leading feature in the geological structure of the country.

Cornbrash.

This formation possesses but little interest. It appears generally as a thin stratum of rubbly stone, having considerable uniformity of character. The nodules or masses are seldom more than a foot in diameter, and are for the greater part much less. In those localities where circumstances have preserved the deposit from denudation, the bottom bed affords a tolerably compact rock, fitted for the construction of rough walls. The stone is exceedingly tough, and varies in colour from almost white to a dingy brown; but the lower part of the stratum at the junction of the subjacent clay is frequently blue. On being broken, the substance of the nodules exhibits generally a close, pasty, or earthy texture, sometimes of great evenness of composition, sometimes of a variable degree of consistency, irregular layers of a soft nature traversing the blocks, and apparently pointing out that their decomposition is the origin of the rubbly form of the superficial or exposed parts of the deposit. The cornbrash assumes occasionally a crystalline structure.

The surface occupied by this formation is comparatively small, and extremely irregular. The western boundary has been already given in detailing the extent of the forest marble. The eastern defines a waving outline, from the neighbourhood of Kington St. Michael, by Chippenham, to Laycock. At that village the two boundaries merge into one; and the cornbrash forms a narrow band by Shut-in-Lane, Wick Farm, and Whitley, to Atford, where it acquires a greater importance; and the eastern boundary may be traced from the foot of Atford Common, by Linton Farm, Great Chalfield, Holt and Widbook, to Midway. At this point the formation again contracts into another band, which passes along the western extremity of Winfield Common to Vagg's Hill, Langham Mill, and Rowde. From that village the cornbrash takes an eastern direction, and circles around the elevated ridge of forest marble, which extends from Beckington to Cutteridge, passing through Mark's Lane, Lamber's Marsh, Southwick, Pole's Hole, Cutteridge-House-Farm, Lower Ridge, and Standerwick Court, and thence to Clink and Stile's Hill.

In addition to these continuous districts, the cornbrash appears on the summit of Pipe-House-Hill near Midford, and at Wick Farm near Farleigh. It likewise forms a narrow strip extending from the neighbourhood of Upper Studley, by Trowbridge and Hilperton, to Semington, and an outlier around Chatley House, Woolverton, and Lullington.

Oxford Clay.

The Oxford clay is seldom laid open in Wiltshire. On the surface it appears invariably as a stiff, pale blue or yellowish clay, which effervesces vividly with acids. At the junction with the Kelloway rock, a bed occurs of a pale lead colour streaked with yellow; and in some parts of the formation strata are found of a chocolate hue, and thinly laminated structure.

Near the bottom of the Oxford clay is a bed of calcareous sandstone, from three to five feet thick, and abounding with organic remains: it is usually known by the name of the Kelloway rock. The fossils are occasionally so numerous as to constitute nearly the whole of the stratum, but are often wanting; and the stone then agrees in character with the calcareous grit interposed between the Oxford clay and the coral rag. The usual colour of the rock is brown on the surface, but blue or grey in the interior.

The accompanying section was procured from the quarry at Christian Malford.

Pale lead-coloured clay, streaked with yellow.	
Rotten, rubbly stone, highly charged with oxide of iron, and inclosing few organic remains	5 feet.

Sandstone, abounding with fossils .... 3 feet.
Sand .... 4 feet.
Clay.

The Oxford clay composes a plain of great variableness of breadth. At Melksham it is about six miles broad, but at Laycock it is scarcely one. The western boundary has been already traced under the head Cornbrash; the eastern, ranges about one-third from the summit of the coral-rag-hills; and passes from the neighbourhood of Lynham, by Charlcot, Bremhill Wick, Studley, Redhill, Bowden Hill, Spy-Park, Chitway, Sandridge, Nonsuch, Bromham, Rowde Hill, Seend Bridge, Sell's Green, Baldham Mill, Hinton, Cold Harbour, Stourton Farm, Abury Common, Rowde Ashton Park, West Ashton, Heywood House, Brook Farm, Brumridge Farm, Dilton, the Black Dog, Berkley Lodge, Heath-House-Farm, and Corsely, to Chapmanslade.

Coral Rag.

The coral rag formation in Dorsetshire, as described by the Rev. W. D. Conybeare in the "Outlines*," and by Professor Sedgwick in the Annals of Philosophy †; and in the Vale of Pickering by Mr. Phillips ‡, consists of two beds of sand, separated by a third of limestone. In Wiltshire a similar arrangement exists, but the upper sand is for the greater part wanting; and where it occurs, it is thin and of little apparent importance. The following table exhibits a general type of the Wiltshire beds.

			Thickness.	Localities.
1. Upper calcareous grit§	*a*	Sand	10 ft.	Between West Ashton and Dunge, and between Keevil and Rey Down.
	b	Ferruginous clay	10 ft.	Near Steeple Ashton and Westbury Field.
2. Coral rag	*a*	Perishable freestone	40 ft.	Calne.
	b	Rubbly oolite	40 ft.	Calne. Steeple Ashton.
	c	Irregular beds of Polyparia	40 ft.	Calne. Steeple Ashton.
3. Clay		....	40 ft.?	Chilvester Hill, near Calne.
4. Lower calcareous grit§		Sand, with beds of calcareous grit and impure limestone	50 ft.	Spirthill, Bremhill, Sandridge, Studley, &c. &c.

1. The sand (1 *a*) is of a fine grain and of a ferruginous colour. The clay (1 *b*) which underlies the sand, is slightly oolitic, and contains at Steeple Ashton numerous specimens of *Belemnites abbreviatus*, a Mya, and occasion-

* p. 191 note, and p. 192. † For the year 1824.

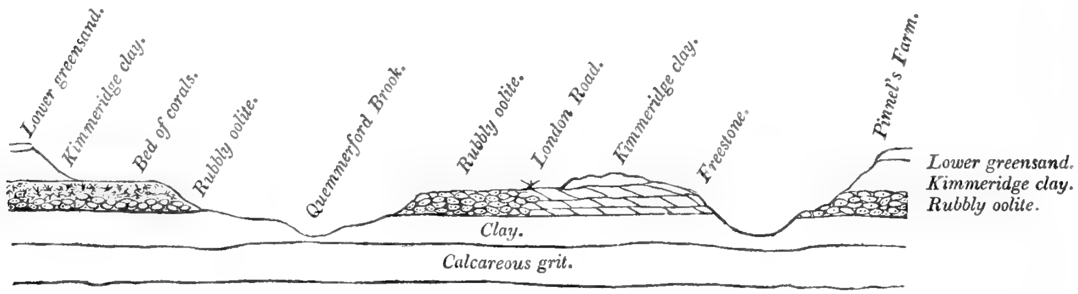
‡ Phil. Mag. vol. iii. p. 248. Geol. of Yorkshire, p. 32.

§ This term is adopted from Mr. Phillips.

ally an undescribed, discoidal Ammonites. The sand and clay are almost confined to the localities given in the preceding table*.

2. The second division may be described as consisting of an earthy limestone, divisible into strata which do not preserve any definite arrangement, and which pass insensibly into each other. The beds of Polyparia, to which the division has been indebted for its name, sometimes occur near its top, sometimes in its middle, and sometimes at its bottom. They are likewise of limited extent.

The accompanying diagram, drawn from Pinnel's Farm near Calne, to the quarry on the north-east side of the brook at Quemmerford, will illustrate the passage of the different varieties of the coral rag into each other.



The freestone, or "Oxford oolite," (2 *a*) occurs only at Calne. It is composed of alternations of hard, shelly oolite, used for flags, and soft, earthy,

* The sand is seen to the greatest advantage at Highworth, a town near the north-east angle of Wiltshire: it is likewise visible about one mile from Lynham towards Wotton-Basset. The following section is from the Brick-kilns near Highworth.

	Top.	Ft.	In.
1.	Calcareous grit, in some parts oolitic:—thickness small.		
	Rubbly oolite	1	0
	Very fine sand, 1 foot to 3 feet	2	0
	Sandy clay	3	0
2.	Rotten oolite	2	6
	Oolitic clay	1	0
	Indistinctly oolitic limestone	1	1
	Friable oolite, with fragments of shells	0	3
	Indistinctly oolitic limestone	0	6
	Oolitic clay	0	3
	Shelly, oolitic limestone	1	0
	Rubbly oolite, containing numerous Caryophyllia	1	0
	Shelly, earthy limestone	1	6
	Masses of blue, oolitic limestone, abounding with fragments of shells	3	0
4.	Calcareous grit.		

perishable limestone, which has scarcely a trace of oolitic texture. The beds are divided into blocks by seams oblique to the plane of stratification. The colour of the stone is pale yellow, except where it is in contact with the subjacent clay, when it is blue.

The rubbly oolite (2 *b*) constitutes the greater part of the coral rag of Wiltshire. It is formed of a nodular limestone of an earthy aspect, a brownish, yellowish, or blueish-white colour, and abounds with fragments of Echini and shells. Sometimes the nodules possess sufficient hardness to be used in the repair of the roads, but they are much oftener soft and unserviceable. The oviform particles are frequently very indistinct, or extremely small; but in that variety which is called pisolite, they are numerous, and are sometimes three tenths of an inch in diameter. In the neighbourhood of Spirthill the stone acquires a beautifully oolitic character, the spherules being regularly formed. Thin beds of clay occur in many of the quarries, and give them the appearance of a regular stratification; but these divisions are not to be traced for any distance.

The irregular beds of Polyparia (2 *c*) consist of nodules or masses of crystallized carbonate of lime, which afford invariably evidences of the labours of the Polypus; and associated with them are others of earthy limestone, which bear only partial proofs of an organic origin. The whole are connected by a pale blueish or yellowish, stiff clay. It happens frequently that a bed is composed of one genus of Polyparia. At Calne and Westhook the prevailing fossil is a small species of Astrea; at Hannington Hill near Highworth, Caryophyllia form the entire mass of the coral rag: but at Steeple Ashton both these genera are associated with Agaricia.

The bottom bed of the coral rag occasionally affords a dark blue, crystalline rock, which bears considerable resemblance to some varieties of the carboniferous limestone. Quartz crystals and flint sometimes occur in this division.

3. The clay which separates the strata we have been considering from the lower calcareous grit has a pale blue colour, is of a stiff nature, and effervesces slightly with acids. It is apparently co-extensive with the formation from Lynham to Westbury Field.

4. The fourth division of the coral rag, the lower calcareous grit, consists of a thick stratum of sand, inclosing irregular beds of a siliceous rock. The sand is more or less intermixed with calcareous matter, arising principally from the decay of organic remains. The particles are generally small, and are never intermingled with rounded pebbles. The prevailing colour is dingy yellow, of various shades. Thin laminæ of clay are not unfrequently dispersed through the sand.

The grit or siliceous rock is composed of fine grains of quartz, which exhibit in general great uniformity of size in the same mass. Occasionally, from a thin coating of lime upon some of the grains, the stone assumes an oolitic character. Organic remains are scattered through all the beds, and are frequently so numerous as to change the grit into an impure, shelly limestone. The masses or irregular beds of stone possess no definite cleavage, and are generally so hard as to require the aid of gunpowder in dividing them. On being broken, the fractured surface often presents small, shining, parallel facets. In some localities a friable stratum occurs, which consists almost entirely of decomposed fragments of shells. The colour of the grit is principally pale brown on the exterior, but blue in the interior.

The accompanying lists are given, to illustrate the connexions between the stone and the sandy strata.

Quarry at the foot of Seend Hill, and on the south-east side of the Trowbridge Road.

Top.	Ft.	In.
Grit, split into irregular laminæ, 1 foot to 3 feet	2	0
Sand, with occasionally masses of grit	1	6
Grit, with many fragments of shells	1	0
Sand, inclosing in some parts nodules of grit.		
Very finely-grained grit, containing numerous fragments of shells, and composed of flat masses, which are sometimes in contact, sometimes separated by sand	1	0
Sand	3	0
Sand, with numerous fragments of shells, and intermixed with clay	0	3
Sand, containing masses of grit 2 feet to 4 feet	3	0
Grit, 4 to 6 feet, in some parts separated into two beds by a layer of sand 6 inches thick	5	0
Sand, 6 to 18 inches	1	0
Grit, a very hard stone	1	4
Sand	1	6
Grit	1	3
Sand	3	0

Quarry at Spirthill, between Calne and Lynham.

The clay which separates the coral rag from the lower calcareous grit	12	0
Grit	0	10
Sand, containing much calcareous matter, and thin laminæ of clay: greatest thickness	3	6
Irregular beds of calcareous grit, varying in their characters, and near the upper part assuming the appearance of a blue, shelly, impure limestone	6	0
Sand.		

The surface occupied by the coral rag in the district to which this memoir belongs is extremely small. In some parts the oolitic beds are wanting, and in others the presence of the formation is concealed by transported matter.

To the north of Calne the coral rag is bounded on the west by the brow of the hills ranging from Lynham to Bencroft near Bremhill, and on the east by a line passing from Preston to Hillmarton, Calne, and Quemerford. To the south-west of Calne it is displayed in the denudation in which is situated Bowood Park; and it forms a narrow but continuous band by Studley, Derry Hill, Red Hill, Bowden Hill, Spy Park, Chitway, Sandridge, Bromham, Rowde Hill, Seend Bridge, and around the western side of the eminence on which Seend is built. To the south of that village the coral rag attains a greater superficial importance: the western boundary passes by Baldham Mill, Hinton, Stourton Farm, and Rowd-Ashton Park to West Ashton; and the eastern extends from Hender's Copse by Keevil, and the north-western extremity of Rey Down to Dunge. Between this hamlet and Westbury Field the formation is not visible, but it reappears at that locality, and constitutes a narrow strip to the lane leading from Westbury Leigh to Brumridge Farm. Beyond this point the coral rag is concealed by the overlying of other formations.

Kimmeridge Clay.

This great argillaceous deposit presents in Wiltshire no natural facilities for examining its characters. It appears on the surface as a reddish brown or lead-coloured clay, which has generally an unctuous feel, and occasionally effervesces vividly with acids. When a small section is laid open, beds appear both of a massive and fissile structure, and vary in colour from light grey to almost black. The fissile or laminated property sometimes arises from the presence of vegetable matter. Strata of a bituminous nature, and said to have been used for fuel, were discovered in sinking a shaft at the brick-yard on the north side of the Bath Road, near the foot of Devizes Hill. Towards the top of the Kimmeridge clay irregular masses of argillaceous limestone occur, inclosing fragments of shells, particularly of a thickly ribbed Ammonites: blocks of sandy marlstone occupy a similar position; and nodules of argillaceous carbonate of iron are frequently met with.

Ostrea deltoidea is the only fossil which I have found in a perfect state in this formation.

In the neighbourhood of Calne the Kimmeridge clay constitutes the greater part of the low ridge near Sand's Farm, and a small denudated district which may be included within a line drawn from Quemerford Bridge by Rough Leaze, Stockley Common, Tossel's Farm, and around the western side of the knowl on which is situated Pinhill's Farm, back to Quemerford.

Between Pinhill's Farm and Lockswell Heath the Kimmeridge clay has been removed, but at the latter locality it appears as a thin bed underlying the lower green-sand, and may be traced along both the eastern and western sides of the heath, and from Bowden Hill, by Spy Park, to Westbrook, and Nonsuch. At Bromham the formation is wanting, the lower green-sand being in contact with the calcareous grit. Near Rowde Hill it reappears as a very thin bed; and at Rowde Wick Farm it begins to assume an important feature in the geological structure of the country. From that point the western boundary follows the brook to the Kennet and Avon Canal, then passes around the western side of Seend Hill, and afterwards by the east of Hender's Copse to Keevil, Rey Down, Dunge, Heywood House, Westbury Field, Penleigh, and Dilton: the eastern boundary ranges from Rowde Hill by Smythick's Farm, the western brow of Polshot Green, Polshot, and Five Lanes, to Cuckold's Green. At this point its continuity is interrupted by several overlying strips of the lower green-sand; but from Earl Stoke it describes a line by Coulston, Hud Mill, Westbury Mill, and Penleigh Mill to Dilton. Beyond this village the formation cannot be distinctly separated from the Oxford clay, on which it immediately reposes. In the lane leading from Dilton towards the Marsh, I found fragments of *Ostrea deltoidea.*

The greatest breadth of the Kimmeridge clay is from the neighbourhood of Baldham Mill to Coulston, a distance of rather more than three miles.

The thickness of the formation has never been ascertained in that part of the district where its superficial extent is most considerable.

Lower Green Sand.

The formation which is now to be described was considered, until the late investigations in the south-west of England, as a portion of those arenaceous beds to which the general term "iron-sand" was applied. The accompanying table exhibits the leading characters of the lower green-sand of Wiltshire.

Sand containing beds of	*a*	Calcareous grit with sandy clay....	30 ft.	Heddington Wick.
	b	Sandstone		Crockwood Mill near Urchfont.
	c	Quartzose conglomerate		Lockswell Heath.
	d	Spheroids of concentric crusts of iron-stone		Seend. Griffin Lane, summit of Bowden Hill.
	e	Chert		Near Greenland's Farm.

The sand, of which the formation is principally composed, consists of siliceous particles, which vary considerably in their size; and it often incloses quartzose pebbles. The colour is generally yellow, but is occasionally pale brown, and sometimes light greenish grey, or dingy yellowish green. The two latter varieties bear considerable resemblance to some portions of the upper green-sand. They occur between Great Cheverell and Worton, and near Cuckold's Green. The sand is almost universally friable.

a. The calcareous grit appears at Heddington Wick, and near the top of the formation. It is composed of thin laminæ of a reddish white colour; it is tolerably soft, and is imbedded in sandy clay.

b. The sandstone is displayed only at Crockwood Mill near Urchfont, where it forms two strata immediately under the galt. It consists of rather coarse grains of quartz cemented by carbonate of lime, and contains many, very small, polished particles of brown iron ore. Fragments of a large Pecten, with nearly equal ears, are common in both strata. The natural divisions between the blocks of stone are generally coated with crusts of argillaceous carbonate of iron.

c. The conglomerate is composed of pebbles of quartz cemented by a highly ferruginous sand. The pebbles are generally small, seldom attaining an inch in diameter, and are very unequally dispersed through the basis: sometimes they form the greater part of the mass, but at others are almost wanting. The oxide of iron, forming the cement, is frequently so abundant as to constitute a rich ore, which was formerly smelted to a considerable extent. The conglomerate seldom possesses any great degree of hardness, but yields with facility to the hammer, and appears occasionally as a loose rubble, locally called gravel. The colour of the basis is a deep brown, and that of the pebbles white. The blocks of which the conglomerate consists are imbedded in an irregular manner in the sand.

d. The spheroids are formed of concentric crusts of iron-stone, either in contact, or separated by zones of sand, and have a nucleus of loose sand or sandstone. They occur chiefly at Seend and Griffin Lane, and are either placed in juxtaposition, when they interfere with each other's form, or are parted by layers of sand.

e. Chert is comparatively rare in the lower green-sand; but a stratum containing the casts of an Astarte, a Trigonia, and a Natica, is occasionally worked near Greenland's Farm; and close to Crockwood Mill is a cherty sandstone with green particles.

Organic remains have hitherto been observed by me at only two localities; the one just mentioned, and Lockswell Heath, where casts of a beautifully imbricated Patella, and three or four species of bivalves, are to be found in a bed of the quartzose conglomerate.

The extent of the lower green-sand in Wiltshire is limited; and between Calne and Great Cheverell, the southern boundary of its range, it has been removed in many places by denudation. In the neighbourhood of Calne it constitutes the summit of the knowl near Sand's Farm, and of the hill on which is situated Pinhill's Farm: it occurs likewise between the Lodge and the Devizes Road in the new approach to Bowood from Quemerford. Its first appearance as a continuous stratum is at Lockswell Heath; whence its western boundary may be traced by Peter's Farm, Bowden Hill, the upper part of Spy Park, Chitway, Nonsuch, Bromham (where the lower green-sand and the calcareous grit are in contact), Rowde Hill, Rowde Wick, Smythick's, Barley-Hill Farm, and the western brow of Polshot Green to Polshot. Here the continuity of the boundary is interrupted; but the lower green-sand re-appears on the ridge to the south of Worton, and may be traced thence to Stove-Croft near Earl Stoke. The eastern boundary passes from Lockswell Heath by Sandy Lane to Wands House, where it turns east, and follows nearly the line of the Roman Road to Heddington Wick: at that hamlet it once more takes a southern direction, and proceeds by Bromham House to Nether Street, and by the brook nearly to Rowde Farm: afterwards it ranges by Conscience Lane, the turnpike at the foot of Devizes Hill, and the eastern side of Polshot Green, to the junction of the brooks flowing from Whistley and Devizes. Between this point and Cuckold's Green near Worton, the formation is concealed; but from the latter locality it may be traced by Rashley Common to Crockwood Mill, and lastly by Pottern-Park Farm to Dues Water, Greenland's Farm, and the knowl between that point and Long Street.

Seend Hill and the summit of the two eminences on the north and south of the main road between Seend Bridge and Foxhanger, are outliers of the lower green-sand.

Galt.

The usual appearance of the galt in Wiltshire is that of a blue or yellowish clay or marlstone. The former, which constitutes the greater part of the formation, is generally of a friable nature, and yields readily to the frost. Some of its beds effervesce, but others do not. It occasionally contains nodules of indurated marl and small septaria. It is used in the manufacture of bricks. The yellow clay, which is not of universal occurrence, is stiff, and soapy to the touch; it yields less readily to the frost, and is employed in the making of tiles. Both the clays abound with minute spangles of mica. Near the junction with the upper green-sand the galt sometimes becomes sandy, and contains many particles of silicate of iron.

Pyritical wood is the only organic body which I have found in the formation.

The galt is concealed for the greater part of its extent by transported matter from the Chalk Downs; but it is visible at Blacklands, Calstone Willington, Heddington, Dunkirk, the Canal Locks near Devizes, Drews Pond, Eastwell, Crockwood Mill, the side of the hill near Lavington Lodge, the brick-yard between Dues Water and Great Cheverell, Coulston, Bratton, Eden Vale near Westbury, and Westbury Leigh, and may therefore be inferred to constitute a band ranging at the foot of the Chalk Hills.

Upper Green Sand.

This formation is composed of siliceous sand, containing beds and nodules of calcareous sandstone and chert.

The sand is generally of a very fine grain, the particles being for the greater part not distinctly visible to the unassisted eye; but it is sometimes, though rarely, of a coarser texture. The colour varies from light grey to dark green, and is occasionally of different shades of yellow. No permanent order is visible in the arrangement of the colours, but in some districts (Earl Stoke, Coulston, Urchfont,) the dark green occupies the upper part of the formation, the grey the middle, and the yellow the bottom. The sand seldom possesses any great degree of compactness; but, from the presence of argillaceous matter, it becomes sometimes a friable sandstone.

The calcareous sandstones are likewise principally of a fine grain; occasionally, however, they pass into quartzose conglomerates; and from certain portions being tinged with oxide of iron, they not unfrequently assume the characters of a breccia. The calcareous cement often appears in distinct crystals, and gives the rock a glistening aspect. The colour varies from light grey to dark green and yellow. The hardness of the sandstone is sometimes considerable, but at others it is trifling. Blocks are occasionally found, of which organic remains constitute the greater part.

In the lower portion of the formation near its junction with the galt, small patches or streaks of blue clay are frequently visible.

Spangles of mica are generally diffused through the sand and sandstones.

Chert occurs abundantly in the neighbourhood of Warminster; but in the district to which this memoir in particular belongs, it appears to be entirely wanting.

The upper green-sand forms a narrow band ranging along the foot of the Chalk Hills from Cherhill by Calstone Willington, and Heddington to Roundaway. At New Park near Devizes, commences a narrow plain belonging to this formation, and extends by Wick Green to Pottern, and thence to Sleight Farm, Stert, Urchfont, Market Lavington, and Little and Great Cheverell to Earl Stoke, where the superficial dimensions again contract to another narrow band, which may be traced by Tinhead, Edington, Bratton, Westbury, and Westbury Leigh to Isomley. At this village begins a projecting ridge of upper green-sand, which reaches by Chapmanslade to Berkley Lodge.

Chalk Marl.

The chalk marl presents no peculiar characters. Its general appearance is that of a greyish white, argillaceous, soft limestone, the detached blocks of which on exposure to the weather desquamate into small globular or spheroidal masses. Near Warminster some of the beds contain much fine sand disseminated through the cretaceous basis. Streaks of grey or pale blue frequently traverse the strata, and become on being wetted almost black. The passage from the upper green-sand into the chalk marl is often well displayed, and is generally effected in a very few feet.

The chalk marl ranges along the centre of the escarpment of the hills bordering on the Marlborough Downs and Salisbury Plain. At the gorge of the vale of Pewsey it has been almost entirely removed by denudation, only two small eminences being left, the highest of which is called Etchilhampton Hill.

Lower Chalk.

The lower chalk, which forms the summit of the downs in this part of Wiltshire, consists of beds of soft chalk alternating with others composed of roundish nodules, and with strata of a hard, splintery limestone, which yields to the frost. The accompanying section from Bratton Castle near Westbury will illustrate the connection of these varieties of stone.

Top.	Ft.	In.
Malm, or rather soft chalk	1	6
A layer of flints.		
Roundish nodules of hard chalk, of a ferruginous colour	0	9
Hard, splintery, white limestone	1	0
Malm	2	6
Roundish nodules of hard chalk of a ferruginous colour	1	2
Hard, splintery, white limestone	1	6
Malm.		

At Cherhill, well known to the traveller by its White Horse, the hard, splintery, limestone is wanting, and the formation is composed of alternations of malm and round nodules; but the former greatly preponderates in quantity.

Gravel.

Extensive beds of gravel accompany the Avon through the whole of its course from Kelloway to Keynsham, but they do not present any peculiar features, and are formed of the debris of the neighbouring rocks. In the vicinity of Farleigh are likewise widely spread accumulations, composed of water-worn pebbles of every formation from the Wiltshire Downs to the Mendip Hills. The most interesting circumstance connected with the gravel of the district to which this memoir belongs, is the existence of chalk flints on some of the isolated downs and hills in the neighbourhood of Bath. They occur abundantly on Farleigh Down and Hampton Down; but the latter is separated from the former by the deep valley of Warley, and its prolongation is everywhere bounded by precipitous escarpments. In the vicinity of Cherhill the surface of the chalk has been worn, in many places, into deep pits, and afterwards filled with flints, which are now dug for the repair of the roads. The sides of the pits are often lined with layers of a very ferruginous clay, which has a smooth, slickenside appearance.

In the gravel-pits in the neighbourhood of Bath the remains of Mammalia are frequently found. At that near Larkhall the following vestiges of the former inhabitants of this island have been procured:

Elephas...............Grinders of the Mammoth.
Sus ....Molar teeth.
Rhinoceros tichorhinus..Molar teeth, scapula? and metatarsal bone.
Equus ....Incisor and molar teeth.
Bos ....Molar teeth, tibiæ, humerus, astragalus, os calcis, and cervical vertebræ.
Ursus? ....Canine tooth.

Alluvium *.

The springs used for domestic purposes in Bath abound with carbonate of lime, which they precipitate in great quantities in the pipes by which the water is conveyed to the city. The rivulets are likewise strongly charged with lime, and often coat their banks with a thick crust of tufaceous matter.

Organic Remains †.

Geol. Position.	*Class.*	*Genus.*	*Species.*	*References.*	*Localities.*
Lias . .	Polyparia.	Alcyonium?		. . . .	Weston.
	Radiaria.	Pentacrinites	tuberculatus.	Miller, Crinoidea.	Ibid.
		Echinus.		. . . .	Ibid.
	Crustacea.			. . . .	Saltford.
	Conchifera.	Pholadomya	ambigua.	Min. Con. Tab. 227.	Radstock.
		Cardita?		. . . .	Corston.
		Unio	concinnus.	Ibid. Tab. 223. f. 1. 3.	Weston.
		Modiola	Hillana.	Ibid. Tab. 212. f. 2.	Ibid.
		Lima	antiquata.	Ibid. Tab. 214. f. 2.	Ibid.
		Avicula	inæquivalvis.	Ibid. Tab. 244. f. 2. 3.	Ibid. Radstock.
		Plagiostoma	gigantea.	Ibid. Tab. 77.	Ibid.
			punctata.	Ibid. Tab. 113. f. 1. 2.	Ibid.
			duplicata.	Ibid. Tab. 559. f. 3.	Ibid.

* The author is indebted for the above list to his friend H. Woods, Esq. F.Z.S. &c.

† In this Table those fossils only are detailed which were procured by the author.

Geol. Position.	*Class.*	*Genus.*	*Species.*	*References.*	*Localities.*
Lias . . .	Conchifera.	Plagiostoma	Hermanni.	. . . .	Weston.
		Pecten	barbatus.	Min. Con. Tab. 231.	Ibid.
		Gryphæa	incurva.	Ibid. Tab. 112. f. 1. 2.	Ibid.
			obliquata.	Ibid. Tab. 112. f. 3.	Ibid.
			Maccullochii.	Ibid. Tab. 547. f. 1—3.	Radstock.
		Ostrea	læviuscula.	Ibid. Tab. 488. f. 1.	Weston.
		Terebratula.		. . . .	Ibid. Corston, Radstock, &c.
		Spirifer	Walcotti.	Ibid. Tab. 377. f. 2.	Camerton.
	Mollusca.	Helicina	solarioides.	Ibid. Tab. 273. f. 4.	Ibid.
			polita.	Ibid. Tab. 285.	Ibid.
		Turbo.		. . . .	Ibid.
		Trochus	Anglicus.	Ibid. Tab. 142. *T. similus.*	Weston.
		Turritella.		. . . .	Camerton.
		Belemnites	aduncatus.	Miller, Geol. Trans. 2nd series, vol. ii. Pl. 8.	Weston, &c.
			longissimus.	Ibid. Ibid.	Ibid.
		Nautilus	lineatus.	Min. Con. Tab. 41.	Ibid.
		Ammonites	Greenoughi.	Ibid. Tab. 132.	Keynsham.
			Bucklandi.	Ibid. Tab. 130.	Weston.
			rotiformis.	Ibid. Tab. 453.	Ibid.
			Johnstoni.	Ibid. Tab. 449. f. 1.	Ibid.
			Conybeari.	Ibid. Tab. 131.	Ibid.
			armatus.	Ibid. Tab. 95.	Ibid.
			obtusus.	Ibid. Tab. 167.	Ibid.
			planicostâ.	Ibid. Tab. 73.	Batheaston.
	Pisces *.			. . . .	Weston.
	Reptilia.	Ichthyosaurus	communis.	Conybeare, Geol. Trans. 2nd series, vol. i.	Ibid.
			platyodon.	Ibid. Ibid.	Ibid.
			tenuirostris.	Ibid. Ibid.	Ibid.
		Plesiosaurus	dolichodeirus.	Ibid. Ibid.	Ibid.
Marlstone . .	Mollusca.	Ammonites	undulatus.	Smith, Stratigraphical System, p. 114. A. Strangwaysi, Min. Con. Tab. 254. f. 1. 3.	Box.
Inferior Oolite.	Polyparia.	Astrea.		. . . .	Midford Hill, Widcomb Hill.
	Annulata.	Serpula.		. . . .	Canal banks opposite Limpley Stoke.
	Conchifera.	Mya.		. . . .	Ibid.
		Pholadomya.		. . . .	Ibid.
		Lutraria?		. . . .	Ibid.
		Mactra.		. . . .	Widcomb Hill.
		Crassatella?		. . . .	Ibid.
		Astarte.		. . . .	Ibid.
		Cardita.		. . . .	Canal banks opposite Limpley Stoke.
		Isocardia	rostrata.	Min. Con. Tab. 295. f. 3.	Ibid.
		Cucullæa	oblonga.	Ibid. Tab. 206. f. 1. 2.	Ibid. Widcomb Hill.
		Arca.		. . . .	Ibid.
		Trigonia	costata.	Ibid. Tab. 85.	Ibid.
		Unio	concinnus.	Ibid. Tab. 223.	Ibid.
		Axinus	obscurus?	Ibid. Tab. 314.	Ibid.
		Modiola	gibbosa.	Ibid. Tab. 211. f. 2.	Ibid.
		Pinna.		. . . .	Widcomb Hill.
		Lithodomus.		. . . .	Sion Hill.
		Perna.		. . . .	Ibid.
		Avicula	inæquivalvis.	Ibid. Tab. 244. f. 2. 3.	Canal banks opposite Limpley Stoke.
		Lima	proboscidea.	Ibid. Tab. 264.	Near the Dundas Aqueduct.
		Plagiostoma.		. . . .	Beacon Hill, Widcomb Hill.
		Pecten	æquivalvis.	Ibid. Tab. 136. f. 1.	Canal banks opposite Limpley Stoke.
			barbatus.	Ibid. Tab. 231.	Ibid.

* Teeth.

Geol. Position.	*Class.*	*Genus.*	*Species.*	*References.*	*Localities.*
Inferior Oolite.	Conchifera.	Ostrea	Meadei.	Min. Con. Tab. 252. f. 1. 4.	Canal banks opposite Limpley [Stoke.
			acuminata.	Ibid. Tab. 135. f. 2. 3.	Ibid.
			obscura.	Ibid. Tab. 488. f. 2.	Widcomb Hill.
		Terebratula	emarginata.	Ibid. Tab. 435. f. 5.	Canal banks opposite Limpley [Stoke.
			ornithocephala.	Ibid. Tab. 101. f. 1. 2. 4.	Ibid.
			obovata.	Ibid. Tab. 101. f. 5.	Ibid.
			subrotunda.	Ibid. Tab. 15. f. 1. 2.	Ibid.
			concinna.	Ibid. Tab. 83. f. 6.	Ibid.
			media.	Ibid. Tab. 83. f. 5.	Ibid.
			spinosa.	Smith's Stratig. System, p. 108.	Ibid.
	Mollusca.	Natica.		. . . .	Ibid.
		Trochus	elongatus.	Min. Con. Tab. 193. f. 2—4.	Ibid.
			granulatus.	Ibid. Tab. 220. f. 2.	Ibid.
		Cirrus	carinatus.	Ibid. Tab. 429. f. 3.	Ibid.
		Terebra.		. . . .	Ibid.
		Belemnites	abbreviatus.	Miller, Geol. Trans. 2nd series, vol. ii. Pl. 7. f. 9.	Bathcaston.
		Nautilus	obesus.	Min. Con. Tab. 124.	Smallcomb Wood.
		Ammonites	annulatus.	Ibid. Tab. 222.	Canal banks opposite Limpley [Stoke.
			sublævis.	Ibid. Tab. 54.	
Fuller's Earth.	Annulata.	Serpula.		. . . .	Foot of High Barrow Hill, &c.
	Conchifera.	Pholadomya	lyrata.	Ibid. Tab. 197. f. 3.	Ibid.
		Mya	angulifera.	Ibid. Tab. 224. f. 6. 7.	BathfordHill, brow of Charmy- [down, &c.
		Astarte?		. . . .	Midford Hill.
		Isocardia	concentrica.	Ibid. Tab. 491. f. 1.	Brow of Charmydown, Wid- [comb, &c.
		Arca.		. . . .	Frome.
		Modiola	Hillana?	Ibid. Tab. 212. f. 2.	Bathford Hill.
			plicata.	Ibid. Tab. 248. f. 1.	Green Parlour near Radstock.
		Avicula	inæquivalvis.	Ibid. Tab. 244. f. 2. 3.	Bathford Hill.
			echinata.	Ibid. Tab. 243.	Ibid.
		Ostrea	acuminata.	Ibid. Tab. 135. f. 2. 3.	Ibid.
		Terebratula	bullata.	Ibid. Tab. 435. f. 4.	Near Cold Ashton.
			globata.	Ibid. Tab. 436. f. 1.	Gloucester Road, $5\frac{1}{2}$ miles [from Bath.
			media.	Ibid. Tab. 83. f. 5.	Ibid.
			concinna.	Ibid. Tab. 83. f. 6.	Frome.
			acuta.	Ibid. Tab. 130. f. 1. 2.	Ibid.
	Mollusca.	Ammonites	sublævis.	Ibid. Tab. 54.	Bathford Hill.
Great Oolite.	Polyparia.				
		Berenicea	diluviana*.	Lamouroux, Exp. Meth. Tab. 84. f. 12. 14.	Bradford.
		Flustra.		. . . .	Murrel near Bradford.
		Alecto	dichotoma*.	Ibid. Tab. 81. f. 12. 14.	Bradford.
		Spongia	clavaroides*.	Ibid. Tab. 84. f. 8—10.	Murrel near Bradford.
		Theona	chlarata*.	Ibid. Tab. 80. f. 17. 18.	Kingsdown near Bradford.
		Chrysaora	Damæcornis*.	Ibid. Tab. 81. f. 8. 9.	Corshamside near Corsham.
			spinosa*.	Ibid. Tab. 81. f. 6. 7.	Murrel.
		Millepora.		. . . .	Ibid., Corsham-side, Bradford.
		Terebellaria	ramosissima*.	Ibid. Tab. 82. f. 1.	Kingsdown, Ibid.
		Spiropora	cæspitosa*.	Ibid. Tab. 82. f. 11. 12.	Bradford.
		Idmonea	triquetra*.	Ibid. Tab. 80. f. 13—15.	Ibid.
		Meandrina?		. . . .	Kingsdown.
		Astrea.			
		Explanaria?			
		Eunomia	radiata*.	Ibid. Tab. 81. f. 10. 11.	Farleydown near Bathford.
		Alcyonium?		. . . .	Murrel.
	Radiaria.	Apiocrinites	Prattii.	Gray, Phil. Mag. Sept. 1828.	Lansdown.
			rotundus.	Miller, Crinoidea, Pl. 1—7.	Hamptondown near Bath- [Hampton.
		Pentacrinites.		. . . .	Lansdown, Bannerdown, near Batheaston.
		Cidaris.		. . . .	Bannerdown, Hamptondown.

* These fossils are found in the *Calcaire à Polypiers* at Caen in Normandy.

Geol. Position.	*Class.*	*Genus.*	*Species.*	*References.*	*Localities.*
Great Oolite .	Radiaria.	Clypeus.		. . . .	Bannerdown, Hamptondown.
	Annulata.	Serpula.		. . . .	Ibid.
	Conchifera.	Astarte	orbicularis.	Min. Con. Tab. 444. f. 4—6.	Hamptondown.
		Lima.		. . . .	Farleydown.
		Plagiostoma.		. . . .	Huddock's Hill near Dunkerton.
		Ostrea	costata.	Ibid. Tab. 488. f. 3.	Hamptondown.
		Terebratula	digona.	Ibid. Tab. 96.	Ibid.
			furcata.	Ibid. Tab. 535. f. 2.	Ancliff.
			coarctata.	Ibid. Tab. 312. f. 1—4.	Hamptondown.
	Mollusca.	Pileolus	plicatus.	Ibid. Tab. 432. f. 1—4.	Kingsdown.
		Acteon	acutus.	Ibid. Tab. 455. f. 2.	Ancliff.
		Turbo	obtusus.	Ibid. Tab. 551. f. 2.	Ibid.
		Ammonites.		. . . .	Huddock's Hill.
	Pisces *.			. . . .	Box.
Bradford Clay .	Radiaria.	Apiocrinites	rotundus.	Miller, Crinoidea, Pl. 1—7.	Bradford.
	Annulata.	Serpula.		. . . .	Ibid.
	Conchifera.	Arca.		. . . .	Ibid.
		Nucula	pectinata?	Min. Con. Tab. 192. f. 6. 7.	Ibid.
		Avicula	costata.	Ibid. Tab. 244. f. 1.	Ibid.
		Chama.		. . . .	Ibid.
		Ostrea.		. . . .	Ibid.
		Terebratula	digona.	Ibid. Tab. 96.	Ibid.
			coarctata.	Ibid. Tab. 312. f. 1—4.	Ibid.
	Mollusca.	Trochus.		. . . .	Ibid.
Forest Marble †	Polyparia.	Berenicea.		. . . .	Pickwick.
		Millepora.		. . . .	Ibid.
		Spongia.		. . . .	Near Atford.
		Terebellaria	ramosissima.	Lamouroux, Exp. Meth. Tab. 82. f. 1.	Farleigh Hungerford.
	Radiaria.	Apiocrinites	rotundus.	Miller, Crinoidea, Pl. 1—7.	Near Pickwick.
		Pentacrinites.		. . . .	Farleigh Hungerford.
		Cidaris.		. . . .	Wormwood.
	Annulata.	Serpula.		. . . .	Pickwick.
	Conchifera.	Corbula.		. . . .	Farleigh Hungerford.
		Nucula.		. . . .	Ibid.
		Exogyra?			
		Chama.		. . . .	Wormwood.
		Plagiostoma?		. . . .	Giddy Hall near Marshfield.
		Pecten	fibrosus.	Min. Con. Tab. 136. f. 2.	Wormwood.
			vagans.	Ibid. Tab. 543. f. 3—5.	Ibid.
		Ostrea	many species.	. . . .	Ibid. Pickwick, &c.
		Terebratula	maxillata.	Ibid. Tab. 436. f. 4.	Pickwick.
			digona.	Ibid. Tab. 96.	Ibid.
			obsoleta.	Ibid. Tab. 83. f. 7.	Ibid.
			coarctata.	Ibid. Tab. 312. f. 1—4.	Ibid.
	Mollusca.	Patella	rugosa.	Ibid. Tab. 139. f. 6.	Wormwood.
		Natica.		. . . .	Lypeat near Corsham.
		Turritella.		. . . .	Ibid.
	Pisces ‡.			. . . .	Ibid. Wormwood, &c.
Cornbrash . .	Polyparia.	Fungia	orbulites.	Lamouroux, Exp. Meth. Tab. 83. f. 1—3.	Atford.
	Radiaria.	Clypeus.		. . . .	Ibid.
	Annulata.	Serpula.		. . . .	Ibid.
		Vermicularia.		. . . .	Near Chippenham.

* Palatal teeth.

† On the surface of the masses of grit are almost invariably found cylindrical bodies, some of which present no traces of organic structure, but others exhibit striæ, which have occasionally a longitudinal and occasionally a transverse direction. Similar bodies are obtained, though rarely, with Serpulæ or Bereniceæ attached to them. No impressions of the fronds of ferns, or the leaves of other plants, occur in any of the Wiltshire quarries; but large masses of bituminized vegetables are abundant at many localities; and the planes of separation between the blocks of grit are frequently covered by thin layers of carbonized matter.

‡ Teeth, palatal bones, scales, and radii.

Geol. Position.	Class.	Genus.	Species.	References.	Localities.
Cornbrash . .	Conchifera.	Pholadomya	producta.	Min. Con. Tab. 197. f. 1.	Atford.
			lyrata.	Ibid. Tab. 197. f. 3.	Ibid.
		Lutraria?		. . . .	Ibid.
		Astarte.		. . . .	Near Chippenham.
		Cardium	striatulum?	Ibid. Tab. 553. f. 1.	Cutteridge.
		Isocardia	minima.	Ibid. Tab. 295. f. 1.	Hilperton.
		Trigonia	elongata.	Ibid. Tab. 431.	Ibid.
		Chama?		. . . .	Atford.
		Modiola	imbricata.	Ibid. Tab. 212. f. 1. 3.	Ibid.
		Avicula	echinata.	Ibid. Tab. 243.	Ibid.
		Ostrea	Marshii.	Ibid. Tab. 48.	Ibid.
		Terebratula	bullata.	Ibid. Tab. 435. f. 4.	Ibid.
	Mollusca.	Ammonites	discus.	Ibid. Tab. 12.	Cutteridge.
	Pisces *.			. . . .	Atford.
Oxford Clay .	Conchifera.	Nucula.			
		Gryphæa	dilatata & var. β.	Ibid. Tab. 149. f. 1. 2.	
	Mollusca.	Ammonites	Gulielmii.	Ibid. Tab. 311. f. 5.	
Kelloway Rock	Polyparia.	Fungia	orbulites.	Lamouroux, Exp. Meth. Tab. 83. f. 1—3.	Kelloway Bridge.
	Conchifera.	Pholadomya.		. . . .	Ibid.
		Mya?		. . . .	Whitley near Melksham.
		Cardium.		. . . .	Kelloway Bridge.
		Isocardia	tener.	Min. Con. Tab. 295. f. 2.	Ibid.
		Trigonia.		. . . .	Ibid.
		Unio?		. . . .	Christian Malford.
		Modiola	bipartita.	Ibid. Tab. 210. f. 3. 4.	Kelloway Bridge.
		Pinna?		. . . .	Ibid.
		Avicula	inæquivalvis.	Ibid. Tab. 244. f. 2. 3.	Ibid.
		Lima?		. . . .	Ibid.
		Gryphæa	dilatata var. β.	Ibid. Tab. 149. f. 2.	Ibid.
			nana.	Ibid. Tab. 383. f. 3.	Ibid.
		Terebratula	ornithocephala.	Ibid. Tab. 101. f. 1. 2. 4.	Ibid.
			tetraëdra.	Ibid. Tab. 83. f. 4.	Ibid.
		Magas.		. . . .	Ibid.
	Mollusca.	Ammonites	Kœnigi.	Ibid. Tab. 263. f. 1—3.	Ibid.
			Calloviensis.	Ibid. Tab. 104.	Ibid.
			sublævis.	Ibid. Tab. 54.	Ibid.
		Belemnites.		. . . .	Ibid.
Coral Rag . .	Polyparia.	Caryophyllia.		. . . .	Steeple Ashton †.
		Agaricia.		. . . .	Ibid. †
		Astrea.		. . . .	Ibid. Calne, Westbrook †.
	Radiaria.	Cidaris.	Three species at least.	. . . .	Calne †.
		Echinus.		. . . .	Steeple Ashton †.
		Clypeus	sinuatus.	Parkinson, Introd. p. 123.	Lynham near Calne †.
	Annulata.	Serpula.		. . . .	Calne †.
	Conchifera.	Mya?		. . . .	Steeple Ashton †.
		Lutraria?		. . . .	Ibid. †
		Trigonia	costata.	Min. Con. Tab. 85.	Ibid. †
		Lithodomus.		. . . .	Calne †.
		Pecten	fibrosus.	Ibid. Tab. 136. f. 2.	Ibid. †
		Perna	aviculoides.	Ibid. Tab. 66.	Seend ‡.
		Ostrea	gregarea.	Ibid. Tab. 111. f. 1. 3.	Westbrook †.
	Mollusca.	Terebra	striata.	Ibid. Tab. 47.	Steeple Ashton †.
			Heddingtonensis.	Ibid. Tab. 39.	Ibid. †
		Natica.			
		Turbo	muricatus.	Ibid. Tab. 240. f. 4.	Ibid. †
		Trochus.			
		Turritella	muricata.	Ibid. Tab. 499. f. 1. 2.	Ibid. †
		Belemnites	abbreviatus.	Miller, Geol. Trans. 2nd series, vol. ii. Pl. 7. f. 9.	Ibid. †

* Molar teeth. † Coral rag. ‡ Calcareous grit.

Geol. Position.	*Class.*	*Genus.*	*Species.*	*References.*	*Localities.*
Coral rag . .	Mollusca.	Ammonites	catena.	Min. Con. Tab. 420.	Seend*.
			perarmatus.	Ibid. Tab. 552.	Ibid.*
			vertebralis.	Ibid. Tab. 165.	Studley*.
			annulatus.	Ibid. Tab. 222.	Seend*.
			cordatus.	Ibid. Tab. 17. f. 2. 4.	Ibid.*
Kimmeridge Clay . .	Conchifera.	Ostrea	deltoidea.	Ibid. Tab. 148.	Dilton Marsh near Westbury.
LowerGreen-sand . .	Conchifera.	Astarte.		. . . .	Near Greenland's Farm.
		Trigonia.		. . . .	Ibid.
	Mollusca.	Patella.		. . . .	Lockswell Heath.
		Natica.		. . . .	Near Greenland's Farm.
UpperGreen-sand . . .	Polyparia.	Alcyonium?			
		Hallirhoa	costata.	Lamouroux, Exp. Meth. Tab. 78. f. 1.	Neighbourhood of Warminster†.
		Chenendopora	fungiformis.	Ibid. Tab. 75. f. 9. 10.	Ibid.
		Hippalimus	fungoides.	Ibid. Tab. 79. f. 1.	Ibid.
	Radiaria.	Echinus.		. . . .	Ibid.
		Clypeus.		. . . .	Ibid.
		Cassidulus	lapis cancri.	Parkinson, Introd. p. 125.	Ibid.
		Galerites.		. . . .	Ibid.
		Spatangus	punctatus.	Ibid. p. 141.	Ibid.
			retusus?	Ibid. Ibid.	Near Coulston.
	Annulata.	Vermicularia	concava.	Min. Con. Tab. 57. f. 1—5.	Westbury.
	Conchifera.	Thetis	major.	Ibid. Tab. 513. f. 1—4.	Devizes.
		Astarte	striata.	Ibid. Tab. 520. f. 1.	Ibid.
		Trigonia	aliformis?	Ibid. Tab. 215.	Edington.
		Cucullæa	glabra.	Ibid. Tab. 67.	Neighbourhoodof Warminster.
		Exogyra	haliotoidea.	Ibid. Tab. 25.	Ibid.
		Gervillia	solenoides.	Ibid. Tab. 510. f. 1—4.	Ibid.
		Pecten	asper.	Ibid. Tab. 370. f. 1.	Ibid.
			quinquecostata.	Ibid. Tab. 56. f. 4—8.	Ibid.
			quadricostata.	Ibid. Tab. 56. f. 1. 2.	Ibid.
		Terebratula	lyra.	Ibid. Tab. 138. f. 2.	Ibid.
			lata.	Ibid. Tab. 100.	Ibid.
	Conchifera.				
	Mollusca.	Ammonites	inflatus.	Ibid. Tab. 178.	Near Coulston.
			varians.	Ibid. Tab. 176.	
Chalk Marl .	Pisces‡.			. . . .	Edington.
	Conchifera.	Mya?		. . . .	Compton near Calne.
		Mytiloides	labiatus.	Cuvier, Oss. Foss. Tom. 2. Tab. 3. f. 4.	Ibid.
	Mollusca.	Ammonites	Nutfieldiensis.	Min. Con. Tab. 108.	Ibid.
			varians.	Ibid. Tab. 176.	Ibid.
Lower Chalk .		Turrilites	costata.	Ibid. Tab. 36.	Ibid.
	Radiaria.	Galerites.		. . . .	Warminster.
		Ananchytes.		. . . .	Ibid.
		Spatangus.		. . . .	Ibid.
	Conchifera.	Inoceramus	mytiloides.	Ibid. Tab. 442.	Ibid.
			concentricus.	Ibid. Tab. 305.	Ibid.
		Terebratula	biplicata.	Ibid. Tab. 90.	Ibid.

* Calcareous grit.

† Although Warminster is not included within the boundaries of the district described in the preceding pages, yet the author has thought it advisable to enumerate the fossils which he procured from its neighbourhood. ‡ Teeth.

XV.—*On a Fossil Fox found at Œningen near Constance; with an Account of the Deposit in which it was imbedded.*

By RODERICK IMPEY MURCHISON, Esq. Pres. G.S. F.R.S. F.L.S.

[Read January 18th, 1830.]

THE remarkable fossil quadruped which has given rise to this memoir was found in the quarries of Œningen near Constance, in the autumn of 1828, immediately before my first visit to them. The novel occurrence of an entire carnivorous quadruped regularly imbedded in stone led me to put together a few observations on the deposit which contained it; but I deferred the publication of them until the specific character of the animal should have been correctly ascertained. This point has now been accomplished through the scientific labours of Mr. Mantell, and I have since re-examined the locality accompanied by Professor Sedgwick.

It may be well to preface the following observations by a short sketch of what other naturalists have written on the same subject.

The quarries of Œningen are known to have been worked as early as the year 1680; and when their contents were first described and figured by Scheuchzer in his *Herbarium Diluvianum**, so great an interest was excited, that numerous collections were rapidly formed by Gessner, Lavater, Ammann, and other naturalists of the neighbourhood†.

Up to the beginning of this century various authors have written on the deposit of Œningen, or some of its contents; amongst whom may be specified Andræa, Gessner‡, de Saussure§, Razoumofsky ||, and Blumenbach ¶. Of these works the relation of Razoumofsky is the most detailed. He was followed by Karg of Constance, who in the year 1800 published a clear and faithful section of the quarries, with a very copious list of all the animal and

* Published 1700.

† The most complete collection was that made by Professor Pfeiffers, under the patronage of the Bishop of Constance, in the year 1784, and placed in the palace of Mersburg, from whence it has passed to the Grand Ducal museum of Carlsruhe.

‡ *Lettres sur la Suisse.*

§ *Voyage dans les Alpes*, vol. iii. p. 331.

|| *Mémoires de l'Académie de Lausanne*, vol. iii.

¶ *Manuel, und Gotha Magazin.*

vegetable remains*. The variety of this list would astonish any geologist unacquainted with the wonderful fertility of these quarries; for in it are mentioned several quadrupeds and birds, a vast number of fishes, reptiles, insects, and innumerable plants, all of which were by him, as well as by Razoumofsky and other cotemporary writers, identified with existing species†.

At that period, however, fossil zoology had not the fixed character which it has since assumed through the labours of the illustrious Cuvier, who has clearly shown that several of the organic remains of Œningen have in fact no exact types in living nature, and that the celebrated *Homo diluvii testis* of Scheuchzer was in reality an aquatic salamander‡. Much however remained to be examined; for it was still left in doubt whether amidst the fishes, insects, shells, and plants, many might not yet prove to be of existing species. Cuvier satisfactorily established, that all the mammalia discovered in this deposit up to the time of the publication of his work were Rodentia, and that no *carnivorous* quadruped had been hitherto found in it.

Previous to the appearance of the *Ossemens Fossiles* M. Brongniart had

* *Denkschriften der Vaterländischen Gesellschaft der aerzte und Naturforscher Schwabens*, vol. i. p. 1. Tubingen, 1805.

† In the memoirs of Scheuchzer, Razoumofsky, and Karg, will be found the three principal theories by which it has been attempted to explain the nature of the Œningen formation.

1st. Scheuchzer referred the whole to the Mosaic deluge, bringing forward, as a proof of it, his *Homo diluvii testis*, an animal which subsequent German authorities considered to be a skeleton of a large fish, but the true nature of which was only established by Cuvier, who has clearly shown that it was an "aquatic salamander."

2ndly. The hypothesis of Razoumofsky (*Annales des Sciences de Lausanne*, vol. iii.) was, that the sea in retiring had left a vast freshwater lake which extended fifty-nine leagues in length, covering all the country between the lakes of Geneva and Constance. In support of his theory this author identified the fossil species of this lacustrine deposit with those of the lignite beds near Vevay, where it is now well known that a few land and fluviatile shells, differing entirely from those of Œningen, are mixed up with marine remains. He further imagined that volcanic subterranean agencies had indurated, altered and bituminized the marls, calcined the shells, and carbonized the plants. It is remarkable that this author seems to have been unacquainted with the existence of the adjoining volcanic group of Hohentwiel, which might have served to confirm his views as to the igneous consolidation of the deposit. (See a description of the volcanic rocks of Hohentwiel. *Denkschriften der Naturforscher Schwabens*, vol. i. p. 204.)

3rdly. Karg and others imagined that the strata were formed in tanks or fish-ponds within the period of history. This singular notion was adopted under the false supposition, that as all the animals and plants were of existing species, they most probably inhabited ancient fish-ponds which the legends of the adjoining convents asserted to have formerly existed in this neighbourhood.

‡ *Ossemens Fossiles*, vol. v. part 2. p. 431.

visited Œningen, of which he has given a section and description*, and in which differing from Karg, who had not only asserted that the deposit was superposed to all other formations of the neighbourhood, but had even been accumulated within the historic period, he endeavours to prove that it is subordinate to the adjoining molasse, and of about the same geological age as the Palæotherian strata of the Paris basin. My observations, however, whether derived from actual sections, or from a consideration of the organic contents of the quarries, have induced me to come to different conclusions from both these authors, and to think that the Œningen formation is exclusively of ancient, lacustrine origin, yet entirely posterior to the molasse of Switzerland†. To prove this position I shall offer,

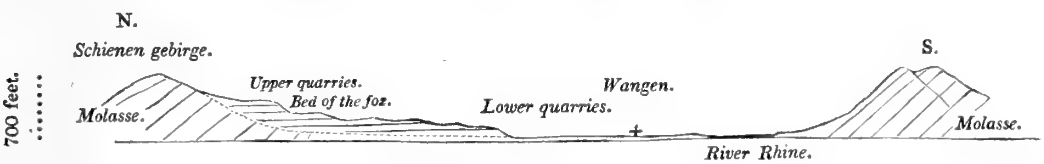
1st, A description of the deposit and its relations to the surrounding country, with actual sections of the quarries.

2ndly, A sketch of their contents, including a special account of the carnivorous quadruped by Mr. Mantell, and a synopsis of other organic remains formerly and recently discovered.

3rdly, Conclusions drawn from the previous details.

The Rhine, in its course from Constance to Schaffhausen, flows for many miles in a depression of the tertiary marine formation known by the name of Molasse, which being cut through transversely, is exposed in hills on both banks, at heights varying from seven to nine hundred feet. These hills, consisting of micaceous sandstone and conglomerate, form the western prolongation of that great range of tertiary deposits which extends along the flanks of the Austrian and Bavarian Alps, and has been described by Professor Sedgwick and myself. The marls and limestone of Œningen are recumbent on this molasse, and are seen in various patches on the sides of the hills, and are worked in two quarries at different elevations overlooking the Rhine.

Section across the Valley of the Rhine, showing the Relations of the Lacustrine Formation of Œningen to the Inferior Marine Molasse.



* *Environs de Paris*, p. 307.

† In justice to M. Brongniart it is right to state, that the quarries had not been worked for some years previous to the period of his visit, and were probably then too much encumbered with rubbish to admit of his making a satisfactory section. (See his observations, *Env. de Paris*, p. 308.)

The quarries seen in the accompanying wood-cut are situated on the right bank of the Rhine, just where the river re-issues from the Zeller-See or lesser lake of Constance, about two miles distant from the village of Œningen, and three miles west of the town of Stein. The lowest of these is near the village of Wangen, about two hundred feet above the level of the river; the highest is nearly one mile further distant from the Rhine, and about six hundred feet above its level. In both the upper and lower quarries are found an abundance of freshwater and terrestrial remains, to the entire exclusion of anything marine; and in both cases the marl beds rest upon molasse, which rock thus forming the bottom of the basin, is exposed beneath the lower quarries in the denudation of the Rhine, and rises behind them into the woody hills of Schienen. It would therefore appear from the configuration of this district, that the valley in which the Rhine now flows was, at a remote period, deeply excavated in the molasse, and that subsequently, a lake was formed in one of the broader parts of this valley, in which marls and limestone were gradually deposited: indeed the arrangement and shape of the strata scarcely allow of any other hypothesis; for the beds though nearly horizontal, thicken slightly towards the centre of the basin, whilst the nature of the organic remains, and their deposition in successive layers, not only prove the long period of time which must have elapsed during their accumulation, but also demonstrate the lacustrine origin of the deposit*.

Lower Quarries.

The lower quarries have never been extensively worked on account of the incoherent nature of the stone, nor have they afforded the same quantity of organic remains as the upper quarries; they are however at present exposed to the depth of about twenty-five feet. The principal beds are cream-coloured marlstones, with a blue, internal fracture, and have in parts a considerable proportion of sand and some mica, which seem to have been derived from the detritus of the formation of molasse on which they rest. These strong beds are separated from each other by thin way-boards of unctuous, argillaceous marl. Plants chiefly dicotyledonous, fishes, and shells, are distributed throughout the finer bands of marlstone, which separate the coarser beds from each other. Amongst the plants I here found that remarkable impression of a leaf described in the sequel as *Populus cordifolia*, several small fishes, a few shells of Anodonta, &c.

* In corroboration of these views, see Karg's Memoir, cited, p. 278.

Upper Quarries.

These were ascertained by the barometrical observations of de Saussure to be six hundred feet above the town of Stein; but Karg, who examined the formation thirteen years later, places them at only five hundred feet. This discrepancy is easily reconciled; for in fact numerous quarries of freshwater limestone have at distant periods been opened on the sides of the Schienengebirge at very different elevations: hence it follows that the sections made by geologists who may visit this locality at different times will seldom precisely correspond*. It will be found however, on comparison, that Karg's section, made in the year 1800, accords very nearly with my own. The present quarries consist of two sets of works at slightly different levels, and separated from each other by about one hundred paces. The carnivorous quadruped was found in the lowest of these, and overlaid by upwards of twenty feet of marl, limestone, and building stone, the beds being arranged in the following descending order.

	Ft.	In.
1. Superficial covering of brown, stiff, argillaceous, marly earth	5 to 6	0
2. Crumbling and incoherent, calcareous marls, with broken vegetable remains and shells, &c.	5 to 7	0
3. Fissile, fetid marlstone, splitting into thin slabs, containing many impressions of leaves and stems of plants in the laminæ of division, a few flattened shells of Planorbes, and a small Limnea	2	0
4. Thin wayboard of dark-coloured marl	0	2
5. Strong bed of cream-coloured, fine-grained, hard and fetid limestone of dull fracture, earthy texture, high specific gravity, with here and there a minute scale of mica, and an occasional transverse vein of carbonate of lime. Fishes are sometimes found in the lines of separation	4	0
6. Very finely laminated, white marlstone, the surface spotted over with innumerable, blackish stems of plants and carbonized vegetables. Insects abundant in the finest and most paper-like laminæ. Fishes, crustacea (Cypris) and shells (Planorbis) also occur in these thin layers	1	2
7 Darker coloured, thin layer of marlstone, in which was found this year (1829) a magnificent specimen of a *fossil tortoise*, probably the largest ever seen. It is about three feet in length. Three of the pats, the head, the neck, and tail, being well preserved and adherent to the body†	0	4
	20	8

* In the time of Karg the quarries were much larger than at present.

† This splendid fossil tortoise may possibly still find its way into an English museum: in the mean time I would remark that the only existing species that has reminded me of the fossil, is a large *Testudo Indica* which I recently saw in the museum at Leyden.—Jan. 1831.

	Ft.	In.
Brought forward....	20	8
8. Thin band of highly fetid, finely laminated, whitish grey marlstone. This bed contained the *fossil fox*. The fissile nature of this stone has occasioned it to split into two slabs with such uneven surfaces, that characteristic portions of the bones or impressions of them are seen in each. The slab containing the more perfect portion of the animal has been selected by Mr. Mantell for his operations of clearing away the surrounding rock. It is worthy of remark, that the fox and the great tortoise present themselves in their fossil state in such an undisturbed position, that we may suppose them to have scarcely moved after they sunk down amidst the fine silt and mud of the ancient lake, with which their bones have since become partially mineralized. In this layer also occur other organic remains, among which are fishes of great size, one of which in a very perfect state had just been found previous to my first visit, and resembled a large pike	0	5
9. Two or three fine layers of marlstone, differing very little from Nos. 7. and 8. and containing leaves..	0	10
10. Great building stone of granular texture; it resembles somewhat No. 4. but is harder, and is considered the best building stone of the quarry. In its less adherent parts shells of *Anodonta Lavateri* are disseminated, with their "nacre" well preserved; and fishes are also found between the laminæ of division	4	6
11. Finely laminated, white, slaty marlstones, resembling Nos. 7. 8. and 9. in slabs of three to six inches each, and containing fishes, plants, Anodonta, &c..	2	0
	28	5

Here the work was stopped by water, in the autumns of 1828 and 1829, owing to the wetness of those seasons; but in dry weather several inferior, slaty layers are to be seen, and beneath them the micaceous sandstone or molasse.

The adjoining quarry, which is to the north-west of the preceding, consists of beds of rather a more arenaceous texture, and of a darker colour than those just described. These beds contain plants and fishes, and a great number of *Anodonta Lavateri*, but none of the insects which characterize the more finely laminated layers of the middle and lower beds.

All the strata are nearly horizontal, having only a very slight inclination of two or three degrees to the south; and hence it may be inferred, that the upper beds, which are about one mile from the river, were originally continuous over those of the lower quarries, which are about half a mile distant, and nearer to the Rhine*. This conclusion is further borne out by the differences of mineral character, and by the absence in the lower quarry of many of those organic remains which characterize the upper.

Several distinguished naturalists have examined and described the organic remains which I collected; and to their observations I beg to add a short synopsis of some other Œningen fossils which have come under my notice, and which are now scattered through the principal museums of Europe, in the hope that such a list, however imperfect, may stimulate other inquirers to complete the identification of a vast number of objects which are yet undescribed, or which in former times have been inaccurately named. To commence, however, with the carnivorous quadruped. The following account of it is given by Mr. Mantell in a letter to myself†.

"In compliance with your request, I beg to offer a few remarks on the osteological characters of the extraordinary fossil discovered by you in the Œningen limestone; a fossil which far surpasses in interest any of the wonderful remains which had been found in that deposit.

"When you first submitted this matchless specimen to my chisel, you expressed your conviction that it would prove to be a species of fox; and as I proceeded in the interesting task of removing the stone from the skeleton, I found myself warranted in agreeing with you in that opinion. When the specimen was entirely exposed, I procured a recent fox, and dissected the skull, extremities, &c., and upon comparing them with the fossil could detect no essential difference. Through the kindness of Mr. Clift I have since been able to examine the skeletons of several varieties and species of the genus Vulpes in the museum of the College of Surgeons; namely, five or six individuals of the *Vulpes communis;* the black fox, the cross fox, and the Isatis, or white fox. The skull of the last-mentioned species is more obtuse than that of the fossil; but the skulls of the common fox and its varieties do not differ more from the fossil than from each other; in fact there was not a greater difference observable than between the skulls and teeth of individuals of the recent animal, of various ages and countries. In making this observation I would, however, particularly remark, that the skull of the fossil is unfortunately so much broken and defaced, that the true form of the frontal bone, post-orbital apophyses, &c., cannot be correctly determined, and that these alone might be expected to afford essential, specific characters.

"In the other parts of the skeleton, the only differences I noticed were the

* See Wood-cut, p. 279. † Plates XXXIII. and XXXIV. fig. 1, 2 & 3.

following; viz. the spinous process of the *dentatus* appeared to be more expanded; the *radius* more cylindrical and elegant near its brachial extremity; and the *fibulæ* larger, and more rounded, than the corresponding parts of the skeletons of the *Vulpes communis,* which I had an opportunity of examining. I do not, however, think that these slight variations in osteological structure are alone sufficient to establish a variety, much less a species. Near the angle of the lower jaw of the fossil, there is a process of bone so like the *styloid* in form, and occupying the situation which it might be supposed to occupy, if these animals possessed such a process, that its appearance was at first very puzzling: upon minute examination I am inclined to believe that it is a spiculum of bone, displaced by the fracture and compression which the skull has sustained, and that its situation is accidental; it is, however, too remarkable an appearance to be passed by without comment.

"I very much regret that from my limited means of observation I cannot offer more satisfactory results: the remark of Baron Cuvier on the bones of the animals of this genus found in caverns, 'that they may with almost equal propriety be assumed to belong to one recent species as to another*,' will apply also to the splendid specimen before us. If the skull were perfect, more rigid conclusions might be obtained; but as this is not the case, I beg to submit that the only inferences we are warranted in deducing are the following:

"1st. That the fossil animal belonged to the genus Vulpes.

"2ndly. That it bears a closer analogy to the *V. communis* than to any other with which it has been compared.

"Lastly, that notwithstanding its resemblance to the recent, it may possibly belong to an extinct species, since specific differences cannot always be detected in the skeleton."

In addition to what Mr. Mantell has said of this animal, I have to observe, that the occurrence of a portion of black-coloured matter in the place of the abdomen, immediately beneath the lumbar vertebræ, induced me, under the supposition of its being the fossil fæces of the animal, to submit a portion to the examination of Dr. Prout, who, after analysis, has pronounced it to be of the same nature as the balls of *Album Græcum,* and coprolites of Dr. Buckland. This is the first instance in which this fossil substance has been found in the body of a land quadruped, although Dr. Buckland had observed that it occurred in the abdominal regions of saurians. In this case, however, it is not the coprolite alone which contains phosphate of lime; for by other experiments of Dr. Prout it appears that the entire block of the surrounding marlstone is also impregnated with the same mineral. There seems therefore to

* *Ossemens Fossiles*, tom. iv. p. 465.

be every reason to conclude, that the bituminization of this mass of rock* is due, in a great measure, to the destruction of the large quantity of animal matter contained in it; for the coprolite itself only differs from the surrounding matrix in containing a greater proportion of phosphate of lime.

All the other mammalia hitherto found at Œningen are Rodentia; and for an account of several of them I refer to the works of Baron Cuvier †. One specimen of these, which is in the British Museum, has subsequently been figured, and named by Mr. König *Anoœma Œningensis* ‡.

Another animal of this order was brought from the quarries this year by Professor Sedgwick, which M. Laurillard of the Jardin du Roi, Paris, refers to Lagomys.

Birds.

These are considered by Blumenbach and Karg to be chiefly aquatic, and according to the former they consist principally of Grallæ. The latter author enumerates birds of other classes, as well as detached specimens of beaks and feathers §.

Reptiles.

Of these the most curious is the large aquatic Salamander, described by Cuvier, and of which there are several individuals; one of which, in admirable preservation, is in the British Museum. In the Carlsruhe Museum I observed specimens of Rana and of Testudo. Besides the splendid individual mentioned, p. 281. in the section of the quarries, the *Testudo orbicularis?* is said to have occurred ||.

Fishes.

The fishes of Œningen have not yet been fully described, although Andræa, Lavater, Knorr and Scheuchzer, published and figured many genera and species, comprehending lamprey, trout, pike, seventeen species of carp, &c. Cuvier and Blainville doubt the accuracy of many of these identifications, although they both allow they have not as yet seen a sufficient number of specimens for comparison, and the former distinctly reserves his opinions for a

* See similar conclusions as to the cause of the bituminization of the rock at Seefeld in the Tyrol containing fossil fish, in a memoir by myself read before the Geological Society, and published in the Philosophical Magazine and Annals of Philosophy, July 1829.

† *Ossemens Fossiles*, tome v. Partie 1. p. 61—64.

‡ *Icones Fossilium Sectiles*, inedited.

§ Karg's list of organic remains is not given, because many of his specifications cannot be depended upon. Of the specimens alluded to by him the greater number are now in the Carlsruhe Museum; others are in the British Museum, and a few are at Paris and Vienna.

|| Karg's Memoir.

subsequent work on Ichthyolites. Blainville, however, recognizes the *Esox lucius* * to be a true pike, but is not quite decided that it is of the common species. *Cyprinus jeses* and *C. bipunctatus* are also identified by him, but with a slight doubt †.

Insects.

These are found in abundance when the quarries are in activity, but being disregarded by the workmen are usually thrown away with the refuse: I could therefore collect only a few specimens, one of which is referred by Mr. Curtis to the family of Formicidæ, and another to the Hymenopteræ ?. Amongst the Œningen insects in the British Museum ‡, Mr. Samouelle has noticed the larvæ of two species of Libellula; Anthrax two species, Coccinella one, Cimex one, Cerambyx one, Blatta one, Nepa one. Now it is highly interesting to remark that several of these insects, such as Anthrax, Cerambyx, &c., are in living nature found upon such marshy plants as they are here associated with in a fossil state, so that we can have little difficulty in supposing that they dropped into this ancient lake from the vegetation which surrounded it. Again, the larvæ of Libellula above mentioned, exactly resemble our common English species *Libellula depressa,* which is aquatic, the perfect insect frequenting lakes and stagnant waters; whilst the Nepa is a well known inhabitant of the bottom of muddy pools.

Mr. Stokes has obligingly granted me the use of some nearly perfect insects from Œningen, three of which have been kindly drawn for me by Mr. Swainson, and described by Mr. Curtis in these words:

"Plate XXXIV. fig. 4. A young larva of an Œshna (Libellula Linn.) perhaps *Œ. grandis.*
———— fig. 5. The underside of a pupa of the same insect, showing the curious mask, the insertion of the legs, and the spiraculæ.
———— fig. 6. An Agrion, perhaps *A. sanguineum.* The stigmata of the wings not being visible is what might be expected, because even in recent specimens, soon after their exclusion from the chrysalis, those parts are of so pale a colour as not to be apparent, and must consequently be injected by fluid to colour them, which by pressure or absorption would disappear from the stigmata as well as the nervures."

In examining these bodies the entomologist can neither assert nor deny the identity of the greater number of them with existing species §. We may safely state, however, that although they are very unlike those of the gypseous ter-

* See Knorr, *t.* 1. *tab.* 26. and Scheuchzer, *Pisc. Quer. tab.* 1.

† In the British Museum there are many fine specimens of Œningen fishes yet undescribed.

‡ Ammann and Lavater's original collections.

§ It is very much to be desired that some able entomologist may soon examine the splendid collection of these insects, now placed in the grand Ducal Museum at Carlsruhe.

tiary formation of Aix in Provence*, yet both there and at Œningen the forms and generic characters of the fossils, with few exceptions, accord with those of the insects now living in each district.

Crustacea.

A species resembling *Cancer fluviatilis* (Potamophilus of Latreille), is cited by M. Brongniart†; and crabs are figured by Karg from the Lavater and Gessner collections. Other specimens of Crustacea are to be seen in the museum at Carlsruhe. Cypris resembling *C. faba*, occurs abundantly, as has been noticed in the sections of the quarries.

Conchifera.

Anodonta Lavateri‡ is the only bivalve which I have observed; but it is very abundant.

Mollusca.

Limnea resembling *L. ovum*§; and a very small, much flattened, Planorbis of a species not yet determined||.

Plants.

A very long catalogue is to be seen in Karg's memoir, wherein he mentions many species of modern European forest trees, shrubs, flowers, ferns, &c., for some of which he refers to the figures in Scheuchzer and Knorr. M. Gmelin, Professor of Botany at Carlsruhe, has also assured me that many of the fossil vegetables of Œningen in the museum of that place were not distinguishable from existing species¶. If these identifications have been pushed too far, the specimens in this country, which have been closely examined by eminent botanists, prove that most of the Œningen leaves in the British Museum belong to dicotyledonous plants, and that they all have a modern character. A pentapetalous flower in this collection has been recently figured by Mr. König, and named by him *Viburnum Œningense***.

Mr. R. Brown has discovered that among these plants, one is almost undis-

* Described by Mr. Curtis in a Memoir by Mr. Lyell and myself; Edinb. Phil. Journal. No. XIV. p. 287—298. See also by M. Marcel de Serres.

† Cuvier and Brongniart, *Env. de Paris*, p. 309. ‡ Ibid. § Ibid.

|| *Patella* (*Ancylus*) *lacustris?* and other shells are cited by Karg.

¶ Amongst these he enumerates *Populus tremula*, *Betula Alnus*, *Salix caprea*, *S. alba*, *S. viminalis*, *S. Helix* (*purpurea*), *Acer pseudo-platanus*, *Fraxinus excelsior*, *Sparganium erectum*, *Potamogeton natans*, *P. pusillum*, Confervæ, &c.

** *Icones Fossilium Sectiles*, ined.

tinguishable in the leaf, from the *Acer villosum,* a species of maple brought from Nepaul by Dr. Wallich.

The specimens which I collected have been referred to Mr. Lindley, who has favoured me with the following report. "I have again examined your Œningen fossil vegetables, but with as little success as before. That some of the leaves may have belonged to plants still existing is highly probable; but the evidence about many of them is not perfect enough to enable a botanist to speak positively. I retain the opinion which I expressed to you last year, that one of them is the lateral pinna of *Fraxinus rotundifolia;* and I see no reason to change my belief that the lobed ones have belonged to some kind or kinds of Acer. If they all belonged to one kind, it must have been a species more variable in the foliage than any at present existing; but it is possible that two kinds may have been intermixed. Some of the impressions, particularly a beautifully perfect one, are not to be distinguished by comparison from the young leaves of *Acer opulifolium,* a species still existing in Dauphiny and Piedmont; others are extremely like *Acer pseudo-platanus* (the common Sycamore), but I cannot assert that they are the same; indeed I incline more to consider them different. The fact is, that these forest trees vary so much in the outline of their leaves, that it frequently is difficult to determine them even from *fresh* specimens.

"Among the fossils is however one in so good a state of preservation, that I am able to say with confidence that it is not of any species at present native of Europe, and I think unknown elsewhere. It is a large cordate roundish leaf with the remains of a petiole, a coarsely toothed margin, and a distinct impression of two elevated glands, at the point where the leaf joins the petiole. Now there are no European trees in which these glands exist, that need be compared with the fossil, except the poplar tribe; and there is no known poplar which bears leaves that do not essentially differ in character from this: I have therefore named it *Populus cordifolia. Populus nigra,* and all its varieties, have smaller leaves, which are truncate, never deeply cordate at the base, and their glands are both smaller and differently formed. *Populus canescens,* in which the leaves are cordate in an equal degree, and as large, has no glands, and its outline is more ovate. *Populus græca* has leaves with two glands placed as in the fossil, but the leaves are much less cordate, and without toothing at the margin.

"Upon the whole I should say the fossils may be considered to consist of one or two species of Acer, possibly referable to existing European species, but probably extinct;—A plant that is not distinguishable from *Fraxinus rotundifolia;*—An extinct species of Poplar; and some other plants bearing a great general resemblance to the leaves of existing trees, but not in such a state as to be satisfactorily identified."

In addition to these observations I may remark, that the greater number of the leaves of forest trees have their petioles still adherent, as if they had fallen off spontaneously, and in their due season.

In conclusion it may be observed,

1st. From the nature of its organic remains, that the deposit of Œningen is of unmixed lacustrine origin; and, from the fine lamination and structure of the beds, that they could only have been formed during a long period of time.

2nd. This deposit of marl rock having taken place in a basin of the molasse, that formation must have been deeply excavated prior to the existence of the lake in which the marly strata were accumulated.

3rd. From the intermixture of species undistinguishable from those now existing, with others decidedly extinct, this deposit may be considered an important link in the history of the earth's structure, indicating an intimate connection between the ancient state of nature and that which now prevails.

4th. The deposit differs essentially in its organic remains from any other freshwater formation at a distance from it with which we have hitherto been made acquainted, either in France, or in the adjacent regions of Germany*; thus satisfactorily affording proof of the independence and isolation of these lake formations, amongst which, this of Œningen, both from its contents and superposition to the molasse, must be considered one of the most recent.

5th. Yet recent as must have been the epoch of this formation, the basin in which it was deposited has subsequently been re-excavated to a considerable depth; the proof of which is, that horizontal beds still present escarpments several hundred feet above the Rhine, without any barrier between them and that river.

Lastly. However long the epoch of this accumulation must have preceded the period when the Rhine attained its present level, we are taught by

* The freshwater limestone of Ulm is deposited in Jura limestone, and contains the *Helix morognesi*, the *Limnea ovata*, and other shells, which peculiarly characterize the lacustrine formations of the Limagne d'Auvergne, and a striated Planorbis, like that of the Isle of Wight.

At Steinheim near Heidenheim the freshwater strata are also deposited on Jura limestone, and contain the *Limnea ventricosa* (Brongn.) of the Paris basin, and a shell (*Paludina variabilis* of Bronn) which M. Deshayes refers to "Ampullacère," a genus of New Holland, &c.

At Bouxweiller near Strasbourg, the lacustrine limestone rests upon a rock of about the age of the great oolite of England, and some of its fossils are identical with those of the freshwater formations of the Isle of Wight. These and several other analogous formations in Swabia, &c. were visited by Professor Sedgwick and myself, on our return from the Austrian Alps, in the autumn of 1829.

the organic remains, that even in those early days, though some few species were distinct from any now known, the meadows teemed with plants of a very modern type—that the lakes were filled with fishes, and their banks covered with insects, differing little or not at all from existing species—whilst the forests contained birds and beasts, from among which the carnivorous quadruped here described has been perfectly preserved in its stony envelope, and is scarcely distinguishable from the common fox now inhabiting our latitudes.

XVI.—*Anatomical Description of the Fox.*

By GIDEON MANTELL, Esq., F.G.S., F.R.S., F.L.S.

THE skeleton is attached to the stone by its dextral aspect; the head and neck are slightly extended; the tail is rather elevated; and the left fore-leg is placed immediately in front of the right. Although in the drawing a general outline of the skull appears, yet this must not be assumed as exhibiting the true form of the original, since the *frontal bone*, the *zygomatic apophyses*, &c., are too much broken to afford any decisive characters; and the skull being irregularly separated vertically, some parts are attached to the slab of stone here represented, while others are imbedded in the corresponding portion; the external surface of the skull and jaws is therefore seen but in few places.

Fig. 1. represents the specimen diminished one half.

Fig. 2. the skull (seen as in fig. 1.) of the natural size.

Fig. 3. the corresponding portion of the skull attached to the other slab of limestone.—As the latter contained no other essential parts of the skeleton, it was not considered necessary to represent the whole.

Head.—The skull appears to be too deep in proportion to its length, as compared with that of a fox: but this is owing to the displacement of the lower jaw, the right ramus of which (B) is thrown above the left (A).

Jaws.—A. The left lower jaw; the fractured surface only appears; traces of the alveoli of some of the molares are seen at * * *: at A. (fig. 3.) the corresponding part of this bone with the teeth is represented.

B. The inner surface of the right lower jaw, with the molares; some of the teeth are broken and displaced; the canine tooth of this jaw is seen (*b*) passing under the corresponding tooth of the right upper jaw (b'').

C. The fractured inner surface of the right upper jaw; portions of the molares (*g. g.*) and a perfect canine tooth (b'') remain.

D. (fig. 3.) The fractured surface of the left upper jaw, with the canine tooth (*b*).

Teeth.—From many of the teeth having suffered fracture and displacement, it is scarcely possible to point out the entire series in the drawing; but on a careful comparison of the fossil with the skull of a recent adult fox, there appeared no doubt that the dentature of both was the same; viz. incisors $\frac{6}{6}$, canine $\frac{1-1}{1-1}$, molar $\frac{6-6}{7-7}$. Total 42.

In the lower jaw (A. fig. 3.) the following teeth are seen.

a. one of the incisors.

b. canine tooth.

c. d. e. f. four tearing grinders (*fausses molaires*).

g. chewing grinder (*fausse carnassière*).

h. i. two bruising grinders (*fausses tuberculeuses*).

The spicula of bone near the lower jaw, previously mentioned, is shown at *k*.

Vertebræ.—As in the fox, there are seven cervical (E. E.), thirteen dorsal (F. F.), seven lumbar (G. G.), three sacral (H H H), and nineteen or twenty caudal vertebræ (K. K.). The spinous process of the *dentatus* (L) seems to be rather larger than in the fox, but this appearance may perhaps arise from compression.

Ribs.—Almost all the ribs are seen, although in some instances they are displaced, and lie in confusion; those of the left side are marked (M. M.), those of the right (N. N.).

Sternum.—The greater part of the sternum remains (O. O. O.).

Scapulæ.—P. the left, and Q. the right scapula. The head of the left scapula is seen at (*m.*), the body of the same (*n.*) is displaced and lies above the dorsal vertebræ. The right scapula is not broken, and extends under the vertebræ and displaced portion of the left.

Humerus.—R. the left, and S. the right humerus; the heads of the bones lie in contact with the glenoid cavity of the scapulæ.

Ulna.—T. the left, and V. the right ulna.

Radius.—U. the left, and W. the right radius. It has already been mentioned that the head of this bone appeared to be more cylindrical, and the shaft more rounded, than in the common fox with which it was compared. In conjunction with other osteological differences this might have been important.

Pelvis.—X. The pelvis is unfortunately in a very mutilated and indistinct state: the ischium is seen at (*o*).

Femur.—Y. the left, and Z. the right femur.

Patella.—&. Probably one of the patellæ.

Tibia.—A''·· The left, and B''·· the right tibia.

Fibula.—C''·· The left, and D''·· the right fibula.

Carpus.—The bones of the left carpus are seen at E''··, those of the right at F''··; the phalanges are marked 1. 2. 3, the ungueal 4.

Tarsus.—G''. The left os calcis or calcaneum, and H''. the right.

I''. The right astragalus, and K''. the left.

L''. Other bones of the tarsus.

The phalanges are numbered like those of the carpus. Several of the sesamoid bones remain; two are seen almost *in situ* at 5. 5.

XVII.—*On the Astronomical Causes which may influence Geological Phænomena.*

BY J. F. W. HERSCHEL, ESQ. M.A. F.G.S. F.R.S. L. & E.
CORRESPONDENT OF THE ROYAL ACADEMY OF SCIENCE OF PARIS, &c. &c.

[Read December 15, 1830.]

ALTHOUGH the more immediate object of geologists in the actual state of their science is rather the collection of facts, and such an induction of conclusions from them as shall be, so far as possible, independent of theory; yet when theory confines itself to pointing out the influence of causes which we know to exist, in modifying the general condition of our globe, and enables us to estimate the extent of their action, it may be regarded as rendering a real service to science. It thus tends in some degree to diminish the complexity of the problems to be resolved, or at least to reduce them to their true difficulty, by showing what portion of them can and what cannot be accounted for on known principles, thereby narrowing the field of research, and directing the efforts of future speculators to the discovery of causes of another description.

This consideration has induced me, not without some degree of hesitation, to offer to this Society, though in a very crude and imperfect state, some views which have occurred to me of a possible explanation of a portion, at least, of that great geological phænomenon,—the difference between the actual climates now prevailing over extensive regions of the earth's surface, and perhaps over its whole extent, and those which the organic remains discovered in its strata lead us to conclude have formerly subsisted during very long periods of time. The ingenious attempts which have been lately made to account for this remarkable fact, while they show the sense of geologists of the importance of the subject, seem to indicate an impression that it is one on which we need not despair of coming to just conclusions, and that in consequence no inquiry will be considered as irrelevant which has for its object to bring into view the action of causes which demonstrably must have an influence, and respecting which the only question is its amount.

Impressed with the magnificence of that view of geological revolutions which regards them rather as regular and necessary effects of great and general causes, than as resulting from a series of convulsions and catastrophes regulated by no laws and reducible to no fixed principles, the mind naturally turns to those immense periods with whose existence in the planetary system the astronomer is familiar; at first attracted by the analogy offered by a duration commensurate to those lapses of time which geology contemplates, and afterwards with a hope of discovering something in the fluctuations to which the orbit of our own planet is liable, which may tender a reason for at least some of the events in its geological history.

The sun and moon are the only bodies in our system whose influence can at all directly affect the condition of our globe: *both* by their effect in causing tides—the *former* by its heat. The tide produced by any luminary is, as is well known, inversely as the cube of its distance. Hence it is evident that any considerable approach of the moon to the earth would greatly increase the tides. If, for instance, the mean distance of the moon were diminished by only one tenth of its actual amount, the mean rise and fall of the tides would be increased by a full third of their present quantity, which would of course produce a great increase in their erosive action on the continents, as well as in the transporting power of the waters of the ocean over the materials of the land.

The mean distance of the moon is actually on the decrease, and has been so from the earliest ages, producing the astronomical phænomenon known by the name of the "*acceleration of the moon's mean motion.*" But this decrease, which takes place with extreme slowness, has been demonstrated by Laplace to be incapable of going to any such extent as that above spoken of, and, after a period of enormous length, will be again converted into an increase, which, in like manner, will never be so great as to make any considerable change in the relations now contemplated.

The excentricity of the lunar orbit is also liable to fluctuation; and it is far from proved that, if we extend our views backwards for many millions of years, it may not formerly have been materially greater than at present, in consequence of some extensive periodical inequality, or the accumulation of many such. Now should this ever have been the case, the tides in the perigee of the moon would of course have experienced a corresponding increase. But there is no reason to believe that any possible approximation of the moon to the earth, arising from increased excentricity in her orbit, should have brought her to within two thirds of her actual perigean distance; in which supposition (purposely assumed as an extravagant one) the lunar tide would still have had less than $3\frac{1}{2}$ times its present magnitude; one which no doubt would suffice, if at once attained, to cause great local devastations in estuaries and confined channels, but which would not account for any great diluvial phænomena, especially when it is considered that, the change taking place gradually, they would become modified in their form by insensible gradations, and thus accommodated to the altered circumstances; a remark which may be extended to the general outlines of coasts, which would be no doubt in some degree altered. It does not appear, therefore, that any admissible extent of perturbation produced by the sun's action on the lunar orbit can have materially influenced the geological state of the earth.

Let us next consider the changes arising in the orbit of the earth itself about the sun, from the disturbing action of the planets. In so doing it will be obviously unnecessary to consider the effect produced on the solar tides, to which the above reasoning applies much more forcibly than in the case of the lunar. It is therefore only the variations in the supply of light and heat received from the sun that we have now to consider.

Geometers having demonstrated the absolute invariability of the *mean* distance of the earth from the sun, it would seem to follow that the mean annual supply of light and heat derived from that luminary would be alike invariable: but a closer consideration of the subject will show that this would not be a legitimate conclusion; but that, on the contrary, the *mean* amount of solar radiation is dependent on the excentricity of the orbit, and therefore liable to variation. Without going at present into any geometrical investigations, it will be sufficient for the purpose here to state it as a theorem, of which any one may easily satisfy himself by no very abstruse geometrical reasoning, that "*the excentricity of the orbit varying, the* total *quantity of heat received by the earth from the sun in one revolution, is inversely proportional to the* minor *axis of the orbit.*" Now since the major axis is, as above observed, invariable, and therefore, of course, the absolute length of the year, it will follow that, the *mean annual* average of heat will also be in the same inverse ratio of the *minor* axis; and thus we see that the very circumstance which, on a cursory view, we should have regarded as demonstrative of the constancy of our supply of solar heat, forms an essential link in the chain of strict reasoning by which its variability is proved.

The excentricity of the earth's orbit is actually diminishing, and has been so for ages beyond the records of history. In consequence the ellipse is in a state of approach to a circle; and its minor axis being therefore on the increase, the annual average of solar radiation is actually on the *decrease.*

So far this is in accordance with the testimony of geological evidence, which indicates a general refrigeration of climate; but when we come to consider the amount of diminution which the excentricity must be supposed to have undergone, to render an account of the variation which has taken place, we have to consider that, in the first place, a great diminution of the excentricity is required to produce any sensible increase of the minor axis. This is a purely geometrical conclusion, and is best shown by the following table.

Excentricity.	Minor axis.	Reciprocal, or Ratio of Heat received.
0.00	1.000	1.000
0.05	0.999	1.002
0.10	0.995	1.005
0.15	0.989	1.011
0.20	0.980	1.021
0.25	0.968	1.032
0.30	0.954	1.048

By this it appears that a variation of the excentricity of the orbit, from the circular form to that of an ellipse having an excentricity of one fourth of the major axis, would produce only a variation of 3 per cent. on the *mean* annual amount of solar radiation ; and this variation takes in the whole range of the planetary excentricities, from that of Pallas and Juno downwards.

I am not aware that the limit of increase of the excentricity of the earth's orbit has ever been determined. That it has a limit has been satisfactorily proved ; but the celebrated theorem of Laplace, which is usually cited as demonstrating that none of the planetary orbits can ever deviate materially from the circular form*, leads to no such conclusion, except in the case of the great preponderant planets Jupiter and Saturn ; while, for anything that theorem proves to the contrary, the orbit of the earth may become elliptic to any amount.

In the absence of calculations which, though practicable, have, I believe, never been made, and would be no slight undertaking, we may assume that excentricities which exist in the orbits of planets both interior and exterior to that of the earth, may *possibly* have been attained, and may be attained again, by that of the earth itself. It is clear that, such excentricities *existing*, they cannot be incompatible with the stability of the system generally ; and that therefore the question of the possibility of such an amount in the particular case of the earth's orbit, will depend on the particular data belonging to that case, and can only be determined by executing the calculations alluded to, having regard to the simultaneous effects of at least the four most influential planets Venus, Mars, Jupiter, and Saturn, *not only on the orbit of the earth, but on those of each other*. The principles of this calcula-

* *Mécanique Céléste*, Book II. No. 57.—Equation (u).

tion are detailed in the article of Laplace's work cited. But before entering on a work of so much labour, it is quite necessary to inquire what prospect of advantage there is to induce any one to undertake it.

Now it certainly at first sight seems clear, that a variation of 3 per cent. only, in the mean annual amount of solar radiation, and that arising from an extreme supposition, does *not* hold out such a prospect. Yet it might be argued, that the effect of the sun's heat is to maintain the temperature of the earth's surface at its actual mean height, not above the zero of Fahrenheit's or any other thermometer, but above the temperature of the celestial spaces out of the reach of the sun's influence; and what that temperature is, may be a matter of much discussion. M. Fourrier has considered it as demonstrated that it is not greatly inferior to that of the polar regions of our own globe; but the grounds of this decision appear to me open to considerable objection*. If those regions be really void of matter, their temperature can only arise, according to M. Fourrier's own view of the subject, from the radiation of the stars. It ought therefore to be as much inferior to that due to solar radiation, as the light of a starlight night is to that of the brightest noon day; in other words, it should be very nearly a total privation of heat†,—almost the *absolute zero*, respecting which so much difference of opinion exists; some placing it at 1000, some at 5000 degrees of Fahrenheit below the freezing point, and some still lower, in which case a single unit per cent. in the mean annual amount of radiation would suffice to produce a change of climate fully commensurate to the demands of geologists.

Without attempting, however, to enter further into the perplexing difficulties in which this point is involved, which are far greater than appear on a cursory view, let us next consider, not the *mean* but the *extreme* effects which a variation in the excentricity of the earth's orbit may be expected to produce in the summer and winter climates in particular regions of its surface, and under the influence of circumstances favouring a difference of effect. And here, if I mistake not, it will appear, that an amount of variation, which we need not hesitate to admit (at least provisionally) as a possible one, may be productive of considerable diversity of climate, and may operate during

* *Mém. de l'Acad. Royale des Sciences*, 1827, tom. vii. p. 598.

† The proportion of the light of the sun to that of the moon has been estimated by Bouguer as 300,000 to 1. If we regard the illumination of full moonlight as only 100 times greater than that of a bright starlight night, which is a very moderate supposition, we shall have a ratio of 30,000,000 to 1 for the illuminating power of the sun compared to that of all the stars in our hemisphere, and consequently 15,000,000 to 1 for the ratio of the heating effect of the sun to that of all the stars in both hemispheres.

great periods of time either to mitigate or to exaggerate the difference of winter and summer temperatures, so as to produce alternately in the same latitude of either hemisphere a perpetual spring, or the extreme vicissitudes of a burning summer and a rigorous winter.

To show this, let us take at once the extreme case of an orbit as excentric as that of Juno or Pallas, in which the greatest and least distances of the sun are to each other as 5 to 3, and consequently the radiations at those distances as 25 to 9, or very nearly as 3 to 1. To conceive what would be the *extreme* effects of this great variation of the heat received at different periods of the year, let us first imagine in our latitude, the place of the perigee of the sun to coincide with the summer solstice. In that case the difference between the summer and winter temperature would be exaggerated in the same degree as if three suns were placed side by side in the heavens in the former season, and only one in the latter, which would produce a climate perfectly intolerable. On the other hand, were the perigee situated in the winter solstice, our three suns would combine to warm us in the winter, and would afford such an excess of winter radiation as would probably more than counteract the effect of short days and oblique sunshine, and throw the summer season into the winter months.

The actual diminution of the excentricity is so slow, that the transition from a state of the orbit, such as we have assumed, to the present nearly circular figure, would occupy upwards of 600,000 years, supposing it uniformly changeable;—this of course would not be the case: when near the maximum, however, it would vary slower still, so that at that point, it is evident, a period of 10,000 years would elapse without any perceptible change in the state of the data of the case we are considering.

Now this, adopting the very ingenious idea of Mr. Lyell*, would suffice, by reason of the combined effect of the precession of the equinoxes and the motion of the apsides of the orbit itself, to transfer the perigee from the sum-

* Principles of Geology, p. 110.—Mr. Lyell, however, in stating the actual excess of eight days in the duration of the sun's presence in the northern hemisphere over that in the southern, as productive of an excess of light and heat annually received by the one over the other hemisphere, appears to have misconceived the effect of elliptic motion in the passage here cited; since it is demonstrable that, whatever be the ellipticity of the earth's orbit, the two hemispheres must receive equal absolute quantities of light and heat per annum, the proximity of the sun in perigee exactly compensating the effect of its swifter motion. This follows from a very simple theorem, which may be thus stated: "The amount of heat received by the earth from the sun while describing any part of its orbit, is proportional to the angle described round the sun's centre." So that if the orbit be divided into two portions by a line drawn *in any direction* through the sun's centre, the heats received in describing the two unequal segments of the ellipse so produced will be equal.

mer to the winter solstice, and thus to produce a transition from the one to the other species of climate, in a period sufficiently great to give room for a material change in the botanical character of a country.

The supposition above made is an extreme, but it is not demonstrated to be an impossible one; and should even an approach to such a state of things be possible, the same consequences, in a mitigated degree, would follow. But if on executing the calculations it should appear that the limits of the excentricity of the earth's orbit are really narrow; and if, on a full discussion of the very difficult and delicate point of the actual effect of solar radiation, it should appear that the mean as well as extreme temperature of our climates would *not* be materially affected,—it will be at least satisfactory to *know* that the causes of the phænomena in question are to be sought elsewhere than in the relations of our planet to the system to which it belongs; since there does not appear to exist any other conceivable connection between those relations and the facts of geology than those we have enumerated, the obliquity of the ecliptic being, as we know, confined within too narrow limits for its variation to have any sensible influence.

J. F. W. Herschel.

XVIII.—*A Sketch of the Structure of the Eastern Alps; with Sections through the Newer Formations on the Northern Flanks of the Chain, and through the Tertiary Deposits of Styria, &c. &c.*

By the Rev. ADAM SEDGWICK, Pres. Geol. Soc. F.R.S. &c.
(Woodwardian Professor in the University of Cambridge.)
And RODERICK IMPEY MURCHISON, Esq. Sec. G.S. F.R.S. F.L.S. &c.

[Read Nov. 6, 20; Dec. 4, 1829: and March 5, 1830.]

With Supplementary Observations, Sections, and a Map.

By Roderick Impey Murchison, Esq. Sec. G.S. F.R.S. F.L.S. &c.

[Read Jan. 19, and Feb. 2, 1831.]

Preface.

THE following Memoir contains a series of papers, presented by the authors after their visit to the Austrian and Bavarian Alps in 1829, which would have been already published, but for an unavoidable delay in printing the present Part of the Transactions. The abstracts of these papers no sooner appeared than they were combated, both in British and foreign journals, by Dr. Boué, who, in his system, placed in the lower green-sand what the authors regarded as a connecting link between the great secondary and tertiary deposits. As, however, in confirmation of his own views, he cited phenomena they had not seen, it was important that at least one of them should visit the places referred to; and it also became necessary to describe in greater detail the formations they had considered of the age of the green-sand and chalk, and to prove them inferior to those peculiar deposits which they regarded as intermediate between the chalk and the well-known tertiary groups.

For this purpose Mr. Murchison, during the summer of 1830, again visited the Eastern Alps, and communicated the result of his observations in a memoir, of which an abstract has been recently published in the Proceedings of the Society.

During the progress of the present Part of the Transactions, it became a question with the Council in what order the papers on the Alps should be printed; and it was resolved that they should, if possible, appear in one memoir, arranged in such a way as to show the relations of their several subdivisions to each other. Published in this manner, it was supposed that they would be more instructive: and it seemed anomalous, that in the same Part of the Transactions there should be two sets of communications—one intended to explain or correct the other.

Agreeably to this resolution, the authors were directed to rearrange the materials before them, and to place them, as far as they are able, in a natural order. For this purpose they, in the first place, give such a sketch of the structure of the Eastern Alps as may, they hope, convey a general notion of the distribution of the great mineral masses of the chain, and show the nature of the difficulties they endeavour to clear up in their detailed sections. They then describe a succession of such sections, commencing with the secondary and tertiary systems at the head of the Lake of Constance; and proceeding towards the east along the northern skirts of the chain, they notice, in order, the deposits in the valley of Sonthofen; the junction of the secondary and tertiary systems at Nesselwang; the section along the banks of the Traun, from the mountains above Arzt to the plains of Bavaria below Traunstein; and the sections through the iron-works of Kressenberg, and through the secondary and tertiary groups north of the Untersberg. Taking the relations of the successive groups on the outskirts of the chain as a clew to explain still more difficult phenomena, they then give detailed sections of the overlying deposits of Gosau, Zlam, Windischgarsten, Grünbach, and Wand. Having by this general comparison endeavoured to vindicate the justness of their former conclusions respecting the age of the overlying deposits of Gosau, &c.; they proceed to describe the insulated basin of Häring, some deposits of lignite on the flank of the Bavarian Alps, and some horizontal cretaceous and tertiary deposits at Ortenburg, near the junction of the Danube and the Inn. The tertiary formations of Styria are then described and compared with the newer formations of the Vienna basin: and, finally, the general results, derived from a consideration of all the facts detailed, are exhibited in a short summary.

The largest portion of these descriptions is derived from the observations of Mr. Murchison; and the details respecting the valley of Sonthofen, the section along the banks of the Traun, and the account of the deposits at Zlam, Windischgarsten, Grünbach, Wand, and Ortenburg, are exclusively his own. Both the authors are, however, to be held responsible for the opinions advanced in this memoir, as they entertain the same general views on the structure of the Eastern Alps, and have together reconsidered the evidence on which the several conclusions are founded.—A. S.

Chap. I.

On the general Structure of the Eastern Alps.

Having, in a paper already published, explained our views respecting the general structure of the Eastern Alps, we shall here avoid all details, excepting such as are necessary to make our local descriptions understood, and to supply the deficiencies in some portions of our former transverse sections*. We stated—that the chain, when considered only in a general point of view, was of very simple structure, having an axis of primary or transition rocks, chiefly of slaty texture, flanked and surmounted to the north and the south by two great secondary calcareous zones, which are in their turn surmounted by tertiary sandstones, conglomerates, and clays, descending on one side into high plains of the Upper Danube, and on the other into the Subalpine plains of Italy—that the primary and secondary portions of the chain gradually diminish in elevation in their range towards the east—and finally, that they seem to pass under the recent deposits of the Vienna basin and of Lower Styria†.

The moment, however, we enter on a detailed examination of any portion of this great chain, the apparent simplicity of its structure vanishes; for it has undergone movements of elevation at several successive epochs, probably from some of the oldest down to the newest geological periods. By these movements the relative position of all its subordinate parts has been greatly deranged: the northern and southern calcareous zones are in many places completely rent asunder; and their component groups of strata are not merely thrown into most violent contortions, but are placed in such positions that it is impossible to determine their relative age by any single section. In proof of this we need only state, that in many places on the northern flank of the Alps, the newest secondary deposits, generally considered of the age of the green-sand, are broken off by enormous faults, from the calcareous zone, under which they *appear* to dip towards the centre of the chain; and that, deceived by this appearance, a geologist of great experience was induced, only a few years since, to place the older Alpine limestone on the same parallel with the chalk.

To the east of that part of the valley of the Inn which traverses the great secondary zone, the derangements are, however, we believe, in no instance so great as to produce an entire inversion of the calcareous groups: the transition rocks and red sandstone on the flanks of the central axis are uniformly surmounted by the oldest portion of the system of Alpine limestone; and the

* See Phil. Mag. and Annals of Philosophy, N. S. vol. viii. August 1830.

† See Plate XXXVI. fig. 1.

secondary rocks on the outskirts of the chain, however anomalous their dip or position, belong in general to the newest part of the series. But when we pass to the west side of the great chasm through which the Inn escapes into the plains at the northern base of the Alps, the dislocations become much more complex; and there are, if we mistake not, two distinct axes of elevation ranging nearly parallel to each other; one through the old central line of the Alps, the other through the centre of the northern calcareous zone. The effect produced by the second axis is such, that some of the higher secondary calcareous groups are carried, with an inverted dip, right against the old rocks of the central chain, and *appear* to pass under them. This extraordinary derangement of the strata passes through the dolomitic peaks of the Rhetian Alps at Mittenwald; and we have been informed, that derangements of a similar kind have been traced into the heart of Switzerland.

Notwithstanding the difficulties arising from these great derangements in the relative position of the formations, and the frequent absence of any distinct mineralogical subdivisions, the successive deposits of the great chain may, we think, be separated into a series of natural groups, admitting of at least a general comparison with the principal geological groups of England.

These natural groups, in the ascending order, are as follows. 1. Primary crystalline rocks forming the mineralogical axis of the chain. 2. Crystalline rocks with calcareous beds, in some rare instances containing traces of organic remains; the system graduating, at its upper extremity, into rocks conforming to the ordinary transition type. 3. Red marl, sandstone, and magnesian limestone, &c. &c.; with subordinate beds and masses of gypsum, and, more rarely, with rock salt. 4. Older Alpine limestone. 5. Shale limestone and sandstone, with brecciated saliferous deposits. 6. Younger Alpine limestone—The groups 4, 5, 6, are supposed to represent the lias and oolitic series. 7. Alternations of limestone, calcareous gritstone, sandstone, and marl, &c. &c., with numerous impressions of fucoid bodies, and sometimes with other fossils, apparently of the age of the green-sand or chalk. 8. All deposits superior to the chalk, comprehending several distinct tertiary groups.

In the paper above alluded to, the sixth and seventh groups were both included in the "younger Alpine limestone." But we distinctly stated, that under this name were comprehended two groups of deposits; the lower "commencing in the upper system of the oolitic series," and the upper "terminating on the outskirts of the chain, in ridges of indurated shale, sandstone, and limestone, supposed to be the equivalents of the green-sand and chalk*." We further stated, "that these outer ridges appeared to be greatly expanded

* See Phil. Mag. and Annals, N.S. vol. viii. August 1830.

towards the eastern termination of the chain;" but being unable to define their lower limits, we did not think it necessary, in our mere outline sketch, to attempt their separation from the younger Alpine limestone.

1. *Primary Rocks of the Central Axis.*

We stated that the rocks of the central axis have their culminating peaks on the eastern borders of the Tyrol, where the Grosse Glockner and the Venediger Alp rise to the respective elevations of 12,281 and 12,201 English feet above the level of the sea*; that in their range to the east, the central ridges, dividing Carinthia from the Salzburg country, diminish gradually in elevation; and that after following the direction of the Mur for a considerable distance, they finally separate into two irregular branches, one of which is prolonged into the Bacher Gebirge, and forms the south-western boundary of the Gratz basin; while the other is continued in the direction of the principal axis of the Alps, and forms the boundary between the basins of Vienna and Styria. Such a general description was sufficient for our purpose, and we added, chiefly on the authority of Von Buch's map, that the main branch, in the direction of the central axis, after disappearing under the recent deposits connected with the basin of Vienna, emerges in the neighbourhood of Presburg, and is prolonged into the mountains which range in a north-easterly direction towards the Carpathian chain.

In 1829 we had no means of ascertaining whether the old rocks of the principal axis of the Alps rose from beneath the newer deposits in any part of the basin of Vienna†; but during last summer Professor Partsch and one of the authors ascertained the existence of a nucleus of primary or transition rocks in the low ridge of Leitha Gebirge, which separates Austria from Hungary. The old rocks of this ridge form a true anticlinal axis, from which the tertiary deposits dip in opposite directions; and there can no longer be any doubt of the prolongation of the Alpine chain in the direction above indicated.

Any mineralogical details connected with the structure of the primary axis would be out of place in this introductory sketch. We may however observe, generally, that in its range towards the east, the granite or granitoid gneiss, which forms some of its higher western elevations, seems gradually to give way to mica schist and other primary slaty rocks; and that in some places on

* The published heights which we have copied and reduced are 11,775 and 11,698 Vienna feet above the level of the sea.

† We were however aware, on the authority of Von Buch's map, that the primary system did emerge near the south end of the Neusiedler See.

the northern side of the chain, the central system seems to pass gradually into the next superior group, through the intervention of argillaceous and chloritic schist, with subordinate bands of limestone*.

2. *Crystalline Rocks with Calcareous Beds, in some rare instances containing traces of Organic Remains, the system graduating at its upper extremity into Rocks conforming to the ordinary Transition type.*

We pretend not to define the inferior limits of this subdivision, nor do we assert that it can be followed throughout the chain; but it unquestionably exists, as a natural group, in the eastern Alps, as we have proved in our published paper†. The occurrence of encrinital limestone in association with mica slate and chlorite slate (near the village of Tweng, at the foot of the Tauern Alp), was a new and important fact in the history of this portion of the chain. Similar mineralogical associations, however remarkable at first sight, have been observed in the western Alps; and encrinital stems do not by themselves define the age of any rock. But we have shown that in this instance the encrinital limestone is not only interlaced with the central system of the chain, but that it is inferior to a long series of strata which every geologist has placed below the secondary system of the Alps. In short, this singular group, with the subordinate encrinital limestone, is surmounted by an immense succession of deposits, which gradually present a coarser and more mechanical texture, and at length acquire an undeviating inclination towards the north, by which they are carried under the great precipices of secondary limestone. At the upper limit of these deposits, and therefore on the confines both of the secondary and transition systems of the Alps, occur those great masses of sparry iron ore which are so extensively worked on the northern side of the central axis‡.

At Bleiberg in Carinthia, on the south side of the central axis, we also found transition rocks with organic remains precisely in the place where, theoretically, they might have been expected. In that region the metalliferous dolomites are based upon red sandstone and red gypseous marls; and the whole secondary system rests unconformably upon coarse greywacké passing

* See Phil. Mag. and Annals, N.S. vol. viii. August 1830.

† Phil. Mag. and Annals, N. S. vol. viii. p. 87—91.

‡ The sparry iron ore of the Hartz is subordinate to the slate rocks, and is we believe in some instances arranged in irregular masses round the protruding bosses of granite. This position seems to indicate an origin of the sparry iron ore connected with some of the causes which produced the protrusion of the granite.

into conglomerate and greywacké slate, with subordinate calcareous beds full of organic remains. Among the fossils collected by ourselves from this locality are the following: *Producta hemisphærica, Producta latissima,* a species resembling *Producta Martini,* and a Pecten resembling a species in the transition series of Cork; to which we may add fragments of shells of the genus Spirifer, Encrinital stems, &c. &c.

These facts demonstrate, that transition rocks with organic remains are not, as has been sometimes asserted, altogether wanting in the eastern Alps. Of this error we ourselves partook before we visited the places above mentioned. A deposit full of organic remains, ranging through the very mine-works of Carinthia, could not possibly have escaped notice; but in no memoir with which we were acquainted had these very remarkable fossils been described in such a way as to lead to any intelligible conclusion.

After what has been stated we might perhaps affirm, that many parts of the supposed primary axis are probably of the transition age, their present crystalline texture having been superinduced by some cause which, with rare exceptions, has obliterated the traces of their organic contents. In using the terms primary and secondary, we merely endeavour to conform to the language current among geologists. The two classes of rocks cannot, perhaps, in any case be precisely separated from each other: and as far as regards the central peaks of true granite, they may be of any age, and some of them are probably among the most recent mineral masses of the chain.

3. *Red Marl, Sandstone, Magnesian Limestone, &c., with subordinate beds and masses of Gypsum, and more rarely with brecciated Rock-salt and Brine Springs.*

The great calcareous zones of the Alps often present enormous, bare, mural escarpments towards the central axis, and in consequence the primary and secondary systems of the chain are separated from each other by a succession of deep longitudinal valleys. The waters collected from the central crests roll down these valleys, till they meet with a great transverse cleft or fissure (probably formed during some period of elevation), through which they escape into the comparatively low regions on the outskirts of the chain. This phenomenon is so general and striking as to force itself on the observation, and has been noticed by almost every one who has written on the structure of the Alps.

The great calcareous precipices above mentioned do not however rest immediately upon the transition rocks of the central region, but are separated from them, on both flanks of the chain, by a deposit, remarkable for its character and continuity, described by us in some detail in a former paper*. This deposit sometimes forms a single terrace, composed of red sandstone and red or variegated gypseous marls, not to be distinguished mineralogically from the new red sandstone series of this country. In other places it contains great subordinate beds of *rauchwacké* and magnesian limestone, and is extended into a succession of undulating ridges, ranging nearly parallel to the escarpment of the Alpine limestone. Excellent sections of it, in its more simple form, are seen near Bleiberg in Carinthia, and near the gorge of Werfen on the Salza; and it is finely exposed, in its more complex form, on the left bank of the Inn, from Häring to Schwatz. On the southern flank of the chain it is frequently associated, as is well known, with masses of trap and porphyry; but on the north flank, igneous rocks are, with very rare exceptions, unknown in this formation. We do not however wish to repeat our former statements, and we only allude to them here for the purpose of introducing some additional facts observed by one of the authors during his last visit to the eastern Alps.

(1.) The *rauchwacké*, or magnesian limestone, associated with the new red sandstone, is as largely developed near the eastern termination of the Alps as it is in the prolongation of the chain into the Tyrol. Highly instructive sections of this rock were seen at Söbenstein in ascending the valley of the Leytha, previous to a traverse of the primary ridge separating the basins of Lower Styria and Vienna. It is also exposed on the edges of the mountains which close in the south-western corner of the basin of Vienna, whence it runs up into the valleys of St. Johann and Rosenthal, where it is associated with a slaty, red and green sandstone containing casts of certain elongated bivalves resembling Mytili†. Near Kirch-bückl it is traversed by two dykes of serpentine, irregular in their directions, but generally bearing about north and south.

In its mineral characters and relations, this porous *rauchwacké* and yellowish magnesian limestone is nearly identical with the rocks in the valley of the Inn, between Häring and Schwatz; and like them it forms low ridges and terraces, the beds of which plunge under peaks of Alpine limestone.

(2.) In the sections illustrative of the general structure of the Austrian Alps‡, the formation we are describing was made only to appear along the

* Phil. Mag. and Annals, N. S. vol. viii. p. 92—96.

† Similar casts of bivalves occur in the same red sandstone of the Salzburg Alps. The presence of organic remains in this formation is in harmony with the facts discovered in Alsace by M. Voltz and others.

‡ Phil. Mag. and Annals, N. S. vol. viii. pl. 2.

lines of the longitudinal valleys at the base of the great escarpments of the calcareous zones. More recent observations have, however, shown that it occasionally reappears in other longitudinal valleys further removed from the central axis, being sometimes brought into unconformable contact with deposits of a much younger age. This is clearly seen in the country south of Salzburg: for the red sandstone, which at Werfen dips under the Alpine limestone of the Tännen Gebirge, is either by a great flexure or by a break reproduced in a parallel valley, extending from Golling to Abtenau, where it passes on one side under a slaty, black limestone and shale, which are, for reasons hereafter to be given, referred to the lias; whilst on the other side of the valley it abuts against the shelly deposits of the adjoining valley of Gosau *.

The same deposit reappears in like manner in other longitudinal valleys; a fact which seems to prove that during some period of elevation were produced a series of enormous breaks or flexures, ranging nearly in the direction of the principal axis of the neighbouring region of the Alps: and the parallelism of these lines of dislocation confirms, at least in part, some of the great views published in the researches of M. Elie de Beaumont, which will be referred to more than once in the subsequent portions of this paper.

This formation of red sandstone may be traced in great detail in the valley of the Lammer, between Golling and Abtenau. At Schäffau the slaty beds contain imperfect casts of bivalves, and bosses of gypsum, with much iron glance here and there scattered through them. Near this place there is also a small protuberance of basaltic greenstone, a rock of very unfrequent occurrence in these regions; but, unfortunately, the thick covering of detritus, and the vegetation which surrounds it, make its immediate relations obscure. The limestone nearest to it on one side is dolomitic; and the strata of red sandstone on the other dip away from it to the east, passing under the black shale and dark limestone of the Stub-berg †. The greatest extent of denudation of the red sandstone is in the bowl-shaped valley of Abtenau; and there the banks of the Lammer present very fine sections of gypsum, the mineral being seen, for the distance of several miles, in most of its modifications, forming cliffs of 100 and 150 feet in height; in one place made up of gypseous and brecciated clays, in another of finely laminated gypsum and marl, and in a third of compact and thick-bedded gypsum, approaching in character to common alabaster.

* See Plate XXXVI. figs. 2 & 10.

† These rocks, and some, hereafter to be described, in the Bavarian valley of Sonthofen, are the only examples of igneous rocks, in the northern calcareous zone of the Alps, which fell under our observation.

Three or four salt springs rise in this valley; and as the red sandstone plunges on both sides beneath the lowest strata of the Alpine limestone series, there can, we think, be no doubt that these salt springs (unlike those of Ischel, Aussee, and Hallein, which have been shown in our published sections to be included in the Alpine limestone) are of the same, or very nearly of the same, age as the great salt deposits in England.

(3.) We are now also disposed to classify the salt deposit of the valley of Berchtesgaden with the red sandstone which is inferior to the Alpine limestone: for the brecciated saliferous masses of that place, associated with variegated marls and red sandstone, not only rise from beneath the lower strata of the Hohe Göll; but after a great flexure plunge towards the north under the base of the Untersberg, and are surmounted by a vast succession of strata representing, we believe, the whole Alpine limestone series*. The coloured map accompanying this paper will serve to indicate the valleys in which the red sandstone group is reproduced, on successive lines nearly parallel to each other and to the central axis of the chain†.

Dr. Buckland was, we believe, the first who ventured to regard the group above described as the equivalent of a part of the new red sandstone and magnesian limestone series of England, thereby excluding every part of the great zone of Alpine limestone from the order of transition rocks. This by itself was a great step towards an explanation of some of the perplexing phenomena of the Alps; and all geologists who have examined the question appear to be now so far agreed, as to place the red sandstone and gypseous marls at the base of the secondary system of the chain. There may be some difficulties in drawing any precise line of separation between the transition and secondary systems; as we, indeed, before acknowledged in alluding to the great masses of sparry iron ore on the north flank of the

* During our visit to the eastern Alps in 1829, we supposed that the saliferous deposits of Hallein and Berchtesgaden were of the same age, and that *both* of them were *superior* to the red sandstone which forms the base of the secondary system of the Alps. We were led into what we now believe to have been an error, by connecting (agreeably to the published system of M. de Lill) the section through the Tännen Gebirge and the salt-works of Hallein, with the range of the Untersberg. (Phil. Mag. and Annals, vol. viii. pl. 2. fig. 2.) In point of fact this connexion is interrupted by an enormous dislocation ranging between the two deposits. M. de Lill, whose memoirs have thrown a great light on the structure of the Salzburg Alps, has considerably modified his opinions since the time of their first publication; and it is right to state, that in the year 1829 (though he then connected the Hallein and Untersberg sections as we represented them) he maintained that the saliferous brecciated formations of Hallein and Berchtesgaden were probably not of the same age.

† Plate XXXV & XXXVI. fig. 9.

Alps*. But mineralogical anomalies interfere with every extensive system of geological arrangement, and in this instance throw no real difficulties in the way of the classification here adopted.

4. *Older Alpine Limestone, representing the Lias and lower part of the Oolitic Series?*

In the general, transverse section accompanying this paper the scale is so small that the whole Alpine limestone series is represented by one colour: but we adopt the three subdivisions of M. de Lill, as being founded on the evidence of natural sections, and at the same time convenient for description †. The present subdivision has its superior limits extremely ill defined; but it is supposed to include all the strata (often forming great bare precipices of limestone) between the red sandstone and gypseous marls, and the parallel of the upper saliferous breccias of the Alps.

We stated in our published paper, that the lower Alpine limestone was separated from the red sandstone and gypseous marls by dark beds of fetid limestone alternating with shale: and having discovered specimens of the *Gryphæa incurva* in the lower parts of this system near Bleiberg in Carinthia, we ventured to conclude from analogy, unopposed by any conflicting evidence, "that the Alpine limestone, immediately overlying the red sandstone group, commences on both sides of the chain with the lias." As, however, this conclusion does not accord with the published opinions of Dr. Boué and some other writers on the structure of the Alps, we now proceed to notice other groups of strata on the north flank of the chain (pointed out to one of the authors by M. de Lill in the summer of 1830), which we are also disposed to class with the lias.

The red sandstone of Abtenau and Schäffau dips unequivocally under great masses of dark-coloured limestone and shale. These rocks are seen in the mountains of Stub-berg and Schwarzenberg, and as they are well exposed in the parallel valley of Gaisau, nearly due east of Hallein, and are there characterized by organic remains, we proceed to give a detailed account of their relations in that locality. These fossil strata are exposed beneath the village of Crispel in a deep gorge of the Mertelbach, a tributary torrent of the Salza, from the banks of which we obtained the following section ‡.

1. Lowest beds,—bluish and greenish marls, with stone-bands of greyish, calcareous grit.

* Phil. Mag. and Annals, N. S. vol. viii. p. 93.

† See Plate XXXVI. fig. 1.

‡ See Plate XXXVI. fig. 2.

2. Thick-bedded, brown-coloured, coarse limestone.

3. Cream-coloured, compact, argillaceous limestone, with a conchoidal fracture, very much resembling the white lias of Somersetshire, and containing true Ammonites of a large species, one of which approaches *Ammonites biplex*.

4. Dark, thinly foliated, calcareous shale, with occasional bands of marlstone.

5. Dark, marly shale, with small nodules of dark blue, argillaceous limestone, in the centres of which are frequently Ammonites and other organic bodies. These concretions are undistinguishable from the cement stones of the lias shale of Whitby. The higher beds of shale are separated by stony beds of dark-coloured, bluish limestone, and in a cliff near the Waterfall are not less than 300 feet in height. Among the fossils we collected are the following.

Ammonites Conybeari, or a variety of it, identical with an Ammonite of the lias of Wirtemberg.

———— a new species.

Mya?

Pecten, very near *Pecten dentatus* and three other undescribed species.

Perna, of more than one species.

Terebratula, near *T. hastata* of the mountain limestone.

Ostrea.

Small Gryphæa?

Other indescribable minute spiral shells.

Caryophyllia (?), &c. &c.

In the preceding section we find that the dark bluish shales and limestones pass, in descending order, into strata of greenish marl with subordinate stone bands, which we consider as the upper portion of the new red sandstone. None of the shells in the overlying limestone bands belong to the peculiar suite of the *muschelkalk*. One elongated bivalve, indeed, somewhat resembles the *Mytilus socialis* of Schlotheim; but all the specimens of chambered shells are true Ammonites, and admit of no comparison with the peculiarly chambered shells (*Ammonites nodosus, &c.*) of the *muschelkalk*. From the mineral character of the upper group of blue shale and limestone, as well as from its position above the red sandstone, and from its group of fossils, we venture to place it on the parallel of the lias.

It may be objected to the preceding classification, that it is founded on imperfect zoological evidence, inasmuch as, perhaps, none of the fossils enumerated can be strictly identified with species found in the lias formation of this country: but the same argument would apply with almost equal force to the whole calcareous zones of the Alps, and shut them out from any comparison with our great secondary groups. It is at least probable, that the distribution of organic forms, during ancient periods in the history of the earth, was governed by the same laws which regulate their distribution in the existing seas. Hence, in cases where contemporaneous formations are widely separated from each other, and have been deposited under widely different circumstances, we have no right to look for any thing more than a general accordance in the characters of their fossils: and we venture to assert, that there is this general accordance between the fossils of the great secondary groups of the Alps, and those of certain corresponding groups in England.

The lias-like shale and limestone of Gaisau, above described, are overlaid on both banks of the Mertelbach by a deep red-coloured limestone, distinguished by a multitude of broken stems of Encrinites, together with some Ammonites, Belemnites, casts of bivalves, &c. This limestone is largely developed in the great valley of the Salza, on the west side of which it ranges beneath the salt deposit of Hallein, and on the east side it is extensively quarried at Wiesthal as well as some other places. Thence it ranges to the east, and reappears in several valleys: we particularly observed it at the southern end of the lake of Halstadt, and again in the neighbourhood of Aussee. In no place, however, is the position of this rock better seen than at Gaisau, where it surmounts the black shale, and is in its turn covered by a grey limestone, forming the higher ridges of the Schnittenstein *.

Near Aussee the red, encrinital limestone is well exhibited in the small, elevated valley of Wiesau, about one league above the salt works, forming a conical hill called the Brunn Kogel; the eastern flank of which is washed by a rapid torrent, separating it from the Pissenstein. The latter mountain is chiefly made up of deep-coloured shale, containing bands of flinty, black slate, approaching in character to Lydian-stone, and much resembling the altered shales of the lias in the south coast of Mull and other parts of the Hebrides. All the strata in the Pissenstein are much contorted, highly inclined, and dislocated, so that their exact relations to the red limestone of the Brunn Kogel are not clearly seen: but as similar, black shale and subordinate, flinty beds occupy the base of the adjoining mountains of the Loser and the Sandling, and appear to plunge beneath the salt beds of Aussee, we are disposed to refer them to the above-described lias group of Gaisau.

The section of the Brunn Kogel not only shows the red, encrinital lime-

* See Plate XXXVI. fig. 2.

stone, but also a thick-bedded, greyish limestone containing Ammonites and numerous specimens of a heart-shaped bivalve. The latter fossil is very prevalent in the Salzburg Alps, where it always seems to appear nearly on the same geological parallel; that is, among rocks corresponding to the lower portion of our oolitic series: but we never procured specimens sufficiently well preserved to have their specific characters determined.

The Ammonites of the red limestone are of at least five species. None of them can perhaps be strictly identified with any English species; there is however one, which if not identical with, at least very nearly approaches to, the *Ammonites multicostatus* of Sowerby.

It would be entirely foreign to our present purpose to enter on any general details respecting the formation of the lower Alpine limestone, or to point out its enormous expansion in some of the great inner escarpments of the calcareous zones; nor shall we now describe the modifications of structure by which it passes into vast, crystalline masses, sometimes dolomitic, and loses nearly all traces of stratification, and of all subdivisions similar to those we have attempted to establish. These modifications are now well known, and have been often described by persons possessing incomparably better means than we had of studying the mineral structure of the chain.

5. *Shale, Limestone, and Sandstone, with brecciated, saliferous Deposits.*

We showed in our former paper that some of the great saliferous deposits of the Alps, occupy an intermediate position between the older and younger portions of the calcareous zones. Such is the position of the saliferous masses of Hall, Hallein, and Ischel, given in our published sections*. We now add, in confirmation of our views, a section through the salt works of Halstadt†.

The salt of Halstadt occurs at a considerable elevation, in a depressed or contorted mass of the Alpine limestone. To reach the works, you ascend from the lake up an almost precipitous face of limestone; first to a boss, on which is built the ancient tower of the Emperor Rudolph, and afterwards to the height of about 1200 English feet above the lake, where you reach the level of the lowest gallery. There are eight principal galleries by which the salt is extracted, and as the highest is 2343 feet above the lake, the salt mass must be at least 1100 feet in perpendicular thickness. Its total thickness however is not yet ascertained; because no gallery can be driven at a much

* Phil. Mag. and Annals, N.S., vol. viii. pl. 2. figs. 1, 2, 5, 6.

† Plate XXXVI. fig. 10.

lower level than No. 8. of the existing section, so long as the present mode of working the mines is continued*.

The salt mass here, as well as at Ischel, Aussee, Hallein, &c., is a breccia of saliferous clay and gypsum, separated from the surrounding, grey limestone by an envelope of blue, gypseous shale. The highest galleries, 1, 2, and 3, traverse the salt mass completely, and reach the overlapping limestone of the Blossen; but the extent of the range of the deposit beneath that mountain is unknown, as the remaining five galleries terminate in the salt without piercing through it. On whatever side of the works the broken rocky region be examined, there are no traces of red sandstone, not even in gorges more than one thousand feet beneath the lowest gallery; on the contrary, nothing is seen at the base of the mountain except compact, Alpine limestone.

By comparing the previous account with what we have already published, it appears, that the salt deposits of Hall, Hallein, Halstadt, Ischel, and Aussee, occur nearly under the same circumstances; being all associated with great, insulated masses of brecciated marl and sandstone, rolled up and encased among contorted beds of Alpine limestone†. As they are entirely separated from each other, it would be impossible to prove, without a much better series of organic remains than we have yet seen, that they are all exactly on the same parallel: but we have no hesitation in so far adopting the system of M. de Lill, as to place them in the middle division of the Alpine limestone series.

In the limestone beds associated with these insulated masses of saliferous breccia are indeed many fossils, few however which are well preserved: among them are Orthoceratites, and Ammonites of which the concamerations are marked by simple or undulating lines: both might seem to indicate strata older than any part of the oolitic series: but along with them are true Ammo-

* The process employed here (and we believe in all the Austrian salt mines) is, to excavate a chamber in the saliferous mass, and then to fill it with water. All issue being completely closed, the chamber is left in this condition for several months, during which the water gradually dissolves the saline matter, whilst the associated clay and gypsum fall to the bottom and form a sediment. When fully saturated, the brine is let out, and conveyed by pipes to evaporating-houses in the neighbouring valleys, where the water is driven off by the heat of furnaces fed by wood from the pine forests. From the works of Halstadt the saline solution is transported to so great a distance, previous to evaporation, that the channel of conveyance necessarily commences at a considerable height above the level of the lake.

† We believe that our published plate (Phil. Mag. and Annals, N.S., vol. viii. pl. 2. fig. 2.) correctly represents the position of the salt of Hallein; the error, alluded to in a previous note, was in connecting the Hallein system with that of the Untersberg. They are separated according to our present views by an enormous derangement, which brings in the lower Alpine limestone a second time at the Untersberg. See Plate XXXVI. fig. 9.

nites with the ordinary concamerations, one of which is very near to *A. mutabilis*; spheroidal masses like the Alcyconic fossils of the green-sand; many casts of shells resembling organic remains of the oolites, and a singular body (found in our Kimmeridge clay and abounding in the Solenhofen slate) to which the name *Tellinites solenoides* has been sometimes given. At Aussee, in the beds of limestone containing the saliferous marls, there are, along with other fossils, Pentacrinites, and Corallines of the genera Tubipora and Astræa*.

If the obscurity of the subject prevent us from determining the exact place of the great, saliferous system of the Alps, it is at least certain that the deposits at Aussee, Halstadt, Ischel, and Hallein, are superior to a great mass of strata above described, which we have endeavoured to compare with the lias and the lower part of the oolitic series. There are, therefore, two salt deposits of the Alps; one probably of the same age with the principal rock-salt formations of England, the other in a position higher than any like formation we are acquainted with in this country. Recent discoveries have indeed proved the existence of salt among rocks of almost all ages. It is daily accumulating in certain inland lakes and marshes; in Poland it probably exists principally, if not entirely, among tertiary rocks; in the Austrian Alps we have placed it in the oolitic system; in Switzerland it is placed by Mr. Bakewell in the lias; in Wirtemberg, Alberti has proved it to be in the *muschelkalk;* in England, our greatest salt mines are in the new red sandstone; but there are two or three copious salt springs in the coal formation, from one of which salt has been largely extracted. In certain parts of the United States, salt-springs issue from old transition slate rocks†; and, lastly, a spring containing a great proportion of salt, rises near Keswick, from the lowest division of the slate rocks of Cumberland.

6. *Younger Alpine Limestone—Upper Portion of the Oolitic Series?*

Under this head we do not, as in our former paper, include all the remaining secondary deposits of the chain, but only those parts of them which intervene between the saliferous system last described, and an outer zone supposed to be of the age of the green-sand or chalk. As the parallel of the

* While this sheet was passing through the press, we were favoured with the sight of the fossils collected by Dr. Buckland from the saliferous limestone of Halstadt in 1820. They have been carefully examined by Mr. J. Sowerby, who refers them to the following genera: Ammonites, Orthocera, Buccinum, and Trochus?

† Phil. Mag. and Annals, N. S., vol. vii. p. 200.

upper saliferous series is ill defined, the base of the younger Alpine limestone cannot in all cases be precisely limited. We may, however, state in general terms—that the formation is very extensively developed—that it exhibits all the irregularities of structure and position peculiar to the calcareous zone—that it now and then rises into peaks of peculiar, fantastic forms, becomes crystalline, and loses nearly all traces of stratification; in which cases it is often dolomitic—and lastly, that it cannot in general be distinguished, by its subordinate minerals or its structure, from the lower division of Alpine limestone.

It is not our intention in such a sketch as this to enter on any details respecting these phenomena, for an account of which we must refer to works expressly devoted to descriptions of the Alpine chain, and especially to the various essays of Dr. Boué *. We shall, therefore, confine our remarks to a brief notice of one or two localities, where the characters of this part of the series are well exposed.

The crystalline structure of the younger Alpine limestone is seen in the mountains on the east side of the Traun-see, where, from the red, encrinital limestone near Ebensee (which may be assumed as the base of the series in the absence of the saliferous deposits) to the grey precipices of the Traunstein, the whole system appears to have undergone some great modification since the period of its first deposition.

At Aussee the system we are describing, is remarkable for the great development of a compact, dull grey, thin-bedded limestone, containing numerous, black, siliceous bands and concretions, and with subordinate strata abounding in several species of Terebratulæ. Rocks of this kind range over the salt deposit, occupying a great part of the Sandling and Loser Mountains, and are well exposed in the Leissling Wand.

Among the formations of the Untersberg, a similar, grey rock is overlaid by a variegated and brecciated, subcrystalline limestone, largely quarried under the name of Salzburg marble; and the marble is surmounted by a grey hippurite-limestone.

In our published sections, the younger Alpine limestone is represented as entirely occupying a broad zone, including several successive ridges between the line of the salt deposits and the northern outskirt of the chain. After what has been above stated, it is obvious that this representation can only be

* Dr. Boué states, that dolomite prevails more in the upper groups of Alpine limestone than in the lower. Our own observations, as far as regards the Tyrol, were in accordance with this remark. In the Salzburg Alps this variety of limestone is much more rare.—See some remarks on the Ichthyolites of the Seefeld, by one of the authors (Phil. Mag. and Annals, N.S., vol. vi. p. 36.).

admitted with modifications. The upper limits of the system (partly in consequence of the enormous derangements of the Alps) are often almost impossible to determine. On the north flank of the Untersberg it ends, however, naturally with the beds of the hippurite-rock*. At the Wand, Windishgarsten, and in the valley of Gosau, there are also bosses of this rock most intimately associated with, and apparently forming a part of, the upper Alpine limestone series, and dipping under certain deposits which we consider of the age of the green-sand. Hence we are disposed to separate the hippurite-rock from the green-sand, and to place it in the highest part of the younger Alpine limestone.

7. *Alternations of Limestone, Calcareous Grit, Sandstone, Marl, &c.; with numerous Impressions of Fucoid Bodies, and sometimes with Fossils of the age of the Green-sand and Chalk.*

There are many portions of the Alps, where we believe no mineralogical separation can be established between the lower part of this, and the higher part of the preceding subdivision: and as the hippurite-rock is by no means continuous, being only found here and there in unconnected masses, it is obvious that the base of the system of beds, we are describing, must be very ill defined. It was this difficulty which prevented us from separating it, in our published "Sketch of the Structure of the Austrian Alps," from the younger Alpine limestone. We however distinctly recognized its existence on the outskirts of the Salzburg and Bavarian Alps, and stated—"that it formed a succession of ridges close to the tertiary system—that it was composed of alternations of limestone, sandstone, and shale; and being more thin-bedded than the older parts of the chain, had been exposed to extraordinary breaks and contortions; sometimes dipping towards the mineralogical axis, and sometimes from it; in one place being vertical, and in another twisted into saddle-shaped masses, and being in some instances absolutely inverted." We further stated—"that this series appears to be greatly expanded near the eastern termination of the Alps—that from the outskirts of the calcareous zone near Reichenhall to the valley of the Rhine, it forms, in the position pointed out, a nearly continuous succession of ridges, easily distinguished from the inner portions of the chain—that in some parts of the series the beds of limestone almost disappear, in which case it passes into a formation of sandstone and shale, not to be separated, without the help of fossils, from the superior tertiary groups—that in other places, lower in the system, the calca-

* Plate XXXVI. fig. 9.

reous beds are of much greater thickness, and have all the common, mineral characters of the Alpine limestone," &c. &c.

Again, we distinctly stated—"that the ridges of indurated shale, sandstone, and limestone, on the northern outskirts of the chain, were considered as the equivalents of the green-sand and chalk; the conclusion being apparently borne out by the position of the subordinate beds, as well as by their fossils, and in some instances also confirmed by their mineral contents." Extending our remarks to the southern Italian Alps, we alluded to the observations of MM. Maraschini and Catullo; adding—"that the latter gentleman had, by the help of a great suite of organic remains, proved the existence of beds of the age of the green-sand, superior to rocks containing organic remains of the oolitic series—and that, near Belluno, Feltri, Canal di Brenta, &c., the system terminates in a red-and-white, fissile limestone (*scaglia*), with many flints, which from its structure, position, and fossils, has been identified with the chalk."

Again, appealing to our personal observations made in the summer of 1829, we described the vast development of a nummulite-limestone between Adelsberg and Trieste, but were unable to decide how far it descended into the secondary series. We however added—"that the formations in the ascending order undergo a great change before they reach the Adriatic; the calcareous beds (chiefly composed of a compact, light-grey limestone, full of Nummulites) no longer predominating; but becoming subordinate to great masses of bluish grey, micaceous shale, and of sandstone of a grey or greenish grey colour, and here and there containing a few traces of carbonaceous matter—that along the shores of the Adriatic for several leagues south of Trieste, the micaceous shale is so abundant as to produce a succession of ruinous cliffs, apparently held together only by the subordinate bands of sandstone and nummulite-limestone"—and, finally, "that this upper system is now generally regarded as the representative of the green-sand and chalk—a conclusion in perfect accordance with our views of the structure of the district*."

We have made these quotations, partly because they give a correct description of some portions of the group we are describing; but chiefly because it has been repeatedly stated by Dr. Boué during the past year, both in British and foreign journals, that we either overlooked this group altogether, or where we did notice it, classed it with the tertiary deposits. Both these assertions are entirely erroneous. It was impossible to overlook the beautifully undulating ridges, (composed of calcareous gritstone, fucoid sandstone, shale, &c.) ranging almost without interruption from the head of the Lake of Constance to Vienna; often widely expanded on the skirts of the chain, and always contrasted by their forms, their vegetation, and their forests, with the bare, sterile

* See Phil. Mag. and Annals, N.S., vol. viii. p. 103—108.

precipices of the older limestone*: and although we did not attempt to follow their range, and had few observations to offer respecting them which we thought worth recording, we were acquainted, through the maps of Keferstein, with the general facts of their geographical distribution.

The peculiar character and position of this group when regarded as a whole, the importance given to it by the elaborate descriptions of Dr. Boué, and its enormous expansion in some of the eastern parts of Europe, make it convenient now to separate it from the older secondary system of the Alps, and to consider it as a distinct formation. Whether it be called *Flysch* or *Vienna grit*, or by whatever name it be hereafter designated, is a matter of very small importance.

It will be our object to show, in the subsequent details of this paper, that some portions of this group admit of at least two subdivisions; a lower, characterized by the Vienna fucoid grits and shales; and an upper, here and there abounding in Nummulites and many other fossils, and containing subordinate beds of arenaceous iron ore: the two are, however, so intimately blended, and have so many characters in common, that we do not venture to separate them; but consider them together, in a general way, as the representatives of the green-sand and chalk. We shall endeavour further to show —that the nummulitic series is enormously developed, and that in some parts of the chain it is placed so exactly on the confines of the secondary and tertiary systems, that the lower portions abound in fossils almost exclusively secondary, while the upper portions contain a great excess of tertiary genera or species —in short, that on the north flanks of the Alps there is an occasional passage from the secondary to the tertiary systems.

To convey a correct, general notion of the distribution of this formation, we must refer to the small, coloured map accompanying this paper†, which has been constructed partly from our own observations, and partly from the inedited maps of M. Partsch of Vienna, and also from an inedited map of the Archduchy of Austria, transmitted by Dr. Boué to the Geological Society during the past year‡.

It was not our object to trace this system into Switzerland, where it appears

* The same remark applies to the corresponding series on the south flank of the chain. Thus the *scaglia* and green-sand of the Possagno Hills, forming an outer fringe of the Alps of Bassano, are verdant to their summits (2000 feet above the tertiary deposits), and form a striking contrast with the bare, arid faces of the neighbouring mountains.

† Plate XXXV.

‡ M. Partsch occupies a considerable part of every summer in collecting materials for a geological map of the Austrian Alps, &c. Detached sheets of the Austrian ordnance map are coloured by him, year by year, on the spot; and when the survey is completed, the colours will be transferred to a general map on a smaller scale, and published.

to be considerably expanded; but in following it along a portion of the skirts of the Bavarian and Austrian Alps, we found it forming a zone of very irregular breadth, consisting sometimes of a number of parallel ridges bearing generally about E.N.E. and W.S.W., and sometimes thinning off to a single ridge and almost disappearing. After stretching through the valley of the Allgau and the ridges above Nesselwang (at both of which places sections will be noticed), it gradually thins off at Fussen, but again expands to the east of the river Lech, and is still more expanded beyond the right bank of the Inn. It offers most instructive sections near the banks of the Traun, which will be described in their proper place; and from thence the slaty, fucoid, calcareous grits and shales, form a succession of characteristic ridges, terminating on the left bank of the Saal in the Högl hills, which shut in, to the N.W., a great bay or recess of the Alpine limestone. It deserves remark, that the slaty, greenish sandstone of these hills, dips at a considerable angle nearly south from the sides of the Stauffen, and directly towards the Untersberg, a mountain forming the northern skirt of the Alpine limestone between Reichenhall and the Salza. Immediately north of the Untersberg, there is only a thin and partial covering of the lower green-sands, but there is a large development of the overlying cretaceous and nummulitic deposits*.

The green-sand series occupies an extensive tract to the north of Salzburg, extending into the hilly region of the Haungsberg, and thence without interruption to the Mond-see. At the southern end of that lake, the shales and slaty sandstones, are placed vertically by the side of a precipice of dolomitic Alpine limestone, but at its northern extremity they dip off from the older system, at a great angle, towards the north.

The fucoid slates and grits occupy a considerable breadth, from north to south, between the Mond-see and the Traun-see; but to the east of the latter lake they again thin off into a narrow belt, so greatly displaced by an enormous fault, that the upper system of nummulitic strata is thrown unconformably against the precipitous face of the Traunstein, which is composed of Alpine limestone†. This remarkable dislocation and inversion of dip, continues to affect the formation in its eastward range beyond the Enns.

* Pl. XXXVI. fig. 9.

† The physical outline of the group we are describing (especially where it is but slightly expanded) approaches very nearly to that of the tertiary series; so that in a hasty passage through the country, when we have not an opportunity of examining the natural sections in detail, we run an occasional risk of confounding one system with the other. It was in consequence partly of this circumstance, and partly of the detestable weather which prevented us from examining the sections at the base of the Traunstein, that we were led into an error in colouring the extreme

To the south of Steyer a transverse section through the wooded mountains of Raming and Tamberg, by Unterwald, exhibits a series of beds composed of calcareous grit—of argillaceous, smoke grey or bluish grey, slaty limestone, crossed with white veins, often nearly compact and with a fine conchoidal fracture, and alternating with grits and shales containing among other Algæ the *Fucoides intricatus* in great abundance—also of a vast thickness of greenish grey sandstone surmounting the preceding. In this sandstone series many parts are fine-grained, micaceous, and thin bedded; but they are associated with a coarser, green sandstone, passing through a very coarse grit into a conglomerate (used for millstones in several parts of the chain), not, however, by any means to be confounded with the very coarse conglomerates of the tertiary system. These various rocks rise in the hills, above mentioned, to the height of more than 2000 feet, close to the valley of the Danube; and beds of the same structure extend for some distance up the Alpine gorges of the Enns, as well as up the lateral depression through which the waters of the Teicher escape from the high valley of Windischgarsten.

We have no intention of offering any description of the formation, as it ranges into the great promontory near Vienna, constituting the north-eastern termination of the Austrian Alps (Wiener Wald). On this subject we must refer to the ample details, published in various memoirs, by Dr. Boué. He states that in the thin-bedded, blue limestones, fucoid grits and shales, which are so extensively developed in that extreme portion of the chain, Ammonites and Belemnites are occasionally found; and that in the same series there are, here and there, thin bands of coal.

We may finally mention, that in the western sinuosities of the chain in Styria, are some magnificent sections of the fucoid grits and shales: for example, in the gorges of the Kainach, and also at Rheinthaler-Hof, where the grits are extensively quarried. The upper beds consist of slaty, micaceous sandstone; the middle beds of fine-grained, bluish grit, used for whetstones; and the lowest of coarser grained, strong gritstone, passing into a conglomerate with rounded pebbles, and used for millstones. Among these beds no organic remains were discovered except fucoids, of which there is one very large, unpublished species. With the exception of a few patches of limestone, these grits and shales are the only deposits, interposed between the primary chain of the Pach Alp and the tertiary formations of Lower Styria.

We have already stated our opinion, that no precise line of separation can be drawn between the group of deposits last described, and the highest por-

northern portion of our transverse section of the Alps, accompanying the paper in the Annals of Philosophy above referred to. This error has been very properly pointed out by Dr. Boué.

tion of the younger Alpine limestone: it is therefore possible, that some of the lowest fucoid grits and shales, may descend into the oolitic series. In a part of the great Vienna promontory they alternate with thick masses of limestone, which, in our visit to that portion of the chain in 1829, we were unable to separate from the older, secondary system of the Alps. Dr. Boué may, therefore, be correct in classifying a portion of these fucoid grits and shales with the upper Jurassic formations: but we repeat our conviction, that in the greatest part of their range along the flanks of the Austrian and Bavarian Alps, these fucoid grits are completely subordinate to, and form a part of, the green-sand series.

8. *All Deposits superior to the Chalk, comprehending several, distinct, tertiary Groups.*

The accompanying map * will show the general distribution of these deposits, which, with very limited exceptions, we shall not attempt to describe in detail. A transverse section at the head of the Lake of Constance, shows the position of a great succession of the newer deposits, which there begin to conform to the type of the series in its range westward through Switzerland. The sections at the eastern termination of the chain through the plains of Styria, also give a long succession of tertiary groups; but, in general, the most important parts of the succeeding details, are confined to the phenomena exhibited at the junction of the former group (No. 7.) with the great tertiary system, which sweeps down from the foot of the Alps to the plains of the Danube.

The preceding account of the general structure of the Eastern Alps, has been given as an introduction to the facts, exhibited in a series of detached sections, the meaning of which could not be fully understood without it. If our slight sketch serve in any way as a help towards a more detailed and perfect classification of phenomena, avowedly of great difficulty and obscurity; and if it should induce any geologists of this country to visit the regions we describe, and become acquainted with the researches of the authors to whom we have referred—our purpose will be more than answered.

* Pl. XXXV.

Chap. II.

A Series of Transverse Sections, intended to explain the Connexion of the Secondary and Tertiary Systems of the Eastern Alps, &c.

1. *Transverse Section through the Formations near the Head of the Lake of Constance* *.

On the east side of the line of section, the tertiary system, composed of great, alternating masses of sandstone, marl, and coarse conglomerate, rises into hills of considerable elevation, which form the parting of the waters of the Rhine, and of the last ramifications of the Danube. The prolongation of these masses, towards the west, is interrupted by the wide chasm through which the Rhine makes its way into the Lake of Constance; and in consequence, the hills ranging along the eastern extremity of the lake, give a succession of transverse sections on an enormous scale, in which the structure and relations of some portions of the tertiary groups are finely exhibited.

Our present section commences ten or twelve miles south of Bregenz, with the secondary, calcareous rocks on the right bank of the Rhine, which, after rising into the Stauffen and some other finely pointed summits, rapidly descend into the plains, and, near their base, present some great, mural escarpments singularly marked by contorted lines of stratification. From the base of these precipices, a chain of low hills, almost buried under transported materials, extends about a mile and a half to the village of Obersdorf, where a mountain torrent works its way through a great ravine into the plains bordering on the lake.

The valley of Obersdorf is shut in, towards the east, by a mountain ridge called the Rexberg, ranging nearly north and south, and connecting the precipices of secondary limestone with the ridges of *molasse* and conglomerate. The geological features of these mountains are obscure; but we conceive that the secondary and tertiary formations, meet not far from the northern extremity of the Rexberg ridge; and, in that case, their place of junction must be at a great elevation above the level of the Lake of Constance.

The precipices forming the north flank of the Stauffen rest on black shale, which at Haslach is obscured by great blocks of limestone fallen from the escarpments above, and containing innumerable Nummulites. Of these blocks, some are light grey and compact, like the commonest limestone of the Alps; others are of a dark blue colour, and resemble mountain limestone; some are

* Plate XXXVI. fig. 3.

tinged green by disseminated particles of green-sand; others are red and ferruginous; and some of the grey and nearly compact limestone contains balls of pyrites. Above these fallen masses are some compact, grey beds of limestone containing several fossils, among which are large ribbed Terebratulæ, Oysters, and Pectens. Over the preceding is a sandy bed, the lower part black and calcareous; the middle part of a rusty brown colour, highly ferruginous, and passing, here and there, into a true hæmatite forming a subordinate bed about four feet thick, which has been extensively worked for use. The upper part passes into a beautiful green-sand, full of Nummulites, and is surmounted by alternations of black shale and limestone.

This whole system dips nearly south, at an angle of 30° or 40°, and seems to plunge under the great, contorted precipices of the Stauffen, which are also carried, with an inverted dip, towards the centre of the Alps. As we found no indications of great faults, nor any thing in the suite of fossils to contradict the arrangement, we considered the nummulitic and iron-stone beds as forming a part of the newer, secondary groups of the Alps; probably about the same age with a portion of the chain, containing the ferriferous, nummulitic beds of Sonthofen. From Haslach to Obersdorf no section was observed; but in the gorge above the latter place, are beds of grey, indurated marl and calcareous shale, of black shale, and of green-sand, alternating with a few bands of sandy, veined limestone; the whole dipping south at an angle of 70°. In the village are some ill exposed beds of blue and red, impure, sandy limestone, containing many Nummulites. We consider these beds as secondary: for those in the gorge exactly resemble many of the strata of the green-sand and cretaceous series of the Alps; and the nummulitic limestone may be only a repetition of the secondary, nummulitic rocks of Haslach*. For about half a mile to the north of Obersdorf, all the beds are covered with transported materials, washed down from the nearest mountains; but the numerous blocks of greenish, micaceous sandstone and of conglomerate, prove that the tertiary system cannot be far off. Further north we found a quarry, in which the beds dipped S.W. 75°, and gave the following section:

1. Friable, micaceous, slaty sandstone, much charged with carbonaceous matter, and with stems of carbonized plants at the partings of the laminæ	2 feet
2. Coarse calc-grit, passing into millstone; outside brownish, inside greenish blue	5 feet
3. Bands of micaceous sand with coaly matter	1 foot

* The details of this transverse section were read to the Society as they are now printed, not long after our return from the Alps in 1829; yet it has been erroneously stated (both in British and Foreign Journals), that we had described the deposits of Haslach and Sonthofen as tertiary.

4. Fine, bluish and greenish, micaceous sandstone, with many irregular partings, containing a few fragments of slate clay, and, here and there, large carbonized stems, not parallel to the beds, but lying in all directions . . . . 20 feet
5. Slaty, brown and bluish, micaceous sandstone; the bands, here and there, much charged with coaly matter, surmounted by fine, grey, micaceous sandstone . . . . 25 feet

It is difficult to convey a clear notion of such a succession of beds by mere verbal description, or to determine their exact place in the series: but when examined on the spot, we were inclined to consider them of the tertiary age, because they admitted of a very close comparison with the lower, carboniferous, tertiary strata, which we had seen in some other parts of Bavaria. We however regard their place as doubtful.

Still further to the north, above the village of Haselstauden, a great ravine lays bare a series of nearly vertical beds, among which a hard, green, micaceous, sandstone is seen to alternate with, and pass into, a coarse conglomerate. Among the blocks which had rolled down from the mountain side, were some in which the cement was highly calcareous. Many of these masses exactly resemble the most ordinary, tertiary rocks of Bavaria. A green, micaceous sandstone, not to be distinguished from the *molasse* of St. Gall, then begins to predominate; and near a place called Fehlen, beds of this kind are seen to dip S.W. at about 50°.

On the south side of the mountain, which extends from Obersdorf to Schwartzach, the dislocations of the strata add greatly to the difficulty of drawing any exact line of separation, between the secondary and tertiary formations: but on the north flank of the mountain the groups recover what may be considered their natural position; and near Schwartzach may be seen dipping at a high angle of inclination, towards the north. From the last-mentioned place the tertiary beds are prolonged, above the villages of Reichenbach and Wolforth, to the hills on the Ach above Bregenz; and in this whole range dip to a point about magnetic north. They are extensively quarried; and in their mineralogical character exactly resemble the fine, green, micaceous *molasse* of the opposite ridges of St. Gall. Though varying considerably in texture, they seldom pass into a conglomerate form. Sometimes they exhibit traces of carbonaceous matter; and we have seen specimens of lignite, derived from this part of the formation in the hills south-east of Bregenz.

The united thickness of the whole succession of the tertiary beds, we have been describing, must be very great. Respecting that of the inferior, disturbed strata, it is difficult to form any correct estimate, nor do we pretend to define their limits: but some notion may be formed of the thickness of the *molasse*, when it is stated, that a line drawn directly transverse to the *strike* of the beds, from the point where they set on with a regular, northern dip, to the hills on the Ach immediately behind Bregenz, is not less than six miles in length; and that along the whole of this line the average inclination of the beds is not less than 20° or 25°.

Pursuing the same line of section across the river Ach, which here empties itself into the Lake of Constance, we find an escarpment several hundred feet high, composed of brownish red, coarse conglomerate, alternating with a reddish, quartzose sandstone, so fine in parts as to resemble *grauwacké;* but in other and higher alternations with the conglomerate, it passes into a soft, yellowish and brown, micaceous sandstone. In the upper beds of the cliff on which the castle stands, are some large Ostreæ, and fragments of smaller and more destructible shells. The conglomerate is chiefly made up of the detritus of Alpine limestone, and its higher subdivisions begin to alternate with sandstone beds of a slaty character: behind the town of Bregenz it passes under a well-defined *molasse,* undistinguishable from that which abounds so much in the lower parts of this sectional line, as well as from the *molasse* of Rheineck and Roshach on the opposite side of the valley of the Rhine.

This Bregenz *molasse* is largely quarried, and is a good example of that fine, greenish, micaceous sandstone which appears in all the public buildings around the Lake of Constance. Certain varieties of it are used for whetstones or grindstones; a fact, however, from which alone no inference can be drawn respecting the age of the deposit, inasmuch as both the secondary and tertiary, greenish sandstones of the Alps, are occasionally used for these purposes. In the upper and less coherent beds of these quarries, are imperfect casts of bivalves: much finely comminuted, black, carbonaceous matter is also disseminated, especially in the planes of separation of the more slaty masses. This *molasse* is again overlaid by a vast thickness of conglomerate, like that of the castle-hill, with a reddish brown, siliceous cement, and with imbedded pebbles varying from one to eight inches in diameter. Still higher these conglomerates alternate with yellowish, sandy grits, which are marked by red and green spots and concretionary, argillaceous blotches. Then follow sandy marls and thin-bedded sandstones, again surmounted by strong courses of conglomerate: and this system is continued along the hills for several thousand feet, being distinguished in the ascending order by some subordinate beds of grit of a brick-red colour; and by others of green and grey colours.

The rugged outline of this portion of the ridge, is due to the structure we have just described. For the elements have washed away many masses of the incoherent sandstone, and left many knotty protuberances of the less destructible conglomerates, standing out upon the crests and sides of the mountains.

The beds we have so far described, to the north of the river Ach, may be considered as the middle group of the tertiary system, exposed in this section. The upper group may be supposed to commence about three miles north of Bregenz: for bands of white sandstone containing some green grains there begin to prevail, and the conglomerate beds to diminish in thickness and in number. On reaching the castles of Hofen and Halberstein, a most marked change was observed; for the conglomerate series was found to pass under thick beds of variegated, argillaceous marls. A magnificent, vertical section of these argillaceous beds, is exhibited in the upper extremity of the Russbach stream, in the face of the Hand Reutti hill. The beds (which gradually diminish in inclination to the north of Bregenz) are there nearly horizontal, and are seen in regular superposition in the face of escarpments several hundred feet high.

The prevailing masses in these escarpments, are composed of bands of variegated marls, some of which are very unctuous, alternating with thin courses of white sandstone, which occasionally passes into a hard and nearly compact gritstone. Among these beds traces of the conglomerates are still met with; and near the summit of the hill there are some considerable bands of it, subordinate to the marl and the sandstone.

With these beds our transverse section terminates; and we may remark that they are of a structure analogous to that of the upper part of the tertiary system of Bavaria, especially as it is exposed on the banks of the Lech near Schöngau. This agreement might almost have been anticipated; for the strata of the Hand Reutti, being at a great elevation and inclined at a comparatively small angle, are probably in their range towards the north, spread over a considerable portion of the lower plains of Bavaria.

The preceding section places in a striking point of view, the position and enormous development of the tertiary system on the north flank of the Alps; but it derives its chief interest from the green, micaceous sandstone (*molasse*), which enters so largely into the composition of the lower and middle groups above described. In this way the sandstones and conglomerates of the high *plateau* of south-western Bavaria, become connected with, and pass into, the tertiary series of Switzerland. Nor is this conclusion founded upon a merely accidental, mineralogical resemblance; for the beds of *molasse*, composing so large a portion of the hills south-east of Bregenz, reappear with the same *strike* and dip on the other side of the broad valley of the Rhine, and rise into the northern mountains of the Canton of St. Gall; from which they descend in a long succession of inclined terraces to the south shore of the Lake of Constance. Whatever conclusions Professor Studer and other writers have been enabled to establish, by the help of large suites of fossils, respecting the age of the *molasse* of Switzerland, may therefore be extended to at least a portion of the newer deposits of Bavaria. This inference is the more important, because the upper tertiary system of Bavaria is often buried under great accumulations of alluvial matter; and in the places where it is laid bare, we were often unable to find a single fossil, to assist us in making out its relations.

In other respects, the preceding section is comparatively imperfect; as we have not determined the base line of the tertiary system, or derived a single, well-preserved fossil from any bed of it *; nor did we extend our examination, so far up the right bank of the Rhine, as to see the junction of the green-sand series with the Alpine limestone.

2. *Transverse Section through the Valley of Sonthofen, and across a Succession of Parallel Ridges on the Banks of the Iller.*

A part of the tertiary series, above described, after rising into a high, irregular *plateau*, between the basins of the Rhine and the Danube, runs off into ridges composed of *molasse* and conglomerate, ranging nearly parallel to the secondary rocks of the chain; generally, however, separated from them by a longitudinal valley. In this way they cross the Iller at Immenstadt, nearly shutting in, towards the north, the great transverse valley of the Allgau. They there form what might almost be called an irregular, vertical wall of conglomerate and sandstone, entirely unconformable to the older system †; and diminishing gradually both in inclination and elevation, they descend into the newer deposits of Bavaria, containing tertiary shells and lignites. From their place in the section, as well as from their mineral character, they are quite distinct from any rocks entering into the newer, secondary system of the Allgau; we therefore continue to regard them, as an undoubted part of the tertiary series‡.

* In the prolongation of the *molasse* to the left bank of the Rhine, near Rheineck, organic remains are much more abundant, and in a better state of preservation. In a single visit to a quarry near that place we collected several Pectens, several Terebratulæ, one near to *T. Mantelliana;* two species of Cardium; a Pholas; &c.

† Plate XXXVI. fig. 4.

‡ In this conclusion we differ from Dr. Boué, who classes the conglomerates and grits of the Rethenberg with the lowest part of the green-sand.

To the south (or towards the mineralogical axis of the Alps) the valley of the Iller extends by Fischen to Ober Mieselstein, above which it is almost closed in by the longitudinal ridge of the Schwarzenberg. The river has its source in a narrow glen called the Waliser Thal, and in its course by Fischen and Sonthofen, after being swollen by various minor torrents which descend from longitudinal gorges of green-sand, finally quits the mountains by a chasm in the ridge of conglomerate above described, and falls into the plains of Bavaria*.

On entering this valley from the north-east, we skirt the western foot of the high, serrated ridge of the Grünten, the lowest strata of which are composed of a thick-bedded, close-grained, brown, siliceous sandstone, occasionally passing into chert, and are nearly vertical. These are succeeded by bluish green grits, which graduate into a very hard, dark blue, calcareous grit with green grains, traversed by white veins of carbonate of lime, the beds gradually acquiring a dip of about 70° S.S.W. The weathered surfaces of many of these beds present the ordinary appearances of the green-sand of England; and among their fossils Mr. J. Sowerby has recognized small casts of Ammonites, *Inoceramus concentricus, Plicatula pectinoides,* Terebratulæ, two species, *Gryphæa vesiculosa* (?), and a univalve very near to *Cirrus plicatus.* These fossils are characteristic of a portion of the green-sand of England; and as the beds which contain them rest upon masses of chert undistinguishable from that of our green-sand, we have little hesitation in referring the strata at the north-western base of the Grünten, to the lower or middle groups of that formation.

The analogy with the English series, is further confirmed by the overlying beds, which are composed of a dull grey, marly limestone, containing large Ammonites, and resembling the upper green-sand or malm rock of this country; these are surmounted by a thin-bedded limestone (rising into the highest peak of the Grünten, called the Hohe Wand), of a red or variegated colour, and sometimes of an earthy texture, but more frequently hard, compact, having a conchoidal fracture, exhibiting obscure traces of fossils on its weathered surface, and resembling the *scaglia* of the southern Tyrolese Alps. In some deeper sections of this mountain, there are quarries of sandstone of so bright a green colour, as to form a perfect, mineralogical type of the green-sand formation: and it deserves remark, that this rock (like certain corresponding strata of our country) is used as a *fire-stone* in the construction of the neigh-

* We have, as a general rule, described our transverse sections in a regular, ascending order. But we thought it better, in this instance, to notice the successive phenomena nearly in the order in which they appear, as one penetrates the chain by the banks of the Iller; and in consequence, the several deposits are described in a descending rather than an ascending order.

bouring iron furnaces. So far, the strata of the Grünten offer striking analogies to certain, well-known formations of the age of the green-sand, and probably also of the chalk; but in the gorge by which the Starzlach flows into the Iller, we meet with a series of beds entirely unlike any of the British, secondary groups.

From the repeated changes of dip on the south side of the Grünten, it becomes extremely difficult to determine the exact order of the strata. But the *scaglia* (or red chalk ?) and the marly limestone (or *pläner kalk ?*) are thrown off towards the west from the Hohe Wand, and are seen no more between that peak and the Starzlach. The rocks between the highest ridge and the river gorge, being in a nearly vertical position and in different degrees of induration, have weathered into sharp ridges of rugged pinnacles, following the range and flexures of the several beds from the degradation of which, they have derived their form. The most northern of these extraordinary ridges, is made up of a coarse, brown, gritty limestone, passing into slaty beds of calcareous, indurated marl, in which are obscure traces of Terebratulæ. The next is composed of a bluish limestone with white veins, weathering to a brownish red colour : it contains innumerable Nummulites, some fragments of shells, and a few specimens of Spatangi. The third ridge occupies the precipices on the banks of the Starzlach, and consists of indurated, dark coloured, calcareous shale, separated by stone bands of blue grit with white veins. Subordinate to these calcareous shales are vast masses of irregularly bedded, arenaceous iron ore, filled with a profusion of casts of shells, Crustacea, Echini, &c. So convulsed are the strata containing the iron-stone, that the mineral, in one mine, is reached by horizontal galleries from the sides of the ravine, the ore being extracted from tortuous and nearly vertical beds with a slight inclination to the south; in a second, it is worked by shafts, the mineral beds plunging to the north under a mass of calcareous, slaty shale ; in a third mine, the same beds are snapped off at right angles to the preceding, and though accompanied by numerous contortions, are on the whole nearly horizontal.

On the great scale, the calcareous shale and grit containing the ore, may be considered subordinate to the system of nummulitic limestone, which to the north separates the iron mines from the Grünten ; and to the south of the Starzlach rises into another parallel mountain chain, called the Mos, in which iron ore is also partially worked. This limestone appears to contain three species of Nummulites hitherto unpublished—one of them somewhat resembling *N. elegans* is found also in the nummulitic beds immediately overlying the green-sand and cretaceous system of the Untersberg * ; a second species

* See Plate XXXVI. fig. 9.

resembles the *N. lævigatus;* a third is distinct from any species we have seen figured. The limestone also contains Spatangi, Pectens, &c.

The fossils in the calcareous shales and beds of iron ore are very numerous; but unfortunately they are nearly all in the state of casts, so rude as not to permit their species to be well distinguished. Amongst them are Spatangi resembling those of the chalk and green-sand *; several species of Terebratulæ, one of which resembles *T. subrotunda,* another is near *T. lampas;* Spondylus; Plicatula; a univalve near to *Cirrus plicatus;* Astarte; Anomia; Isocardia; *Gryphæa vesiculosa* (?); two or three species of Pecten, one of which resembles *P. reconditus;* Serpula; and Belemnites; but the most abundant fossils of the deposit are Crustacea.

From these details, and the accompanying section, it appears that the nummulitic limestone and iron ores of Sonthofen, are in the highest part of the green-sand and cretaceous system of the Alps. But in following the secondary ridges towards the east, we shall afterwards show that this nummulitic system is very largely developed, and that it passes into higher strata, in which the secondary fossils gradually disappear, and the greater number of the imbedded shells begin to conform to the tertiary type.

If the line of section, just described, be prolonged to the south of the Starzlach, the nummulitic limestone is, as before stated, again found to alternate with calcareous, black, slaty shale and fine-grained grits; the prevailing dip being to the south †. But if another section, parallel to the former, be made on the opposite or western side of the valley of Sonthofen, it traverses a succession of ridges of fine green-sand, having the same general direction (from W.S.W. to E.N.E.), and the same prevailing dip. They are, however, nowhere overlaid by the strata containing iron ore.

In the higher part of the Sonthofen valley, near Ober Mieselstein, is a tributary torrent called the Schinberger-Ach, flowing between the Schwarzenberg and the ridge of the Bolghen. The former mountain is composed of compact limestone and calcareous, green grits; the latter of thick-bedded, brownish, cherty sandstone surmounted by grits and calcareous shales with innumerable impressions of Fuci, amongst which are *Fucoides intricatus, F. Targioni,* and *F. furcatus* of M. Adolphe Brongniart. In other ridges on the left bank of the Iller, between Ober Mieselstein and Sonthofen, there are similar asso-

* These fossils are unquestionably distinct from any of those in the iron beds of the Kressenberg (Plate XXXVI. fig. 7.), described by Goldfuss and Count Münster.

† Plate XXXVI. fig. 4.

ciations of sandstone (sometimes passing into chert and sometimes containing green grains) with the fucoid grits and shales *.

This fact almost demonstrates, that the largest portion of the fucoid shales, are subordinate to the green-sand series. According to M. Adolphe Brongniart, fucoids are highly characteristic of the green-sand and cretaceous periods; and from our own observations in the Eastern Alps, we are disposed to subscribe to that opinion: for in these youngest, secondary groups of the chain, we have never detected the trace of any of those vegetables, which are considered more peculiar to the oolitic series; nor, on the other hand, has the Alpine limestone afforded us a single specimen of a fucoid. By combining these positive and negative facts with the evidence derived from the order of superposition, we are induced, as is stated in the previous chapter, to place the fucoid strata near the base of the green-sand series. This is, at least, as perfect an arrangement, as our present knowledge enables us to venture upon; a more minute acquaintance with the fossil history of the Alps, may hereafter lead geologists to a better defined subdivision of these groups.

It will be seen from the section †, that the green-sand ridges on the left bank of the Iller, to the north of Ober Mieselstein, have all a northerly dip; but in the neighbourhood of that place the beds dip in every direction, and appear at almost every angle of inclination. Breaks and contortions are found in all parts of the calcareous chain, but can seldom be referred to any visible, disturbing cause. In this instance we are however more fortunate; for in the gorge of the Schinberger-Ach several large dykes of basaltic green-stone, are seen to rise to the height of forty or fifty feet up the abrupt face of the mountain, and there to terminate in wedge-shaped masses; which, from the effects they have produced, and their manner of association with the tilted beds of limestone and green sandstone, offer the clearest proofs of their forcible protrusion ‡. The rocks in contact with the trap are hardened and altered; and some of the green-sand beds are almost reduced to a compact state, and from being traversed by joints or fissures separate into prismatic masses. Indeed there is, here and there, so apparent an admixture of the stratified and the igneous rocks, that we could with difficulty draw a line of separation between them. The strata are highly inclined and nearly vertical in the lowest part of the gorge, where they are associated with the basalt; and the overlying calcareous masses of the Schwarzenberg, to which it has not penetrated,

* This sandstone is much quarried as a building stone, and in several places cannot be distinguished from the *quader-sandstein* (green-sand) of the north of Germany.

† Plate XXXVI. fig. 4.

‡ Our attention was called to these dykes by M. Betterich, the venerable pastor of Mieselstein.

are bent into irregular, flattened domes arching over the dykes, and probably over a still larger, concealed mass of trap below.

On the opposite side of the gorge there are other phenomena, placing perhaps in a still more striking point of view, the nature of the elevatory forces, which have acted on the neighbouring strata. From the north side of the Schinberger-Ach rises a mountain called the Bolghen, the base of which is presumed to be of primary rock, because large, angular masses of granitoid gneiss and mica schist, are there seen to rise through the thick, grassy covering. On ascending the mountain side, we again found gneiss protruding above the surface for 300 or 400 feet; and from these facts we concluded that all the masses of primary rock were *in situ*.

Upon a close examination, the granitoid rocks are found to be brought into contact with various members of the green-sand series, which are thereby so singularly displaced as to render it almost certain, that the crystalline masses have been upheaved at a period posterior to the deposition of the overlying beds. For, within the distance of less than a mile, the crystalline rocks are in one place brought in contact with a coarse millstone grit; in another, with slaty, green, micaceous sandstone; and in a third, with calcareous, fucoid shales; all of which beds are tilted off in every possible direction, and at high angles of inclination, from the various, salient points of the primary masses. As the basaltic dykes appear only at a short distance on the opposite side of the gorge, and penetrate the same series of sandstones and shales, it seems probable that the volcanic matter, which was driven up among the strata of green-sand, did not make its way through the gneiss; but acting on it in mass, raised it up, as a great lever, among the overlying deposits, dislocating them, and breaking them in the manner above described *. In this locality we seem, therefore, to have a key to the explanation of the real nature of some of the great, elevatory movements of the Alpine chain †.

Before we quit this subject, we may remark, that the last, great movements of elevation, must have taken place after the deposition of the sandstones and conglomerates of the outer ridge of the Rethenberg, as must be evident by

* We did not examine the eastern side of the valley opposite Ober Mieselstein: we must therefore refer to the published memoirs of Dr. Boué for an account of the minerals and trap rocks which occur in that locality. We are at a loss to comprehend how he can include the primary masses we have been describing in a conglomerate of the green-sand; and we are still more surprised that he should attempt to assimilate this supposed conglomerate to the system of the Rethenberg, which is exterior to all the secondary portions of the chain.

† A similar instance of the upheaving of primary rocks in a solid state, and a consequent derangement of the overlying shelly strata, was described, by one of the authors, in a memoir on the

a mere inspection of the accompanying section. We may further remark, that notwithstanding the enormous disruptions of the strata on the banks of the Iller, all the mountain-ridges preserve a very exact parallelism, ranging through the Allgau in a direction about W.S.W. and E.N.E. These facts, as far as they go, confirm some of the remarkable speculations of M. Elie de Beaumont, on the elevation of the principal chain of the Alps. Finally, we may observe, that notwithstanding the constancy of the dip and the parallelism of the ridges, some portions of this section would probably give an exaggerated notion of the thickness of the green-sand series. The great, longitudinal breaks must unquestionably have been accompanied by vertical, relative movements of the stratified groups ; in consequence of which some of the groups may now be several times repeated on the same line of section. The same observation may be applied to many other parts of the chain, and will assist us, in some measure, in reducing our estimate of the total thickness of the secondary series of the Alps.

3. *Transverse Section through the Alp-Spitz and Nesselwang, &c.*

On skirting the Alps from Immenstadt to Nesselwang, a distance of about fourteen miles, we saw many fine examples of derangements similar to those above noticed ; and at the latter place we examined, in some detail, a transverse section, which we now proceed to describe *.

Immediately to the south of Nesselwang is a peaked range called Alp-Spitz, the highest point of which rises about 1800 feet above the level of the town, and consists of a bluish, thin-bedded limestone of shattery fracture, containing Belemnites and many broken shells. These beds form a saddle at the summit ; and in their range towards the south compose a succession of woody elevations, most remarkably contrasted with the bare precipices of older limestone, which rise up beyond them.

On the northern side of the Alp-Spitz, the strata decline from a nearly vertical position, acquire a northern dip, and are overlaid by a thin-bedded, grey limestone, containing large, turriculated shells, and many pyritous balls (varying from the size of a pea to that of a walnut), which, in decomposing,

Brora Coal-field. In that case, however, no trap rocks are visible ; but in the Isle of Arran the secondary rocks are penetrated by trap, and are also elevated by the granite of Goatfell. The granite was probably raised in mass by the same moving forces which propelled the trap. The dislocation seems to have been precisely of a similar kind to that of the Bolghen. See Geol. Trans. N. S. vol. ii. p. 293. and vol. iii. p. 34.

* Plate XXXVI. fig. 5.

leave small cavities in the rock*. Some of the more compact varieties of these thin beds, resemble the indurated chalk of Antrim; others are not unlike ordinary, upper green-sand, or *pläner kalk* of the Germans. These are succeeded by a great system of shivery, dark-coloured, micaceous shale and marl, with numerous, strong bands of calcareous grit, on the surfaces of which are very large Gryphites (?), Trigoniæ, Terebratulæ, &c. †. In this group we also observed some beds of black, hard limestone, and of dark-coloured, greenish sandstone, with concretions of chert. The whole of the strata composing the summit and flanks of the Alp-Spitz we refer, on a broad scale of comparison, to the chalk and green-sand series.

Overlying the preceding group, is an immense development of very coarse conglomerate (quite distinct from the millstone grits of the Alpine green-sand), and of hard gritstone and shale; which, between the Alp-Spitz and the town of Nesselwang, are exposed in the castle-hill, being cut through by a mountain-torrent, and exhibit a thickness, according to our estimation, of more than 2000 feet—the whole being in a nearly vertical position, and quite parallel to the group last described. The lowest members of this series are composed of an indurated, red conglomerate, the inclosed fragments of which, are made up of Alpine limestone and red sandstone, some rounded and others angular, followed by sandstone and indurated shale. The red conglomerates again set on, in beds from twenty to thirty feet thick each, alternating with strong bands of calcareous grit, and, here and there, separated by courses of thin-bedded, red shale and sandstone.

After many repetitions of similar strata, in which the conglomerates always predominate, is seen a bed of lignite about twelve feet thick. This lignite is placed between an indurated, red, sandy, micaceous shale, in some places so hard as to look like *grauwacké,* and a fine red conglomerate. It is exposed by the side of the torrent in a nearly vertical position, and was formerly worked by horizontal galleries ‡. Above the coal are variegated shales and marls, containing traces of another coal seam, and with subordinate beds of grit, having a prismatic structure, transverse to their vertical direction. Fi-

* In the lowest part of the Bregenz section (Plate XXXVI. fig. 3.), rocks of a precisely similar structure appear on the northern base of the Stauffen, associated with the ferriferous nummulitic deposits of Haslach.

† This series of shales and calc-grits is of great thickness, and is probably on the parallel of the nummulitic iron ores of Sonthofen, forming the extreme limit of the secondary system of the Alps. We did not, however, discover any nummulitic beds in this section.

‡ It was extensively worked about fifty years ago; but the cheapness of wood-fuel in Bavaria caused the works to be abandoned.

nally, overlying all these, are strong bands of calciferous grit, exhibiting on fracture a *chatoyant* lustre, and seeming gradually to pass into a superior, conglomerate system.

The range or *strike* of this series is from E.N.E. to W.S.W.*; and on the whole the strata may be considered vertical: but the inclination is carried a few degrees beyond the perpendicular in some of the younger beds; which thus, by their excess of dislocation, present (as in several other previously described parts of the chain) an appearance of dipping under the older.

The beds immediately superior to the above, are lost in the denudation of Nesselwang; but still higher beds, chiefly composed of conglomerate, appear in the ridges to the north of the town, with the usual range and northerly dip, and are from thence prolonged, without interruption, into the plains skirting the base of the Alps.

The absence of the nummulite-beds takes away from the interest of the preceding section. It however exhibits the peculiar structure and position of the outer secondary system, and, indeed, shows very clearly the relative position of all the successive groups. We did not extend our section far to the north of Nesselwang, as the conglomerates and sandstones in that direction are obviously the lower part of the great tertiary series, which descends into the Bavarian plains. As the best arrangement which the preceding details enable us to give, we commence the tertiary system with the coarse conglomerates, and therefore include the Nesselwang lignites in one of the lower portions of it.

4. *Section, in the ascending order, on the Banks of the Traun.*

Phenomena, similar to those above described, are exhibited in many other neighbouring portions of the chain: but we now proceed to describe two transverse sections (one from the banks of the Traun, and the other through the iron-mines of the Kressenberg, near the south-eastern frontier of Bavaria); as they mutually explain each other, and when taken together, place in a clear point of view the relations of the nummulitic deposits, and the connexion between the secondary and tertiary systems of the north-eastern Alps.

* We adopt the word *strike* from the German geologists: it means the direction of a line drawn in the plane of any stratum at right angles to its line of dip. The word *range* is by no means so expressive. Besides, a word is wanted to express the line of intersection of any stratum with the actual surface of the earth. This line hardly ever coincides exactly with the *strike*, and its direction might be very conveniently defined by the technical use of the word *range*.

The former of these sections (to which the attention of one of the authors was directed by Dr. Boué) exhibits, more or less perfectly, a long succession of deposits from the ridges of Alpine limestone to the tertiary marls, near the town of Traunstein. Each of these deposits we now proceed briefly to notice in the ascending order*.

1. Compact, Alpine limestone, &c., occupying the south side of the gorge of the Miesenbach. This was not examined in any detail, as our attention was chiefly directed to the superior groups.

2. Hills of sandstone and calcareous shale ;—the exact relations of the beds exceedingly obscured by vegetation and forests. At Loheim, a cellular, grey, tufaceous limestone, resembling coarse *rauchwacké* †, has been extensively deposited on the sides of the hills.

3. Black, calcareous, slaty shale, with brown and blue, calcareous sandstone, slightly micaceous, traversed by white veins of carbonate of lime, and breaking into small, cubical fragments : dip W.S.W. 40°. All this part of the series (from the gorge of Miesenbach to the glen of Dieselbach), though of great thickness, is ill exposed : it represents the Vienna grits, and in parts is quite identical with the fucoid shales of the valley of Sonthofen.

4. Thinly foliated, blue and dark green marls in beds nearly vertical ; imperfectly seen in the glen called Dieselbach. From this point the strata are more clearly exhibited in precipitous cliffs on the left bank of the Traun, beginning nearly opposite to the town of Arzt.

5. Ochreous and ferruginous, coarse-grained grit, with Nummulites, Spatangi, large, broken bivalves, &c., in thick beds, with a northerly dip of 80°. These beds contain many brown quartz pebbles, and pass into the next superior group.

6. Hard, thick-bedded, calcareo-ferruginous grit, full of Nummulites, and with traces of many fossils ; among which large Pectens and Spatangi are the only well-preserved genera.

7. Strong beds of calc-grit with Nummulites ; of a still firmer texture than the preceding beds ; from which they differ, in being of a greenish blue colour, and speckled with grains of brown iron ore. The *strike* of all these strata is east and west ; they are quite vertical, and their thickness is at least 800 feet. The hill they occupy is opposite the town of Arzt, and is called the Erzberg, probably from the quantity of iron ore disseminated through the rock.

These strata (4, 5, 6 & 7) appear to occupy about the same place in the series as the nummulitic, calcareous grits and iron ores of Sonthofen, and like them, do not contain any fossils of a decidedly tertiary character. Beyond them is a denudation extending for several hundred yards to the banks of the river ; and through this interval it is impossible to trace the successive deposits ; but from the nature of the strata which are next met with, it is probable that the space denuded was occupied by marls or cretaceous shales.

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* Plate XXXVI. fig. 6.

† The rock in question is of an open, tufaceous structure, and does not appear to be of the same age as the beds with which it is associated. Our reasons for this opinion are : 1. Because the tufaceous rock dips to the east from the peaked hills above Loheim, while the regular strata dip west and south : 2. Because we were unable to find it in the bed of the Traun below the quarries ; where, had it been continuous, it must have been seen alternating with the slaty grits and shales of the section. We therefore concluded, that this rock (regarded by Dr. Boué as a secondary *rauchwacké*) is an ancient *travertino*, produced long after the contiguous formations were consolidated.

8. Light green and red, thinly foliated marls; they are vertical, and parallel to the nummulite-grits just described.

We may here observe, that all these vertical strata are capped by a vast thickness of horizontal, coarse conglomerate, made up chiefly of the detritus of Alpine limestone. In its range from the flanks of the chain towards the plains, it passes in succession over the edges of all the vertical or highly inclined deposits we are describing.

9. Greenish grey, fine-laminated marls, passing in the ascending order into sandy, calcareous grit.

10. Light grey, calcareous grit, with many green grains, and with some minute pebbles of white quartz.

11. Thick beds of coarse, granular limestone, containing many broken stems of corals.

12. Coarse, calcareous grit of a brownish grey colour.

13. Greenish marls, passing into a cream-coloured marlstone, with a conchoidal fracture; very like some varieties of chalk-marl.

14. Thick beds of coarse granular, coral limestone, with precisely the same characters as No. 11. The arrangement of the corals and comminuted shells in these beds nearly resembles that of the coarse, coralline beds which immediately surmount the chalk at Maestricht.

15. Light grey, calcareous and porous grit: the cavities occupied by many crystals of carbonate of lime. This rock is quarried as a building stone.

16. Cream-coloured marl, with a conchoidal fracture.

17. Incoherent green-sand, charged with myriads of Nummulites of an undescribed species, having a central depression in the disk.

18. Fine-grained, grey, calcareous grit, with numerous minute, green grains. It is extremely difficult of fracture, and rather thick-bedded: its *strike* is due E. and W., and therefore parallel to that of the preceding groups. Its vertical edges are well exposed on both banks of the stream, where it is surmounted by thick masses of the horizontal conglomerate.

From the preceding group to the village of Siegsdorf, our section is interrupted by a longitudinal valley of denudation about a mile in breadth, within which the beds are all buried under alluvial accumulations. By a spectator looking up this valley to the east (or in the exact *strike* of the vertical groups above described), a succession of undulating hills would be seen in the distance, ranging directly through the Kressenberg: and as the *strike* of the beds in all this region is remarkably constant, it is obvious, independently of other geological evidence, that we must seek among these hills for a series of strata to interpolate between the group last enumerated (No. 18), and the deposits north of Siegsdorf *. On examination, the ferriferous beds of the Kressenberg are found exactly to satisfy these conditions; inasmuch as they possess an intermediate character, between the nummulite-grits last described, and the newer deposits north of Siegsdorf. We postpone, however, the description of these

* The accompanying section (Pl. XXXVI. fig. 6.) has by mistake become rèversed in engraving. The Loheim ridge ought to have been on the right hand; and in that case, the low ridges seen up the valley south of Siegsdorf would represent the place of the Kressenberg series.

ferriferous beds, as it would interrupt the order of our narrative; and we now proceed to enumerate, in the ascending order, the successive groups from Siegsdorf to Traunstein, commencing with the beds laid bare on the right bank of the Traun in the Hochberg and the Tolberg.

1. Sandy conglomerate, with small pebbles, both of the primary and secondary rocks of the Alps*.
2. Sandy, bluish marls and marlstone bands, occasionally with fragments of plants.
3. Conglomerate of small, rounded pebbles alternating with micaceous, yellowish sandstone.
4. Micaceous sandstone of a greenish hue.
5. Dark coloured marls, with bands of marlstone, and thin, irregular seams of black lignite.
6. Pebble beds with sand, and sandy marlstone.
7. Grey and blue marls.

The lowest beds near Siegsdorf are inclined, to the north, at an angle of about 50°; but as we advance on the line of dip, from the Alps towards the low country, the angle diminishes gradually, so that the strata, last enumerated, dip N. at an angle of not more than 40°. We may however observe, that the *strike* of all this series is perfectly parallel to that of the underlying nummulitic systems of Arzt and Kressenberg.

8. Pebbly conglomerate like the preceding, and of a considerable thickness.
9. Finely laminated, micaceous, sandy, blue marls, separated by bands of marlstone and *molasse*.

About three-quarters of a mile above the town of Traunstein, the left bank of the river offers a more decided escarpment than the right; and immediately below the village of Haslach the preceding group is seen in a cliff for several hundred yards; and as it contains no beds, like the conglomerates, produced by any violent mechanical action, we found in it, as we expected, some well preserved though extremely fragile fossils. They have been examined by Mr. J. Sowerby, who has had the kindness to return us the following list.

Cerithium (or Potamides), resembling *C. funatum*. Min. Con. Tab. 128, London clay.

Cerithium, species uncertain.

Melanopsis incerta. Hist. Nat. Gen. et Particul. des Mollus. Sestos.

Ampullaria or Natica, two species, one of which is found at Marzoll.

Corbula revoluta. Min. Con. Tab. 209, fig. 8—13 } London clay.
——— *Pisum*. Ibd. fig. 4. }

Crassatella? Arca. Cyclas, Mitra? Nassa, Turbo? Turritella, &c., all probably of new species.

* Some of the harder varieties of these conglomerates might easily be mistaken for transition rocks, if we judged only by mineral characters. Dr. Buckland found a similar conglomerate, north of Teisendorf, containing sharks' teeth.

This assemblage of fossils presents us with an admixture of marine and freshwater shells, similar to that which occurs in the London and Paris basins. Indeed this admixture is so common to tertiary formations, that we are led to conclude many of them must have been deposited in large estuaries. The dip of the beds at Haslach is not more than 30°, but their direction is still due east and west, like that of all the underlying strata. This inclination carries them rapidly beneath the same coarse, horizontal conglomerate, which we had seen resting upon the vertical, nummulitic formations near Arzt, the highly inclined edges of the *molasse* and pebble beds, and lastly, upon the blue marls of Haslach, from which it passes over the plains at the extreme northern limit of our section.

The section of the Traun exposes phenomena in strict accordance with those on the southern flank of the Alps in the Canal di Brenta. In both cases the parallelism and inclination of the younger strata afford satisfactory proof, that the last, and perhaps the greatest elevation of the chain, took place after the accumulation of most of the shelly, tertiary deposits, and that no great dislocations took place between the secondary and tertiary periods. The section of the Traun further shows, that this epoch of elevation was succeeded by a period of violent mechanical action, during which vast masses of coarse, horizontal conglomerate and gravel, were spread over the inclined edges of the strata on the outskirts of the chain *.

5. *Section through Kachelstein and the Iron Beds of the Kressenberg, &c.*

This section commences with the metalliferous, Alpine limestone of the Rauschenberg, the beds of which plunge at a considerable angle to the south, and the line passes nearly due north over the Kachelstein and Kressenberg; it afterwards ranges over some undulating ridges north of the village of Neukirchen †. The Kachelstein ridge is composed of alternations of limestone, calc-grit, sandstone, and shale, and (though rarely) contains Ammonites and Belemnites. The limestone is generally compact and thin bedded; the shale is most frequently of a bluish colour, but is sometimes red or variegated, and the sandstone is generally micaceous, and has a greenish grey tinge. The beds of this hill are much concealed by vegetation, but on its northern brow we obtained the following ascending section.

* Enormous masses of horizontal, coarse conglomerate are found in many Alpine valleys; and there are instances where the rivers have eroded gorges out of them to the depth of 600 or 700 feet. In the valley of the Inn near Inspruck, and in that of the Drave between Klagenfurth and Marburg, there are splendid examples of these phenomena.

† Plate XXXVI. fig. 7.

1. Light grey, calcareous marls, with indurated bands resembling *pläner-kalk.*

2. Bluish grey, micaceous marls, of considerable thickness, and with calcareous bands; some of which are composed of calc-grit, others of compact, argillaceous limestone resembling blue and white lias.

3. A great series of bluish grey flag-stones, alternating with marls, generally blue, but here and there of a red or greenish red colour.

It is unnecessary to enter on any further details respecting the structure of this ridge, as it obviously occupies the same part of the series as Loheim, Alp-Spitz, and other hills described in the previous sections. On its south side some of the strata are contorted; but on its northern escarpment they have a constant dip to the south at an angle of about 40°, and therefore *seem* to plunge under the Alpine limestone. This collocation can only be accounted for, on the supposition of one of those longitudinal *faults,* so common in the Eastern Alps, ranging along the base of the precipices of the Rauschenberg.

After descending down the northern side of the Kachelstein ridge, and crossing a narrow ravine, we meet with a series of brown, ferruginous, nummulitic calc-grits, dipping south at an angle of 80°, and rising into a peak called the Kleine Kachelstein, which is connected with, and forms a part of, the Kressenberg system. The difference in the inclination of the strata of the Kachelstein and Kressenberg ridges, their difference of mineralogical character, and the appearance of the ravine between them, would have induced us, independently of any other considerations, to suppose that a second great *fault* ranged along this ravine at the northern base of the Kachelstein, in a direction nearly parallel to the former; and when we compare the details of this section with those derived from the neighbouring parts of the chain, we find our supposition established beyond any doubt. To place the nummulitic series of Kressenberg *under* the Kachelstein ridge, would be a direct inversion of the sequence of deposits observed throughout the Eastern Alps.

Ascending by the highly inclined nummulite-beds above mentioned, we pass over a number of sandy and nearly incoherent strata deeply tinged with hydrate of iron, and here and there containing green grains. Several of the groups could not be mineralogically distinguished from ferruginous varieties of the English green-sand; and in some places, especially where they contain fossils, they pass into calc-grit. We found among them no traces of the blue shale and compact limestone; and indeed we may state generally, that there is little resemblance between the structure of this and the Kachelstein ridge. Further to the north the section crosses a series of highly inclined and ferruginous strata, occupying a surface about 800 feet wide, composed of calc-grit, sand, and sandstone. In general they are deeply tinged with hydrate of iron, and some of them contain green grains, and specks of brown hæmatite: and subordinate to the system are eleven beds, varying in thickness from five to seven feet each, so impregnated with these granular ores, as to yield on smelting not less than forty *per cent.* of iron. Their prevailing colour is rusty brown, occasionally shaded with green; but here and there they become almost black, from the prevalence of the protoxide over the earthy hydrate and brown hæmatite. Innumerable fossils are diffused through them; and nature has in some parts of the beds so adjusted the proportions of shelly and ferruginous matter, that the ore is smelted with no other preparation than that of breaking up the masses, and throwing aside such gritty portions as are too siliceous. They are worked by long, open, horizontal drifts, following the beds in the Kressenberg for the space of 4000 feet; and as their inclination is not less than 70°, they might at first sight be mistaken for true mineral veins. Following their range from west to east, they are found again in the adjoining hill called Frieberg, where they have been also worked, though not to the same extent.

By referring to the accompanying plate*, it will be seen that in the prolongation of the section towards the north, the inclination of the strata gradually diminishes; and in various quarries of yellow sand and nummulite-calc-grit, beyond the village of Neukirchen, the angle of dip is not more than 45°. The elevation of the Kressenberg ridge is four or five hundred feet above the neighbouring northern plains: the ridges north of Neukirchen not only diminish in elevation, but are so covered with transported materials (among which are enormous boulders of primary rocks from the central chain), that we were prevented from following the section in that direction.

So far we have confined ourselves to a description of the position and structure of the successive beds. We now inquire in what part of the geological series we are to place the great Kressenberg group? In attempting to answer this question, we would in the first place observe, that all the component strata of the group are probably presented in an inverted order. We were induced to make this supposition, from a comparison of the successive beds with those of other sections, as well as from the position of the beds themselves. In a country less violently broken up, this might seem a bold hypothesis; and whether it be true or false is a matter of little moment, as the Kressenberg beds unquestionably form but one group.

Notwithstanding the enormous dislocations of the chain, we have stated that the beds often preserve their parallelism and their *strike,* through regions of considerable extent; thus the nummulitic series on the banks of the Traun, in its range towards the east, *strikes* the Kressenberg hills. We also stated that

* Plate XXXVI fig. 7.

the nummulite-grits of the Kressenberg probably belonged to that part of the series, which is buried under the alluvion of the valley south of Siegsdorf*. Now on examining the fossils associated with the iron ore and other beds of the Kressenberg system, we found that they presented a series different from any we have before described. Among them were no Ammonites or Belemnites, and no Spatangi like those in the lower groups†; but there were many Echini of other genera, out of which we may mention the magnificent Clypeaster of Goldfuss, and one or two other species of that genus‡. We further remarked, that the other fossils, though generally ill-preserved and specifically unknown to us, resembled those of tertiary rather than of secondary formations. We therefore concluded, not only that the Kressenberg iron ores were in the highest part of the great nummulitic groups, but that they were superior to the chalk.

Our own imperfect collection might be thought insufficient to warrant such a conclusion ¶; but during a preceding year Count Münster had obtained an immense series of fossils from this locality, and after an elaborate examination of them, published the following results.

1st. Of 172 species of these fossils, 42 exist in, and are characteristic of, the tertiary formations of Germany, England, France and Italy.

2nd. There are three species, two of which resemble, and one of which (*Ostrea semiplana*) is identical with, certain fossils of the chalk.

3rd. Of the remaining 126 species, some are new, and others indeterminable; but for the most part they belong to such genera as are commonly found in tertiary formations.

* Plate XXXVI. fig. 6.

† Dr. Boué (according to our view misled by the analogy of the Sonthofen deposit) appears to assert that Belemnites are found in the Kressenberg. (*Bulletin des Sciences*, *Juin* 1829, p. 329. &c. &c.) We doubt the correctness of this assertion; not as being opposed to our own observations, but on the authority of the *Berg-Meister*, who is the instructor of a small school of mines, has personally superintended the excavation of the deposit for many years, and been in the daily habit of collecting fossils from it. He not only denied that Ammonites and Belemnites were ever found in it, but he pointed out to us, before we had examined the Kachelstein ridge, that the Kressenberg (notwithstanding the deceptive nature of the dip) belonged to a higher system.

‡ See *Petrefacten von Dr. Goldfuss*, Pl. 41. Fig. 6. 7. 8.

¶ It was formed during a season of heavy rain, when the marls were in such a state, that the fossils could hardly be separated from them. They chiefly consist of casts which give no specific characters. Mr. Sowerby has, however, made out the following list of genera from them:—Cardium, Venus, Arca? Lucina, Crassatella? Gryphæa, Terebratula, Dianchora, Spondylus, Teredo, Turbo, Natica, Conus, Voluta, Murex or Rostellaria? Cypræa? Trochus or Solarium, and Nummulites. He adds that a Terebratula, Dianchora, Turbo, and Natica, resemble fossils of the chalk or green-sand, though the prevailing character of the group is tertiary.

4th. Of the characteristic chalk fossils (Ammonites, Belemnites, Hamites, Scaphites, Turrilites, &c.), there is not the least trace: neither are there any traces of the *Gryphæa Columba,* of Inocerami, plicated Terebratulæ, &c. &c.

5th. The only species (excepting the three above mentioned) which at the first glance seem to belong to the chalk, are a Plagiostoma and a Gryphæa. But on a closer examination, they not only differ from the fossils of the chalk, but are ascertained to be of the same species with certain fossils found in the tertiary formations of Ortenburg and Sternberg.

Such is the statement of Count Münster, an accomplished naturalist, possessing the best possible means of forming a correct judgment on this question; and as we have no direct geological evidence to oppose to it, we willingly adopt his conclusion (at which indeed we had arrived, on much more imperfect evidence, before we were acquainted with his paper), that the iron-sand of the Kressenberg is a formation newer than the chalk. If indeed such suites of fossils as he has described exist in the green-sand below the chalk, then there is an end of all zoological distinction between secondary and tertiary formations: but we believe that among the perplexing phenomena of the Eastern Alps, there will be nothing found to justify so anomalous a conclusion.

On the whole (as far as regards this and the preceding section) the geological and zoological phenomena appear in perfect harmony. Zoological evidence leads us to conclude that the Kressenberg beds are newer than any of the nummulitic groups of the previous section *. Geological evidence does not invalidate, but confirms this conclusion, and leads us to place these very beds over the other nummulitic groups, so as to fill up the valley of denudation south of Siegsdorf: and when this is effected, we have then before us a vast development of the nummulitic series, the lower part graduating into the highest secondary, and the upper part into the lowest tertiary system on the north flank of the Alps; and also forming a portion of a series which ascends without any break of continuity into the tertiary marls of Haslach.

It may be objected to the previous conclusion, that it is after all founded solely on zoological evidence; inasmuch as our direct geological evidence is only derived from the hypothetical union of two sections several miles distant from each other. We therefore, in the next place, proceed to describe a section, through corresponding groups of the series, further to the east, in which there is no interruption in the sequence of the several deposits.

* Plate XXXVI. fig. 6.

6. *Transverse Section from the Ridge of the Untersberg to the Valley of the Saal.*

The accompanying figure * commences with the Alpine ridge of Hohe Göll, and thence crossing the saliferous system of Berchtesgaden ranges over the crest of the Untersberg; the beds of which have a regular, northern dip, and terminate in the ascending order with a white, close-grained, sub-crystalline limestone containing an extraordinary congeries of Hippurites. M. Deshayes enumerates two species from this locality; the most abundant of which is found also in the Pyrenees, and has been figured by Picot de la Peyrouse †.

The hippurite-rock is considered as the base of the following ascending section; the details of which are derived from three or four independent, parallel traverses from the base of the Untersberg precipices to the banks of the Saal; the greatest number of beds are, however, laid bare in a ravine by which a torrent descends past Schweiger Mühle into the plains.

1. Fucoid grits and shales very ill developed, and only seen in one section near Kogel Mühle.

2. A regularly bedded series of very great thickness, composed of stiff, unctuous marls with bands of marlstone, which partake both of the range and the high inclination of the Untersberg strata. The lower portions of these marls are in some places of a purple colour, but their prevailing colours are yellowish grey or greenish grey; and the harder bands, when broken, often exhibit dendritic impressions, and resemble the *pläner-kalk* of northern Germany.

3. A group closely associated with the preceding. The marls are more laminated, of a green, red, or variegated colour, and are traversed by indurated bands not to be distinguished by hand specimens from the red chalk of Hunstanton Head and Speeton Cliff on the east coast of England. Some of the hardest specimens resemble *scaglia*, and in some of the sections gypsum occurs in this part of the series.

From different localities in the two preceding groups we obtained the following fossils.

Trochus linearis (a fossil of the upper green-sand, or chalk marl). Mantell, Geol. of Sussex. Plate xviii. fig. 17.

Inoceramus Cripsii (chalk marl). Mantell, Geol. of Sussex, Pl. xxvii. fig. 11.

Lucina.

Belemnites and Baculites.

Spatangi, resembling those of the upper green-sand or lower chalk.

4. Marl beds not so unctuous as the preceding, but becoming sandy and micaceous, and alternating with bands of coarse sandstone passing into conglomerate. These are overlaid by blue, green, red, and variegated marls, some of which contain innumerable crystals of selenite, and bands of gypsum rich enough to be worked for use. In the ravine descending to Schweiger

* Plate XXXVI. fig. 9.

† *Description de quelques Orthoceratites:* 1781.

Mühle there is no red chalk in this part of the series, but it is traversed by bands of coarse sandstone, and of calcareous grit full of Nummulites, some of which are found ranging through the gypsum quarries.

5. A system of great thickness, but much concealed by horizontal, overlying masses of gravel. It is composed chiefly of brown and bluish green, micaceous sandstone, alternating with blue, micaceous, laminated marl and shale, and is supposed to terminate a little below Schweiger Mühle.

6. Alternating beds of pebbly sandstone, gritstone, and blue marl, of great thickness and much concealed like the preceding, but laid bare by some of the torrents descending to the Saal. The upper portion of this group is chiefly composed of micaceous, blue marls, with subordinate bands of calcareous grit, containing many fossils. Though the inclination of the successive beds gradually diminishes as we advance to the north, the dip is considerable even to the extreme limits of the section, where all the strata disappear under the alluvion of the Saal.

Different parts of the group (No. 5.) overlying the variegated, gypseous marls contain, in addition to the Nummulites, several species of fossils. From our collection Mr. J. Sowerby has made out the following list.

Pectunculus.

Pecten.

Natica canrena (green-sand). Parkinson, vol. 3. Plate vi. fig. 2.

Vermetus.

Nummulites, two species.

Operculina (D'Orbigny).

Dentalium.

Serpula, &c.—To which we may add stems of obscure organic bodies, which seen on the fractured surfaces of the calcareous grit might be mistaken for Belemnites.

The blue marls forming the upper portion of the highest group (No. 6.) have a much better preserved suite of fossils. Out of our small collection Mr. Sowerby has selected the following, some of which are identical with shells found in the overlying deposits of Gosau.

Pectunculus calvus. Sowerby, Plate xxxviii. fig. 2.

Cardium productum. ———— xxxix. fig. 15.

Rostellaria granulata. ———— xxxviii. fig. 23.

Pleurotoma, very near *P. prisca* of the London clay. Min. Con. Tab. 386.

Dentalium grande. Calcaire grossier. Deshayes, *Mém. de la Soc. d'Hist. Nat. tome* 2. Plate xvii. fig. 1, 2, 3.

Ampullaria, or Natica, of the same species as one in the highest blue marls of Traunstein*.

Auricula simulata. London clay. Min. Con. Tab. 163, fig. 5—8.

Volvaria. Corals, &c. &c.

* Plate XXXVI. fig. 6.

We believe that MM. de Lill and Boué, as well as every one who has recently examined this portion of the Alps, identify the blue marls containing these fossils with a portion of the overlying series of Gosau. As we partake of this opinion, and intend to describe the Gosau fossils in a subsequent part of the paper, it is only necessary in this place to state, that the shells of the Marzoll marls, considered as a group, have unequivocally a tertiary character, and that in the direction of our line of section they are overlaid by no other regular deposit*.

It appears, therefore, from the preceding details, that on the north flank of the Untersberg, there is an uninterrupted series of conformable deposits, of very great thickness, which may be naturally subdivided into the following groups.

1. Fucoid grits and shales resting on the hippurite-rock.

2. A double group of cretaceous marls with a very characteristic suite of fossils, similar to that which in England is found in the green-sand and chalk marl.

3. A large, arenaceous group (graduating at its lower extremity into the preceding), abounding in Nummulites, and with a peculiar suite of fossils, some of which resemble secondary, and some tertiary species.

4. An arenaceous and argillaceous group, the upper portion of which contains many shells of genera and species considered characteristic of tertiary formations.

There is nothing hypothetical in this arrangement; it is, we believe, a mere statement of facts as they occur in one of the clearest sections on the northern skirts of the eastern Alps; and the conclusions to be drawn from it, are in accordance with those to which we have pointed in our description of the former sections.

7. *Nummulite-beds at Mattsee and St. Pancratz.*

Before we quit this division of our subject, we may shortly notice some detached and nearly vertical portions of the ferriferous nummulite-grits at St. Pancratz and Mattsee; the former place on the north-western, and the latter on the north-eastern, side of the Haungsberg ridge, which stretches to the east of the Salza.

* Dr. Boué (commenting on certain parts of our memoir, with which he became acquainted through the abstracts of the Geological Society's Proceedings) contends that this section ought to be prolonged to the Högl hills north of the Saal. We reply, that to have extended the line in that direction would have vitiated our section, inasmuch as the fucoid grits and shales to the north of the Saal are thrown off from the Stauffenberg ridge, which plunges towards the south, and are in no way directly connected with the Untersberg elevation. To have produced our section to the Högl hills would have made it not natural but hypothetical, and might have introduced an error similar to that of our published paper, where we joined the saliferous breccias of Hallein with the Untersberg ridge. (See Phil. Mag. and Annals, N. S. vol. viii. Plate II. fig. 2.

At St. Pancratz an ancient chapel stands on the vertical edges of a highly ferruginous nummulite-grit, containing numerous large Pectens and Echini of the same species as those at the Kressenberg.

At Mattsee there are two, parallel, low ridges composed of highly inclined beds of grit, calcareous shale, and limestone, which run out into a promontory separating the lake from that of Trum. The lowest of these beds are seen on the lake of Trum, and are chiefly made up of calcareous shales, charged with a Gryphæa (*G. expansa**), which, after a careful examination, is found to differ specifically from the *G. Columba*, or any known fossil of the green-sand and cretaceous period. These gryphite-beds dip at an angle of about 70° under a system of thick-bedded, ferruginous, hard grits, full of Pectens and very large Echini. The higher groups are interrupted by a denudation, into which extends the southern end of the little lake of Mattsee; and on its opposite side the older members of the green-sand series rise out from beneath large accumulations of alluvial matter. We are thus prevented, as at the Kressenberg, from tracing any passage between the nummulitic system and the fucoid grits and shales. The calcareous shale with Gryphites seems, however, to occupy a place intermediate between the two groups.

As there is precisely the same difficulty in determining the relations of the strata at St. Pancratz, we have little doubt that a great fault (similar in kind and direction, and probably of the same age with that of the Kressenberg) ranges through this part of the series; throwing the ferriferous, nummulite grits into a vertical or very highly inclined position, by the side of the older and less inclined system of the green-sands and fucoid shales. Without attending to these great derangements, which affect so many of the exterior portions of the chain, one might form a very erroneous estimate of the relative ages of the several groups of strata above described.

Conclusion.

To the east of the Mattsee we did not find any distinct traces of the nummulitic group; but we have stated enough in the preceding parallel sections (commencing at the valley of the Rhine, and ending near that of the Salza), to show its importance in the natural history of the portions of the chain above described†. Independently, however, of specific characters and the direct evidence of sections, Nummulites prove nothing respecting the age of any rock, inasmuch as the genus abounds both in secondary and tertiary for-

* Plate XXXVIII. fig. 5.

† We have before stated, that a secondary nummulite-rock is very largely developed in some parts of the south flank of the Alps, and probably descends as low as the upper oolites.

mations. Mr. Lonsdale, who has entered on a minute examination of the Nummulites found in the various localities above described, distinguishes (in addition to several discoid bodies with a coralline structure, which have often been mistaken for Nummulites) no less than eight species, all apparently new, and only one of them common to all the ferriferous deposits. This shows the risk we run in attempting to define the age of a formation from the mere fact of its containing fossils of this genus.

On reviewing the phenomena of the six preceding sections, we return to our former conclusions—that along the north flank of the eastern Alps the nummulitic series is very largely developed—that its lower portion graduates into, and forms a part of, the upper green-sand and cretaceous system—that its higher portions contain many fossils hitherto, we believe, unobserved in secondary, but abounding in tertiary, formations—that it is surmounted by, and appears to pass into, higher conformable strata with a large group of tertiary shells—and that, considered as a whole, it may therefore be regarded as a great, transition group between the secondary and tertiary systems of the chain *. We think this statement in no respect hypothetical, and that it is only a translation into intelligible language of the phenomena exhibited in a series of actual sections. If, indeed, the higher strata described in this chapter (for example, those at the northern end of the Untersberg section) were overlaid by any known secondary deposit, we should then be entangled in new difficulties, and might have to account for the peculiar succession and distribution of organic forms in the Eastern Alps. We are not, however, called upon to combat difficulties in the existence of which we do not believe.

As the preceding conclusions are not only important in themselves, but are connected with the general scope of this paper, it may be worth while to fortify them by the following observations.

1. All the previous sections prove that a part of the Alpine chain has undergone a movement of elevation at a very recent geological period; but none of them proves that any great or general movement took place between the secondary and tertiary periods; and, under such circumstances, have we not a right to look for (what in point of fact we find) a continuous succession of deposits between the newest secondary and the oldest tertiary groups?

2. Between the secondary and tertiary formations, both of France and

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* Nummulites, though highly characteristic of certain groups of strata, are of course not equally diffused through them. There are several places in the Eastern Alps where, if we mistake not, a transition is effected, from the secondary to the tertiary system, through the intervention of strata in which Nummulites have not been observed.

England, there is an entire solution of continuity; their position is discordant, and they have not perhaps a single fossil in common. But what right have we to assume, that the forces by which this geological continuity was broken, acted equally over the surface of the earth? Agreeably to all analogy, ought we not rather to look in distant regions for some intervening deposits to fill up the chasm and interpolate between the *calcaire grossier* and the chalk?

3. In the neighbourhood of Maestricht, beds are found superior to the chalk, distinct from it in mineral character, and with a suite of fossils, in which are both secondary and tertiary species*. These beds are, therefore, intermediate between the *calcaire grossier* and the chalk; and, if we mistake not, are on the same parallel with a part of the series described in the previous sections. This analogy is so far important, that it entirely removes the improbability of finding an intermediate series between the secondary and tertiary systems of the Eastern Alps.

That the Maestricht beds are superior to the chalk is universally admitted; and if any one chooses to class them with the chalk, or consider them secondary, we wish to have no dispute with him, and only observe that he must previously define his terms, as he uses them in a sense in which no one has used them before.

Our conclusions are greatly strengthened by other phenomena we are about to notice: as, however, they occur in insulated positions, sometimes far within the limits of the chain, we have reserved their description for a separate chapter.

Chap. III.

On a Series of Overlying Deposits which appear at various Elevations within the Chain, and connect the Secondary and Tertiary Systems of the Alps.

After the details of the preceding chapter, which so clearly prove the great internal dislocations of the chain, we might naturally look for the occurrence of some of the newer groups within the limits of the older formations: and in this position we sometimes find them among the serrated Alpine peaks, torn from the beds of which they once were a continuous part, and lifted out of the basin of the Danube several thousand feet above their natural elevation. Of the insulated deposits in this extraordinary position, the valley of Gosau offers perhaps the most instructive example: and we commence with its

* See the abstract of a paper by Dr. Fitton, Phil. Mag. and Annals of Philosophy, N. S. Feb. 1830, p. 140.

description, as we have examined it in all its bearings, and have procured from it a better series of fossils than from any other corresponding locality.

1. *Overlying Deposits of the Valley of Gosau*.*

Before we visited the Alps, these deposits had been described by MM. Keferstein and De Lill. The former author had been led, partly by an erroneous identification of several of the Gosau shells with certain secondary fossils, and partly by some deceptive appearances in the dip of the strata, to consider the whole of them as inferior or subordinate to the adjoining saliferous limestone. Our friend M. de Lill too clearly perceived the overlying position of one portion of the strata, and was too well acquainted with the structure and fossils of all the neighbouring formations, to commit the error of M. Keferstein : he therefore regarded the insulated deposits of Gosau as a system of newer secondary beds, resting unconformably on the saliferous limestone. We, however, think that he placed them lower in the series than they ought to be, and that he also in some measure misinterpreted the evidence of the fossils †. Before we proceed to describe the accompanying sections, it may be expedient briefly to notice the position of Gosau Thal, and the structure of the surrounding mountains.

In ascending the valley of the Traun from Traun-See to the Lake of Hallstadt, we pass a magnificent succession of phenomena, and almost at every step see proofs of the vast dislocations of the chain.

An Alpine gorge, called Gosauwang, commencing on the west side of the Lake of Hallstadt, and running several miles nearly due west, ascends rapidly, through an elevation of more than 800 feet, to the valley of Gosau. Every part of this gorge is narrow; and in many places it presents on both sides a succession of mural escarpments, between which there is no vestige of any deposits extraneous to the secondary limestone: and it might be described as a great cleft in the older calcareous chain, which had allowed an escape to the waters of the upland valley.

It forms no part of our object to describe the picturesque features of the beautiful valley of Gosau; but we may observe, that it is shut in towards the south by a gorgeous, serrated barrier of Alpine limestone, the highest pinnacles of which (in the Dachstein) reach the elevation of more than 10,000 feet above the level of the sea; whilst to the east (with the exception of the gorge above

* See Plate XXXVI. fig. 10. 11. & Plate XL.

† As far as regards the age of the overlying deposits of Gosau, M. de Lill's opinions seem to have been nearly adopted by Dr. Boué, none of whose memoirs on this subject had, we believe, appeared when the abstract of our paper was published by the Geological Society.

described) it is closed in by the lofty limestone-ridge of Blankenstein ; and to the north by a ridge extending from the precipices on the south side of Gosauwang to Gross Rosen-Kogel*.

In all these mountains the limestone is subordinate to the great secondary system of the Alps, is often highly inclined and contorted, contains Ammonites and Belemnites, and in other respects exhibits many of its ordinary mineralogical characters.

It would be quite foreign to our object to describe these secondary rocks in detail. We may however remark—that the lofty serrated peaks which shut in the vale to the south, are composed of several varieties of compact, subcrystalline and scaly limestone, some of which probably pass into dolomites—that in the Henner-Kogel there are subordinate beds of brown chert penetrated by white, siliceous veins, and sometimes divided in a septarian form by veins of carbonate of lime—and that in the Moderer-berg the prevailing rock is a white marble, in one place compact and with a scaly fracture, in another granular, with cylindrical, crystalline stems probably of organic origin, and with weathered surfaces rarely exposing Terebratulæ and other obscure fossils.

Again, we may remark—that on the north-east side of the valley the ridge of the Rosen-Kogel exhibits a white, crystalline limestone, and a compact, pink and white-coloured marble, with veins of carbonate of lime and thin, subordinate bands of chert—and that rocks of this kind are overlaid by bosses of hippurite-limestone, the largest of which, called the Balvenstein, juts out in the dense pine forests on the mountain side north of the village.

Lastly, we may observe—that the secondary mountains shutting in the valley to the east, are not exclusively composed, like Blossen and the highest ridges of Blankenstein, of Alpine limestone—on the contrary, that the lower ridges of Blankenstein consist of a brown, slaty, calcareous sandstone, and a dull grey, arenaceous limestone, in some parts brecciated, in other parts made up of minute fragments or concretions, giving the rock an appearance of oolitic structure—that in these beds are some Belemnites, and many small Gryphites (identified with the *Gryphæa globosa* of the chalk or chalk marl)—that in their range westward they graduate into earthy, impure, arenaceous limestone, of grey, green, and pinkish colours—and that the whole system, at the Brill Graben, abuts against, or is carried under, the marls and slaty sandstones of a still newer series composing the Ressenberg ridge †.

Such are the secondary rocks surrounding the valley of Gosau. The hippurite-rock on the south side of the Rosen-Kogel, and the green-sand series

* Plate XL.

† Plate XXXVI. fig. 10.

on the west flank of the Blankenstein ridge, escaped our observation during our first visit to this valley: and their discovery was not without importance, as they offer us a new proof of the enormous derangements of the chain, and give us new terms of comparison between these overlying deposits and others of the same age, on the outskirts of the Alps, described in the former chapter*.

The waters which descend from the glaciers of the Dachstein are first received in a basin of Alpine limestone, where they form a lake, called Hinter Gosau See, 1300 feet above the level of the valley: thence they rapidly descend through a narrow gorge into a larger lake, called the Vorder Gosau See. From this basin they emerge into the flat and cultivated meadows of Gosau Thal; out of which, after meandering southwards for several miles, they suddenly deflect to the east, and rush down the gorge of Gosauwang into the Lake of Hallstadt.

On the west side the valley is shut in by a remarkable ridge, the highest part of which, called the Horn, is, according to our computation, more than 2000 feet above the level of the village, and therefore about 5000 feet above the level of the sea. This ridge abuts against the great, serrated barrier before mentioned, then ranges nearly due north, and in that direction terminates against the Kalenberg: it also forms the parting of the waters, which on the west side descend to Abtenau, and after traversing a gorge of Alpine limestone flow into the Salza†.

In mineralogical character the beds of this ridge differ entirely from those of the surrounding calcareous mountains. They are much less inclined, are not contorted, and are composed of variously coloured sandstones, marls, and shales; some of which contain innumerable organic remains in a state of perfect preservation.

In following these beds towards their north-western limit near Pass Geschitt, we did not find them in their line of prolongation plunging under the older calcareous chain of Rosen-Kogel: on the contrary, some of the inferior beds gradually acquired a considerable inclination, and were found to rest upon a highly-inclined conglomerate. This conglomerate, here and there presenting appearances of alternating with some of the marl and shale beds, rises to a great elevation on the side of the neighbouring chain, passing above the forests to the base of the highest precipices of limestone. From thence it descends, and continuing throughout in a position perfectly unconformable to the older rocks, passes under the whole system of the Horn, reappearing at its base in the valley of Russbach; where it separates the secondary red sand-

* *Supra*, p. 346, &c.

† Plate XXXVI. fig. 11.

stone and gypseous and saliferous marls of Abtenau (described in the first chapter*), from the unconformable system of the Horn†.

Were there any doubt that the beds of the Horn are unconformable to the surrounding secondary strata, it is cleared up by the section of Ressenberg, on the opposite side of the valley. The beds composing that mountain form a collective mass not less perhaps than 2000 feet thick: from top to bottom they are very nearly horizontal; and the long horizontal lines which separate the several beds, may be traced almost into contact with the inclined masses of the older system. Here again we meet with the same mineralogical characters we had remarked in the corresponding parts of the system of the Horn. The whole mountain is composed of beds of sandstone, sand, variegated marl, and shale, containing multitudes of fossils identical with those in the sections near Pass Geschitt, and on the flanks of the Kallenberg. We may therefore safely conclude, that the beds of Ressenberg and the Horn do not belong to the system of the saliferous limestone. Their age can, then, be only determined, like that of every other independent formation, by their collective characters, and especially by their organic remains‡.

Section of the Overlying Deposits of Gosau in the ascending order; &c.

Having described the position of the overlying deposits of Gosau, and their relations to the neighbouring mountains, we now proceed to enumerate the principal natural groups into which they may be subdivided.

1. A coarse conglomerate system, chiefly composed of fragments, more or less rounded, of Alpine limestone. It is of great thickness at the Kreutz-Graben, and in other places near the side of the pass leading from Gosau to Abtenau, where it rises to a great elevation up the steep sides of the mountains, and rests against beds of Alpine and hippurite-limestone (fig. 11.). It is seen again, as above stated, in the valley of Russbach, on the west side of the Horn, separating the secondary red sandstone and gypseous marls from the overlying series (fig. 10.); and it there appears to have derived its prevailing red colour, and some of its other characters, from the older system on which it rests, and by the partial destruction of which it has been formed.

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* *Supra*, p. 309.

† Plate XXXVI. fig. 10. Figure 11. has become reversed in engraving. To see the strata as here represented, the spectator must be placed in the valley of Abtenau to the west of Gosau. Had Rosen-Kogel been on the right hand of the Plate, it would have then represented the ridge of the Horn as seen from the valley of Gosau.

‡ In Plate XL. the great serrated chain of Alpine limestone is seen in front; and the woody flanks of the overlying ridges of the Horn and the Ressenberg are seen respectively on the right and left sides of the picture.

The following section of this group was obtained from the side of a torrent descending into the valley of Russbach.

a. Coarse conglomerate at the base of the group; the whole thickness not visible.

b. Beds of red and green marl; with some white, granular gypsum; also with some irregular layers containing plates and regular crystals of selenite.

c. Red and green marl like the preceding, with bands of blue marl containing small crystals of selenite.

d. Red conglomerate, with a calcareous cement, containing many quartz pebbles.

e. Deep red-coloured marls of irregular thickness, and mixed with conglomerates like the preceding. On the N.W. side of the Horn these red marls are immediately surmounted by indurated, blue marls containing Cerithia (the first shells seen in the ascending section), and alternating with bands of calcareous and micaceous grit.

The preceding group has probably in some places a thickness of two or three hundred feet; neither its subdivisions nor its thickness appear, however, to be by any means constant.

2. A group immediately superior to the preceding; of the computed thickness of 150 feet, and probably in some places thicker; composed of arenaceous limestone or calc-grit, here and there in strong bands, alternating with beds of pebbles and great masses of marl. In its beds are fossils of the genera Exogyra, Trigonia, and Inoceramus,—a Pecten not perhaps to be distinguished from the *P. quinquecostatus* of the green-sand; to which we may add two species of Hippurites, a large Nerinea, *Tornatella gigantea*, &c.* So far the fossils might be considered of a secondary rather than a tertiary age. But along with the genera enumerated are found Corals, (Fungiæ,) shells of the genera Cerithium and Pleurotoma, &c.; which in their mode of preservation, as well as their specific characters, resemble fossils of tertiary formations.

The section of this group on the N.W. side of the Horn is as follows:

a. Indurated, blue marlstone, with bands of calcareous and micaceous grits. It contains a few Cerithia, and immediately overlies the highest division (*e*) of the preceding group.

b. Conglomerate of rounded quartz-pebbles, alternating with beds of calcareous grit.

c. Slaty sandstone, more or less calcareous, with carbonaceous stains apparently derived from plants.

d. Thick beds of shale with a few bivalves, and a few siliceous pebbles scattered through the mass.

e. Bands of grey, calcareous grit.

f. Compact, blue marlstone, with white veins of carbonate of lime.

The total computed thickness of the beds in this section is about 150 feet.

The following ascending section, taken at the Wegshad Graben, on the road leading over the Pass Geschitt to Abtenau, is very nearly on the same parallel, but is of greater thickness.

a. Blue marls with bands of grit. In this division are traces of shells.

b. Fine conglomerate. The upper part formed of rounded, black, siliceous pebbles in a calcareous cement.

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* Plate XXXVIII. fig. 9.

c. Blue marls with bands of grit. In the marls are numerous fossils, among which the genera Crassatella and Cerithium are abundant; and in the same beds are lumps or concretions of blue limestone, with two species of Hippurites.

d. Great band of hard calc-grit, traversed by many white, calcareous veins.

e. Blue marls with many fossils; among which may be enumerated Fungiæ; many shells resembling those of tertiary formations; Hippurites; a Gryphæa of a new species, but resembling *G. Columba;* &c. &c.

f. Strong beds of a grey, arenaceous limestone with bluish veins.

g. Blue and greenish marls and bands of sandstone; with obscure vegetable impressions.

The two preceding sections will serve to convey at least a general notion of the mineral structure of this group.

3. A great system of blue marls, here and there with bands of indurated marl, calc-grit, or sandstone, and abounding in well-preserved organic remains.

These shell-marls are of very great thickness, and vary considerably in their composition; being in some places greasy and unctuous, and in others meagre and micaceous: but throughout they contain innumerable fossils. In consequence of a slight inclination of the strata to the east, the shell-marls of the Horn are brought down almost to the level of the valley of Gosau *, and are laid bare by the torrents descending from the mountain side. They also appear at Edelbach Graben, and in various ravines excavated by the waters on the north side of the village of Gosau. In some deep gulleys near the base of the Ressenberg, they are seen resting on thick beds of red and variegated marls, which are probably connected with one of the lower groups.

We may further observe, that the shelly marls of Edelbach Graben and other ravines to the north of the village, are thrown off at various angles of inclination from the salient masses of Alpine limestone (on which the whole series rests unconformably), and are thus carried under the higher groups of the Horn and the Ressenberg.

The extraordinary abundance of well-preserved fossils gives a great importance to this subdivision of the ascending section. In it the Exogyræ, Hippurites, Trigonæ, &c., of the preceding group (No. 2.) are we believe wanting, and their places are occupied by myriads of Pectunculi, Cerithia, Volutæ, Fusi, Mitræ, &c. &c.; a very few Inocerami, and a very few Pectens (of a species approaching *P. quinquecostatus*), only remaining to remind us of secondary strata.

4. A series of strata (best exposed on the sides of the Ressenberg), in the following order:

a. Blue and green marls, with bands of sandstone, and with obscure traces of vegetable remains: apparently forming a passage into the lower group (No. 3).

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* Plate XXXVI. fig. 10.

b. Alternations of blue and grey marls. Both this and the preceding subdivision are of considerable thickness.

c. Alternations of yellow, micaceous sand and sandy marls.

5. Greenish grey, micaceous, thin-bedded sandstone. The finer varieties are largely quarried for grindstones; of the coarser varieties, some resemble the Pennant grit of the Bristol coal-field, and others pass into a fine conglomerate with quartz pebbles. This group is of a thickness amounting to several hundred feet, and portions of it are well exposed near the top of the Ressenberg.

6. Partly on the same parallel with the preceding group, but apparently rising still higher in the series, is a system of beds forming the highest ridges of the Horn. Their aggregate thickness is not less than five hundred feet; and they are chiefly composed of red, slaty, micaceous sandstone (variegated with green and grey blotches, and so far resembling new red sandstone) alternating with greenish and reddish arenaceous marls, and without organic remains.

Such are the groups composing the great overlying deposits of Gosau; and we believe we may assert with the greatest confidence, that in the neighbouring mountains no strata are found of a higher geological order, or which have the semblance of passing over them. They seem to have been deposited in a deep bay of the Alpine limestone, and to have originated in the degradation of the surrounding rocks: and if we suppose that the strata of the Horn were in part regenerated from the new red sandstone of Abtenau, and the strata of the Ressenberg from the green-sand on the west side of Blankenstein, we shall have a probable explanation of some of the appearances put on by the preceding groups.

If we inquire respecting the age of these overlying deposits, the question can only be answered by appealing to their structure, their relations to the older strata, and their fossils; and arguments derived from these sources may be strengthened by the evidence of analogous sections in other parts of the chain. Now, there is nothing in the structure of the Gosau series to prove that the whole of it is older than the chalk; and by the evidence of actual sections it appears to be superior to the secondary hippurite-rock, as well as to a part of the green-sand series of Blankenstein. It seems, therefore, to be precisely on the same parallel with a portion of the beds on the north side of the Untersberg section* above described.

Again, the upper shell-marls of Gosau not only contain innumerable fossils, especially univalves, in their mode of preservation as well as in their other characters, resembling those of known tertiary deposits; but several of them are also identical with species, found in the highest shell-marls of the Untersberg section. Every inference derived from that section might therefore, we

* Plate XXXVI. fig. 9.

think, be safely applied to the overlying deposits of Gosau; and we might conclude, without more evidence,—that a portion, at least, of these deposits is newer than the chalk, and belongs to a transition group in a long unbroken series of formations in the Alps, which we have to interpolate between the *calcaire grossier* and the chalk.

If the preceding conclusion be admitted, the sandstone groups at the top of the Horn and Ressenberg must be classed with the tertiary, micaceous sandstone (or *molasse*), which alternates with conglomerate, and forms so large a portion of the tertiary system on the skirts of the Bavarian Alps.

In order to leave none of the evidence for the system we have adopted unexplained, we proceed to a more particular description of the fossils in the preceding groups (Nos. 2. & 3.). As their specific determination is the work only of experienced conchologists, we have gladly availed ourselves of the kind assistance of Mr. J. Sowerby, and have added two plates of characteristic fossils, which are figured and described by that gentleman*.

Fossils of the Overlying Deposits of Gosau.

1. The first time we saw the Gosau sections we felt a strong conviction, that at least a portion of the component groups were superior to the chalk, and probably of the same age as some of the oldest tertiary deposits (namely those at Bassano, Asolo, the Vicentine, &c.) on the southern flank of the Alps. Our first impressions were greatly strengthened by the opinion of an accomplished naturalist, to whose examination we submitted some of the fossils we had derived from the groups in question. Out of more than eighty species M. Deshayes did not detect a single known secondary or tertiary fossil, but he considered the whole suite as decidedly characteristic of an old deposit superior to the chalk. Mr. J. Sowerby, to whom we submitted a still larger collection, especially of the fossils derived from the inferior shelly group (No. 2.), coincided generally with this opinion, but thought that we might identify some of the fossils both with known secondary and tertiary species; and he further pointed out the perfect identity of a Turbinolia and a Fungia of Gosau, with species derived from the tertiary beds of Bassano.

Since the return of one of the authors from his second visit to the Eastern Alps, a much larger and more perfect collection has been examined by Mr. J. Sowerby, and his re-considered opinions are recorded in the following list. It will be seen that he still identifies a few of the Gosau fossils with known secondary and tertiary species. For example, the secondary fossils *Cucullæa*

* Plates XXXVII. & XXXVIII.

carinata, Trigonia alæformis (var.), and *Pecten quinquecostatus;* and the tertiary fossils *Fusus intortus, Auricula simulata, Pectunculus Plumstediensis, P. brevirostris, Nucula amygdaloides,* and *Cyclas cuneiformis,* will appear in the list at the end of this paper. We may further remark, that the above tertiary species are associated with myriads of shells of the genera Mitra, Voluta, Terebra, Volvaria, Cerithium, Pleurotoma, Fasciolaria, and Fusus, which have hitherto been considered characteristic of beds above the chalk.

M. Goldfuss's work* furnishes an additional confirmation of our views respecting the age of the Gosau deposits. They contain many beautiful and well-preserved corals, several of which he identifies with species which occur in tertiary formations; such are, *Turbinolia duodecimcostata, T. cuneata, Lithodendron granulosum,* and *Fungia polymorpha;* to which we may add *Diploctenium cordatum,* which occurs both at Gosau and Maestricht.

2. We are fully aware of the extreme difficulty of identifying fossil species, especially when derived from localities distant from each other. Very experienced naturalists have differed in the identification of certain species derived from Gosau. For example, a Gryphæa has by some been identified with the *G. columba;* but M. Deshayes contends that it is a new species. From the time we saw this fossil in the cabinet of M. De Lill, before we first visited Gosau, we have entertained the same opinion. It has been contended, that in the absence of specific characters we have no right to decide on the tertiary age of any part of the Gosau series. We reply, that, even granting the statement, the argument is worthless. For if any one chooses to affirm that none of the Gosau beds are tertiary (or newer than the chalk), because we know not the species of the imbedded fossils; we have the same right to affirm, from the absence of known secondary species, that none of the beds are secondary. In cases of this kind we can only form a probable opinion from the aggregate character of the fossils. And that this aggregate character is in favour of our conclusion, we affirm, not on our own experience only, but on the authority of every fossil conchologist whom we have consulted†.

3. It perhaps deserves remark—that in the upper shelly group of the general section (No. 3.), univalves greatly predominate over bivalves—and that almost

* *Petrefacten von Dr. Goldfuss.*

† Because M. Deshayes has not adopted our specific enumeration of a few of the Gosau shells, his authority has been very erroneously quoted as opposed to our views on the classification of the whole deposit. On a question of this kind his authority is of great importance; and from the first he has contended that the Gosau shells, considered as a suite, are such as would characterize an old series of strata superior to the chalk. In short his opinion, founded solely on the organic remains, is in perfect accordance with that which we formed, both from the organic remains and the relations of the component strata.

without exception the myriads of shells are in a state of calcination and not of petrifaction. In these respects they resemble the tertiary groups of the Hampshire coast and the Isle of Wight. In the lower group most of the shells are also in a calcined or earthy state, but among them are some species in the ordinary state of petrifactions; for example, the Gryphæa above mentioned, and both species of Hippurites. This structure gives them (especially when contrasted with the other shells) the exact appearance of secondary organic remains: and, after all, may not some of them be true secondary fossils, derived mechanically from older strata by the destruction of which the overlying groups were formed? We do not build upon this, and only throw it out as an hypothesis. But it is in some measure sanctioned by the bosses of secondary hippurite-rock which stand out close to the brim of the Gosau basin: and we think it possible that what we have (in our general section No. 2.) described as concretions of blue limestone subordinate to beds of marl, may in point of fact be rolled masses of the neighbouring secondary hippurite-rock*.

We have now stated all the facts connected with the overlying deposits of Gosau which appear, as far as we are acquainted with them, of any importance to their history; and after a general review of the whole question, we are compelled to return to our first conclusion—that there is nothing in the structure of the beds themselves, in their relations to the surrounding strata, or in their large series of organic remains, to justify us in considering them as exclusively of a secondary period, and still less in placing them with Dr. Boué on the parallel of the lower green-sand. And, on further comparing the several groups with other analogous deposits on the outskirts of the chain (especially as seen in the Arzt and Untersberg sections†), we find that the development of the newer formations, in all the Alpine regions we have described, is in perfect harmony, and that our first hypothesis, so far from being opposed, is confirmed by the direct evidence of natural sections.

Those who have classed the Gosau deposits with the lower green-sand, have been apparently led to that hypothesis, by the difficulty of explaining their

* If this conjecture be true, it will account for the absence of Hippurites in the corresponding group (No. 2.) under the Horn on the Abtenau side; for the deposit is there at a considerable distance from the bosses of secondary hippurite-limestones. Our specimens from this limestone are unfortunately very imperfect. Of the two species of Hippurites found in the overlying marls, M. Deshayes considers one as identical with a species in the Pyrenees, described by Picot de la Peyrouse (*Description de quelques Orthoceratites*, p. 23.), and figured by him in Plate 5.: the other he considers as an undescribed species, which is found also near Toulon.

† Plate XXXVI. fig. 6. & 10.

present insulated and elevated position. We would however remark, that it is equally difficult to explain their present position among the serrated peaks of the Alps, whether they be considered secondary or tertiary. For we have shown, that similar deposits with the same fossils exist on the outskirts of the chain at low levels; from which it follows, that enormous movements of elevation must have taken place since their formation, whatever may be their age. Now among the phenomena we have so far described in this and the preceding chapter, there is unquestionably nothing which limits the movements of elevation to the secondary periods.

When the doctrine of elevation is admitted, difficulties like that we have just considered at once vanish. We have no right to limit the powers of nature. The forces which upheaved the colossal chain of the Alps *may* have raised some parts of it without greatly deranging the inclination of the subordinate strata; and by such a movement the overlying beds of Gosau appear to have been lifted up to the high level which they now occupy. After the full details we have given respecting the overlying groups of Gosau, a much more concise description will suffice for other corresponding deposits.

2. *Section through the Valley of Zlam near Aussee.*

One of the authors having, during the last summer, seen traces of the Gosau beds near Old Aussee, was induced to ascend, by the side of a mountain torrent called the Weissenbach, to the summer pastures of Zlam. They stretch for about a mile in a direction nearly east and west; their greatest breadth is not more than half a mile, being shut in towards the north and south by mural precipices of Alpine limestone; and they are at an elevation probably of not less than 5000 feet above the level of the sea. The Weissenbach flows from a combe at the higher (or eastern) end of this extraordinary little valley, and lays open a series of shelly deposits which occupy all the lower portions of it*.

The lowest of the overlying beds are on the northern side of the valley, and consist of a red conglomerate of Alpine limestone, which, as at Gosau, graduates into bluish marlstone with the large univalves, Tornatella and Nerinea; the whole series being inclined at a considerable angle against the overhanging precipice of the Gros-Berg, on the sides of which the conglomerate rises to the height of about 300 feet above the level of the rivulet. The overlying beds of blue marl contain small Cerithia, Corals, (Fungiæ) Sharks' teeth, and several species of Gosau shells, (for example *Cerithium conoideum*,

* Plate XXXVI. fig. 12.

Tornatella gigantea, Fungia polymorpha, &c.) and abut against the opposite wall of Alpine limestone called the Telschberg; their absolute contact is however, for the most part, hidden by a talus of fragments from the mountain side. This southern ridge consists of red, metalliferous, encrinite-limestone, which we are disposed to refer to the lower system of the oolitic series.

The northern wall of secondary limestone called the Gros-Berg, is chiefly composed of a compact grey rock, with obscure impressions of some bivalves and Ammonites. The face of this rock is singularly scooped out into grooves or furrows, which, wherever the surface is nearly vertical, are straight, semi-cylindrical, and deeply engraven; but where the limestone sweeps down in a slope, they are wider and shallower, and increase in number, branching out from each main trunk so as to look like gigantic arms with expanded and pendent fingers. These furrows offer an instructive example of the gradual erosion produced by the almost continued descent of water during the summer months from the melting snow, and may, indeed, be considered as so many rude, independent chronometers to help us in counting the periods of time during which the surfaces of the neighbouring rocks have been exposed to the action of the elements.

The Gros-Berg shuts out the valley from the beautiful, narrow lake called Gründel-See, the level of which is about 2500 feet below that of the Weissenbach in Zlam; and by this we may form some estimate of the intensity of the moving powers by which the shelly marls were lifted up to such snowy Alpine elevations as we have here described.

No drawing or description can convey more than a faint idea of the extraordinary contortions and dislocations of the rocks which surround the little upland valley of Zlam. The geological phenomena, however modified by local causes, are obviously of the same kind with those of the valley of Gosau: and we have the more pleasure in submitting them to the notice of the Society, as they appear, so far, to have escaped the observation of those who have written on the structure of the Eastern Alps.

3. *Section of the Overlying Strata of Windischgarsten, &c.*

We now proceed briefly to describe some other insulated groups of strata in the prolongation of the Eastern Alps, cited in various memoirs by Dr. Boué: and though we fully agree with him in referring them all to a common system, we deny that they offer any evidence subversive of the conclusions we have drawn from the shelly deposits of Gosau.

The first example we wish to notice is seen among the ramifications of the

Teucher, one of the tributories of the Enns. A series of overlying grits and shell-marls, nearly bounded to the east by a line drawn from Windischgarsten to Spittal-am-Prynn, are extended towards the west over a triangular area of low undulating hills, and occupy a broad bay, which, though in the very heart of the rugged calcareous chain, communicates through a long transverse rent with the drainage of the Enns and the tertiary plains of the Danube. As these shelly beds are much less inclined than the strata of the secondary system surrounding them (some of which are almost vertical), they offer an obvious and perfect analogy, both in their structure and relations, to overlying groups of Gosau.

In detached hills occupying a part of the valley north of Windischgarsten is a coarse, granular, white limestone, in some places almost made up of small Terebratulæ of four or five distinct species, in other places nearly passing into an irregularly oolitic structure. The relations of this rock are obscure; but it seems from its position to be a part of the green-sand series. The sections on the north-eastern side of the town are, however, much more instructive, and give the following successive groups in the ascending order.

1. Younger Alpine limestone passing, at its superior limits, into hippurite-limestone.
2. Calc-grit, fucoid shale, and sandstone.
3. Overlying hills made up of grits, shell-marls, &c., containing many fossils of the shelly series of Gosau, especially such as are found in the lower group.

The facts of this section are so entirely in accordance with what has been described above, as to require no further amplification or comment.

4 *Sections of the Overlying Deposits at Piesting, Neue-Welt, Grünbach, &c.*

Near the termination of the zone of Alpine limestone on the confines of the basin of Vienna, deposits similar to those above described occupy several inosculating valleys on the eastern side of Schneeberg and the Wand. Near Piesting, for example, there is on the left bank of the stream a succession of conglomerates, marlstones, and marls, containing Corals (Fungiæ), and various Gosau shells, dipping to the east from the Alpine range, and passing beneath the acknowledged tertiary formations of the basin of Vienna near Wollersdorf.

A lofty mural ridge of Alpine limestone called the Wand, ranges from the valley of Piesting to that of Grünbach, in a direction about north-east and south-west, and forms the north-western boundary of a singular, longitudinal valley of elevation called the Neue-Welt (New World), which, though very near to the plain of Steinfeld and Neustadt in the basin of Vienna, is entirely shut out from it by a second mural ridge of Alpine limestone parallel to the Wand, but at a lower elevation.

This *Neue-Welt* is filled with deposits like those of Gosau, the lowest beds of which are thrown up into a nearly vertical position against the face of the Wand; but the superior marly beds are lost in the narrow valley underneath great masses of detritus. Instructive sections are seen at Stahrenberg and near the village of Dreystetten, where the following groups of strata, in the ascending order, are piled up vertically against the mountain side.

1. Reddish calcareous conglomerate alternating with calcareous grit.
2. Blue, impure, arenaceous limestone with *Tornatella gigantea*, Nerinea, &c.
3. Reddish calcareous grit.
4. Bluish, gritty limestone, with the above fossils, and one very small species of Tornatella.
5. Dark-coloured marls with shells, amongst which are a Fusus, a minute Turritella, a small Cerithium, and a Venus, all of species found at Gosau. Of the bivalves, one resembles *Plicatula aspera**, also found at Gosau, and another appears to Mr. J. Sowerby almost undistinguishable from *Cyclas cuneiformis*† of the Woolwich tertiary beds.

These marls and marlstones, dipping rapidly to the east, are soon lost under hillocks of alluvium and pebbles, which cover the surface of the Neue-Welt, and conceal the relations of the higher shelly strata to the lower ridge of Alpine limestone on the east side of the valley.

Near Meyersdorf blue, micaceous shale and marl crop out at the foot of the Wand from beneath a heap of fallen fragments. In these beds we detected minute, flattened specimens of a Placentula? (Lamarck.) It has been stated that Lituolites are found near this place, but we could discover no traces of them.

The best exhibition of the overlying strata in this region is obtained by a section from the south-western face of the Wand to the village of Grünbach, in the narrow transverse valley of that name‡.

The Alpine limestone with which the section commences has a brecciated structure, is semi-crystalline, and of a pinkish hue, so as very much to resemble the Salzburg marble found on the north side of the Untersberg. It graduates into a grey limestone forming small conical bosses, containing two or more species of Hippurites, a Sphærulite or Radiolite, and a singular, attached shell, which at first sight might be mistaken for a Nautilus, but has been proved, by means of a polished, transverse section, to be a bivalve‡.

* Plate XXXVIII. fig. 7. † Min. Con. Tab. CLXII. fig. 2. & 3.

‡ See Plate XXXVI. fig. 13.

§ M. Deshayes, who has seen these fossils, states, that of the Hippurites two species are entirely new; that the Sphærulite or Radiolite is also a new species, but that analogous specimens are found in the cretaceous or upper green-sand formation of Angoulême; and that the attached bivalve (which is found also in the hippurite-rock of the Pyrenees) must probably be formed into a new genus.

These beds of hippurite-limestone are well exposed near the village called Adrigang, and are covered by a grey, hard grit probably of the green-sand series.

The strata of the ascending section are best exposed along the course of a small rivulet which descends to Grünbach, a little to the west of Adrigang. On that line we have the following groups of strata; and we may observe, that as they advance into the valley they gradually become less inclined, those near the side of the Wand being quite vertical.

a. Yellowish sandstone with green grains, alternating with bands of shale: the whole thickness of this group is not exposed.

b. Coal, two to three feet thick, worked on the *strike* of the beds by horizontal galleries driven from the side of the rivulet.

c. Sandy shale and finely laminated marl, at least 300 feet thick, and of various colours, yellowish, blue, grey, and green.

d. Coal. An upper bed of about the same thickness as the preceding, and worked in the same manner. The carbonaceous and hard calcareous grits forming the walls of this seam are full of small, compressed shells, among which a bivalve, probably a Cyclas, is the most characteristic; and a small Turbo appears to be of a species found at Gosau. The best parts of the coal are of good quality, but the refuse is so pyritous that it ignites spontaneously by exposure to the atmosphere.

e. A series of marl and shale beds, ill exposed, being partly obscured by alluvial covering, and partly carried away by denudation.

f. Hard nummulite-grits rising into a ridge. In these beds we could detect no other fossils; and the Nummulites themselves are so cemented in the solid rock as to make it almost hopeless to look for specific characters.

g. An interval in which a series of soft beds have been nearly washed away. They appear to have been composed of blue marls, and to have contained many fossils (such as Fungiæ, &c.), which are found scattered upon the surface.

h. Harder and more arenaceous beds near the village of Grünbach, with shells of the genera Inoceramus, Pectunculus, Rostellaria, &c.

The rocks south of the village consist of micaceous and calcareous sandstone, and are specially distinguished by serpuline bodies very similar to those found in the nummulite-grits which overlie the cretaceous group of the Untersberg section, and underlie the blue marls with Gosau shells*. On this account we are disposed to consider these grits as a part of a group older than the marls in the centre of the valley of Grünbach.

To make the preceding section complete, it ought to be prolonged across the valley and joined to the outer or south-eastern ridge of Alpine limestone. We have, however, abstained from this, as we wish none of our illustrative

* Plate XXXVI. fig. 9.

sections to be hypothetical. Both the succession and position of the overlying groups in that direction are obscure; but we think it probable that the lower groups are again brought up and tilted at various angles against the second Alpine ridge. In that case the whole system will have somewhat of an irregular, trough-shaped arrangement; and in a narrow valley of elevation like that of Grünbach, such a collocation of the overlying masses is not improbable.

It has been stated by Dr. Boué, that Belemnites are found in the overlying series of Grünbach. Professor Partsch and one of the authors of this paper, after an assiduous search, could not discover the least trace of them. The only bodies they found, of which certain fragments might by chance be mistaken for Belemnites, were the large Serpulæ before mentioned. Did Belemnites exist as true characteristic fossils of the beds in question, we should still (after the facts above stated) deny the inference which has been drawn from their supposed presence.

We believe that the several overlying deposits described in this chapter are nearly of the same age, and belong to one common system of formation. The succession of strata, and the groups of organic remains in the Gosau sections (especially when brought into comparison with the series of deposits north of the Untersberg), were the foundation of conclusions we need not again repeat. None of the subsequent details of this chapter offer evidence by any means so complete: we venture, however, to affirm, that as far as it goes it does not invalidate but confirms our previous inferences, and is in harmony with our theory respecting the succession of organic forms in the Eastern Alps.

If the elevations of the various groups described in this chapter offer us a clear proof of the vast movements which have affected the chain within a comparatively recent geological period, the insulated position of the overlying masses seems also to make it probable that they never existed on the outskirts of the chain, but were deposited within it in deep bays or estuaries. May we not suppose that the shell-marl among the Alpine peaks of Zlam and Gosau, and similar masses of shell-marl which appear (e. g. in the valley east of Ischel, and in one or two lateral valleys on the east bank of the Traun-See) at levels lower by two or three thousand feet, were once almost continuous in a deep bay, of which all traces have been since obliterated by vast disruptions and movements of elevation? We only offer this as a natural mode of explaining a very great difficulty, arising out of the position of the overlying masses—one, however, which is not immediately connected with any question respecting the age of these masses, or the conclusions we have drawn from their examination. Our supposition will, we think, be rendered still more probable by the position of the lignite basin of Häring, which we shall attempt to describe in a part of the next chapter.

CHAP. IV.

On the Lignite Basin of Häring in the Valley of the Inn, and on some other Deposits of the same kind on the Outskirts of the Austrian and Bavarian Alps. Section at Ortenburg, near the Junction of the Danube and the Inn, &c.

Before we enter on a detailed section of the tertiary coal formation of Häring, it is necessary to notice the peculiar dislocations of the neighbouring portions of the Alps.

In traversing the mountain gorges by the road from Reichenhall to Inspruck, we find that vast disruptions and inversions of dip have thrown all the central portions of the secondary region into inextricable confusion. Before the road emerges from the calcareous chain into the plains of St. Johann, the strata, however, recover their usual position and elevation; and from that village, bare mountains of the older Alpine limestone (dipping to the north, presenting mural precipices to the south, and resting on terraces of red marl, sandstone, and conglomerate) are seen to range, on one side in the direction of Salzburg, and on the other towards the valley of the Inn. Following the chain towards the east by the foot of the great escarpment, we may remark, that the position of all the component strata is once more disturbed before they reach the right bank of the river near the village of Häring, and that the whole Alpine limestone series of the Bölfen, along with the red sandstone and conglomerate, pitch down at a great angle to the north-west, and plunge under the level of the valley.

One might expect, from the bearing of the chain, that the several groups of strata would, in their prolongation, strike the mountains on the left bank of the river. The order is, however, once more broken, and none of the beds, last described, reappear on that side of the Inn: for we there find a great succession of calcareous precipices composed of a younger part of the Alpine limestone series, without any indications of the red sandstone and conglomerate, and dipping at a high angle towards the north-west; and this dip continues, almost without interruption, as far as Inspruck through the whole saliferous chain; the beds of which have, in consequence, the appearance of plunging under the older formations of the central Alps.

If, on the contrary, we ascend from Häring by the right bank of the Inn, we first see masses of red sandstone and conglomerate at the base of the great precipices of Alpine limestone, and then we find, rising regularly from beneath them, a long succession of dolomitic beds, alternating with red marl and sandstone, dipping to the north, and forming a succession of low ridges as far as Schwatz, where they rest against the primary rocks of the central axis.

In this way all connexion between the strata on the opposite sides of the river is entirely interrupted. A great complex movement of elevation seems to have broken up the neighbouring portions of the chain, and thrown them into positions the most discordant, and at the same time to have formed that long transverse chasm through which the waters of the Inn escape into the plains of Bavaria. What was the date of these internal movements we do not now inquire; but it is obvious that they were anterior to the existence of the unconformable tertiary basin which we now proceed to describe*.

The dislocated secondary rocks which flank the Inn on either side, are expanded between the towns of Rattenberg and Kufstein, in such a manner as to leave between these two places an elliptical basin about twenty miles in length, and four or five in its greatest breadth, on the sides of which are found the remnants of ancient tertiary strata. They are exhibited on the largest scale near the village of Häring, where they form hills seven and eight hundred feet high, and contain a subordinate mass of coal of great thickness, which is extensively worked. No traces of them have been observed higher up the valley than Kranzach near Rattenberg; and all vestiges of them are lost near the narrow gorge of Kufstein, although formations apparently of the same age are largely developed beyond the gorge, and connect themselves with the great tertiary system on the north flank of the chain. It is, however, probable that the overlying beds were once much more extended than they are now; and notwithstanding the few fragments of them which remain, they may formerly have occupied a considerable portion of the whole elliptical basin in the valley of the Inn.

They are not only distinguished by the vast quantity of good, compact lignite which they contain, but also by an abundance of land shells, and by a profusion of vegetable fossils mixed with shells both fluviatile and marine. The form of the country and the structure of the beds, at first sight led us to consider that they were entirely of lacustrine origin. But the presence of marine shells in many of the beds (one or two of which resemble fossils of the older tertiary periods), compelled us to conclude, that an arm of the

* Plate XXXVI. fig. 8.

ancient sea penetrated this part of the valley of the Inn during, and long after, the deposition of the coal.

The general relations of the whole system to the neighbouring secondary rocks, will be best seen by referring to the accompanying section; which shows that it is basin-shaped, and that it dips from the mountain chains, on both sides of the Inn, towards the centre of the valley.

The several horizontal galleries by which the coal of Häring has been reached at different levels, exhibit a gradual thickening of all the associated beds as they descend, unconformably, from the sides of the secondary rocks into the valley of the Inn. Thus the coal which had only a thickness of twelve or thirteen feet in the early works, where the mineral rose to the day on the mountain side, was found to have increased to twenty-five feet when the Francisci-Stollen was driven; and it has a thickness of thirty-four feet where it is now worked at a still lower gallery, the Barbara-Stollen.

For like reason, the lower adit or Barbara-Stollen offers a more expanded section of the several groups than the Francisci-Stollen, which is 160 feet higher; the former extending 730, and the latter only 550 feet through the same series of beds above the coal: and so greatly do the strata swell out in the prolongation of their dip, that were a gallery to be driven on the level of the Inn, it must extend more than 1200 feet through the same overlying beds in order to reach the coal, which at that depth has been proved by actual boring to be about 50 feet thick. From these data, combined with the average inclination of the beds, it has been calculated that the greatest thickness of this tertiary group, when measured on a line perpendicular to the planes of stratification, is not less than 700 or 800 feet.

The gradual thickening of the beds from the sides to the centre of the basin, is a strong proof that the deposit was accumulated in an estuary; for such appears to be the manner in which matter is now deposited at the mouths of rivers which empty themselves upon a steep shore. This analogy is confirmed by other peculiarities of the Häring formation; for the beds accommodate themselves to, and are moulded upon, the declivities of the older formations. Thus we find the overlying strata slightly inclined at their highest level on the mountain side, but their dip increases to 36° (its maximum) at the Barbara-Stollen, which appears to have been the steepest part of the ancient shore; and below it the inclination of the beds again gradually diminishes with the augmentation of their thickness.

The structure of some of the subordinate beds further confirms the propriety of a comparison of this deposit with modern estuary accumulations: for among several parts of it, which by themselves would be difficult to account for, we find indurated and finely levigated river silt, charged with plants and land shells, and occasionally mixed with marine shells; and amidst these masses are, here and there, a few alternating layers of conglomerates, containing pebbles derived from the neighbouring mountains. It seems almost impossible to explain the origin of such beds otherwise than by supposing them to have been drifted by rivers or mountain torrents into an ancient estuary or arm of the sea, extending up this part of the valley of the Inn. In thus endeavouring to account for the position of the overlying groups of Häring, we by no means wish to exclude any agent which has been at work since their deposition. Not only may a great part of them have been swept away from the valley of the Inn, but the position of those which remain may also have been considerably modified, by the disturbing forces which have since acted on the chain.

1. *Detailed Section of the Coal Formation of Häring.*

The following section of the beds associated with the tertiary coal formation of Häring is exhibited in the Barbara-Stollen, one of the adit levels; and the details here given are derived partly from our own observations and the existing documents at the mine, and partly from the information kindly communicated by Mr. Pöhringer of Halle, under whose direction the adit was first undertaken. A very detailed history of the works is given by Professor Flürl of Munich, in his "*Steinkohlen Gebirge von Häring*," from which we have also abridged some parts of the following section. As this author has misnamed several of the organic remains, we are unable, in everything which relates to the zoological history of the strata, to place much reliance upon his specifications*. But with this limitation, his memoir is a valuable official record; although, perhaps, unnecessarily expanded.

The following groups are given as they appeared in driving the adit, and are consequently in the descending order.

	Ft.	In.
1. Layers of yellowish, grey, micaceous, indurated marl, with a few well-preserved organic remains	120	0
2. Conglomerate made up of angular fragments of smoke-grey and reddish		

* For instance, the land shells of the genus Caracolla (of which many flattened specimens exist in the coal beds) are called by him small Ammonites. A single error like this affects the whole nature of the zoological evidence exhibited by the strata. We had no opportunity of seeing many of the organic remains described in Professor Flürl's list. In some of the collections of the country we, however, saw many fossil shells said to be derived from Häring; but the information they communicated was considerably diminished by their not having been carefully separated from the fossils of the secondary limestone.

limestone, cemented by light grey, indurated marl: the smaller fragments are of the size of nuts, and the larger are several inches in diameter. Small ill-preserved organic remains are seen in the lower part of this bed. 4 0

3. A great development of dark grey marls, with a few marine shells 120 0
4. Thin layer of fine-grained, calcareous sandstone, in its lower part passing into a fine, calcareous conglomerate containing various shells, as Ostreæ, Pectens, &c. 20 8
5. Thin-bedded marls with many incoherent, indeterminable shells. Thin lines of white earth made up of these decomposed shells mark the laminæ of deposit. In other layers these shells constitute the whole mass. The more the beds approach the underlying fetid limestone, the better are the organic remains preserved 130 0
6. Bed of very indurated bituminous marlstone of dark colour, and highly fetid: siliceous sand is mixed irregularly with the mass. This bed is stated by Flürl to have contained corals and other marine shells. We observed Serpulæ (probably derived from this bed), which Mr. Sowerby considers of the same species with those of Gosau, but saw no madrepores like those described by Flürl................(*Thickness not given.*)
7. Conglomerate, partly brecciated, partly made up of rounded pebbles of compact limestone, with some fragments of shells 4 6
8. Stinkstone—a great development of a highly fetid, slaty, cream-coloured marlstone, with many plants and some shells. It forms the roof of the lignite, and usually splits into finely laminated slabs, like the lithographic slate of Solenhofen, offering a prodigious number of carbonized impressions of leaves and plants between the laminæ. (*Thickness not given.*)

In the stinkstone the following mineral varieties have been noticed.

a. Hornstone—in small, irregularly spheroidal concretions.

b. *Brand-schiefer*—a kind of porcelain earth in a thin layer above the coal, to the spontaneous combustion of which some of its characters are probably due. A part of this "burnt earth" on weathering resembles bituminized wood, and burns rapidly, leaving out of 800 parts 334 of ashes; so that $57\frac{1}{2}$ per cent. of bitumen and water pass off during the combustion.

c. Carbonate of lime—traversing, in small transverse veins, all the beds of stinkstone and overlying marls. Some of the crystals of carbonate of lime are so charged with bitumen, that when subjected to great heat they give off petroleum.

d. Agaric mineral or mountain milk—subordinate to the fetid marlstone, and similarly laminated. It is called "nichts" by the workmen.

e. Pyrites and Selenite—in crystals between the laminæ.

Mr. Flürl conceives that some of the bituminized and altered fetid marlstones are due to an ancient, spontaneous combustion of the coal.

Among the fossil plants are many which the older authors compared to existing species of Salix, Ligustrum, Rhamnus, Erica, &c., as well as to Ferns and Mosses. We have, however, seen none which appeared to justify such comparisons: and from a considerable number we obtained on the spot, chiefly through the liberality of the *Berg-Meister*, we are enabled to give the following results, which we communicate, as nearly as possible, in the words of M. Adolphe Brongniart, who kindly undertook an examination of our specimens.

"After an examination of all the specimens, I am still in doubt as to the greater number of them; for, either from their being too incomplete, or from not having made a sufficient number of comparisons, I am unable to arrive at very precise results. They appear to me to belong to eleven species.

"1. *Juniperites subulata.* The form and the insertion of the leaves appear to me to indicate a *Juniperus*, allied to, though distinct from, that found in the lignite formations of Bohemia, which I have named in my "Prodromus" *Juniperites acutifolia.* I possess specimens from the freshwater formation of Armissau near Narbonne, apparently of the same species.

"2. *Juniperites* (??) *cespitosa*, (*Lycopodiolites cespitosus* Schloth. *ex specimine ab auctore misso*). The leaves, which are linear, obtuse, and dilated at the base, are more numerous than in the preceding species, and are disposed without any distinct order, which induces me very much to doubt whether it be a *Juniperus*, or even one of the *Coniferæ*. A specimen of my own from the same locality, which appears to me decidedly of the same species, presents *capitula* of fruit at the extremity of the branches, much more resembling a *capitulum* of the *Compositæ* than the fruit of a *Cupressus*, or any other of the *Coniferæ*. The place of this plant is therefore entirely uncertain.

"3. *Thuja nudicaulis.* Branches naked, with small opposite tubercles and a laterally inserted fruit, having only a single scale, and therefore closely resembling the fruit of the *Thuja*. If the fruit really belong to this branch, it is beyond doubt a *Thuja*, and allied to *T. articulata.*

"4. *Comptonia breviloba.* A new species intermediate between the living species and the two known fossil species.

"5. 6. 7. 8. *Phyllites*, four species, differing from all the fossil species I am acquainted with. Judging from the analogous arrangement of their nerves, and the shape of their dentations, they belong apparently to the same genus of plants. It might perhaps be determined to what family they belong, but very numerous comparisons are yet wanting.

"9. 10. *Phyllites*, indeterminable.

"11. *Phyllites*, with three nerves—very distinct, however, from another species with three nerves (common in many tertiary formations), the margin of which is entire, while the margin of this is regularly toothed.

"It is very remarkable that among the multitude of fossil leaves I possess from tertiary formations, there is not one quite identical with any of these specimens; and the forms, elsewhere very abundant in such formations, are not met with at all at Häring. For example, I have never seen among the plants from this place any of the lobed leaves analogous to those of the Maple, which are so common in the brown coal of Frankfort and other places*."

Mixed with the plants are some casts of small bivalves, especially of the genus Cyclas. Where the stinkstone is compact, the shells are generally rare: it was however in one of the most compact layers that we found the *Auricularia simulata* (?) of the London clay, a small Rostellaria, and several minute Ostreæ. In the lower marly laminæ land shells begin to appear; and a tortoise, measuring six inches by three and a half, is stated to have been found in this part of the series.

9. Coal beds.—In the upper part of these beds fetid marlstone and marl alternate with imperfectly formed coal, containing numerous land shells. They are usually flattened and of a spiral shape, and were at one time mistaken for Ammonites. These shells are now referred to the genus Caracolla, and are of two species †. All traces of shells and plants gradually disappear, and the coal passes into a nearly compact mass, of which there are several varieties distinguished by the miners as follows.

a. Pech-kohle—colour velvet black, and with little bitumen.

b. Schiefer-kohle—slaty coal.

c. Schuppen-kohle—a variety resembling Cannel coal.

d. Glanz-kohle—a sort of coke or anthracite, the bitumen having probably been driven off at the period of combustion when the porcelain earth was produced.

Iron and copper pyrites pervade the upper part of the coal; the latter mineral occasionally giving a metalloid lustre to the flattened land shells. The total thickness of the coal beds pierced by this gallery is thirty-four feet; of which more than two-thirds is of good quality, and is largely extracted for the use of the salt-works at Halle near Inspruck.

We have before stated, that the coal increases in thickness on the line of dip, and that by boring below the present works, nearly to the level of the river Inn, it has been proved to be fifty feet thick. The mineral is worked on the *strike* of the beds, which is from N.E. to S.W.; and the dip where the Barbara-Stollen cuts the coal is nearly at its maximum, about 36°. The thickness of the fetid beds overlying the coal is considerable, but it is omitted by Flürl, and we had no means of ascertaining it with precision.

* The plants above described will be figured in a future Number of M. Adolphe Brongniart's *Histoire des Végétaux fossiles*."

† Dr. Buckland has favoured us with a series of specimens collected by himself at Häring in the year 1820. Among them are the following fossils. Caracolla; Cerithium (?); Cyclas (?); Paludina (?); Rostellaria, near to *R. Pes Pelicani;* Crenatula or Perna.

Below the coal there are irregular bands of argillaceous marl, with thin laminæ of imperfect lignite, traversed by numerous small veins of carbonate of lime; and pyrites is so abundant in these thin beds, that much vitriol has been extracted from them.

Finally, the whole deposit is separated from the secondary system, on which it rests unconformably, by a thin, irregular band of conglomerate, almost entirely made up of fragments of Alpine limestone, in which are seen the organic remains peculiar to it, such as Terebratulæ, Belemnites, &c.

The thickness of the beds in the previous section is estimated in Vienna feet, and in the direction of the horizontal drift line. As, however, the several groups of strata along this line are on the average inclined at about 36°, it is obvious that their true thickness, estimated in the direction of a line perpendicular to their planes, is only a little more than half that which is indicated by the numbers affixed to them.

The preceding details have, we hope, conveyed a correct, general notion of the relations of the Häring lignites; and we may remark by way of conclusion, 1st, That the overlying groups on the left bank of the Inn are brought successively into contact with the older Alpine limestone, the red marl and conglomerate, and the dolomitic beds associated with them—that on the other side of the basin, the same groups come into contact only with the younger divisions of the Alpine limestone—and that this collocation arises out of their unconformable position among the ancient formations of the chain. 2dly, That during the progress of the deposit, the sea penetrated far up the valley of the Inn—and that, consequently, the chain must have undergone a great movement of elevation since the completion of the overlying groups. 3rdly, Notwithstanding this last movement of elevation, and the subsequent degradations of the chain—that the valley of the Inn existed somewhat in its present form before the commencement of the deposit—and, consequently, that the great disturbing forces which dislocated and broke up the older parts of the neighbouring chain had come into action at a time anterior to the existence of the whole overlying series.

2. *Sections on the Banks of the Lech; various Deposits of Lignite, &c.*

None of the previous sections, excepting that of Bregenz *, conveys any adequate notion of the enormous thickness of the tertiary series between the north flank of the Alps and the plains of the Danube. Our attention was so much given to the dislocated groups on the skirts of the secondary system, that we had no time for any detailed examination of the strata descending

* Plate XXXVI. fig. 3.

towards the northern plains; and in the few traverses we made in that direction, we found the regular deposits so much concealed by masses of horizontal conglomerate, like that of the accompanying sections (fig. 6. & 9.), as to give very little definite information. Their correct description can only be attempted after a patient comparison of many parallel sections: for the purpose, however, of conveying a general notion of these deposits, we may briefly refer to some of the phenomena on the banks of the Lech between Fussen and Schöngau.

The river, after emerging from the side of the chain at Fussen, runs for some miles in a broad plain covered by the waterworn detritus of the mountains, and then traverses for about ten miles, in a direction nearly due north, a hilly region marked by low, irregular ridges of coarse conglomerate ranging parallel to the chain. Though the beds are ill exposed in the greatest part of this long traverse, we have evidence enough to prove—that they are highly inclined and have an almost undeviating dip to the north—and that the conglomerates (which give an impress to the whole character of the country) alternate, here and there, with micaceous, sandy marl, and greenish micaceous sandstone, hardly to be distinguished from the *molasse* of the Lake of Constance*. There may be some unobserved faults and dislocations, producing a repetition of certain parts of this system: but after every possible deduction, its aggregate thickness must be enormous.

At Lech Bruck (about twelve miles north of Fussen) we have the following ascending section of a remarkable group of strata, which dip nearly due north at an angle of about 60°, and occupy the bed of the river for three or four hundred paces.

1. Micaceous, flaggy sandstone, with traces of carbonaceous matter.
2. Thick-bedded sandstone, with broken stems and carbonized fragments of plants, overlaid by a bluish marl.
3. Fine-grained sandstone, here and there passing into a conglomerate.
4. Greenish grey, micaceous shale, with a seam of coal about three feet thick.
5. Coarse-grained micaceous grit.
6. Beds of coarse and fine grits surmounted by red and variegated marls, with a band of reddish, concretionary limestone resembling the *cornstone* of the old red sandstone.
7. Hard, calcareous sandstone.

These strata have no characters which are not found in secondary deposits; and we did not see a single fossil in any one of them to assist us in deter-

* A fine, greenish, micaceous standstone is extensively quarried to the north of Fussen, but we do not venture to decide upon its relations, as we did not visit the works, and know of no mineralogical means of certainly distinguishing the secondary and tertiary green sandstones of the Alps from each other.

mining their age. Notwithstanding this, from the general position of the group, as well as from the analogy of other sections, we think it undoubtedly a part of the tertiary system.

After quitting the group last described, the river again winds among low round-topped elevations, undeserving of notice, till it passes near the base of Weibach, Peissenberg, and other hills in the neighbourhood of Schöngau, where it exposes a considerable succession of beds, dipping still toward the north, but at a small angle of inclination. The strata, indeed, in this latitude seem to have been comparatively little affected by any elevatory movements of the Alps. The following section, in the ascending order, derived from the escarpments south-east of Schöngau, will give a general notion of the structure of these upper tertiary groups.

	Feet.
1. Yellow and blue, unctuous marls, with bands of greenish grey, micaceous sandstone containing a few rolled pebbles. .... Thickness exposed	28
2. Conglomerate, with a cement of sandstone	3
3. Unctuous marls throwing out springs	20
4. Bluish grey marls, with obscure traces of shells	12
5. A system of blue and yellowish marls; in some parts unctuous, in others sandy and micaceous: containing bands of coarse, brown sandstone, of greenish blue, micaceous flagstone, of calc-grit passing into conglomerate, and, near the top, of indurated marl, assuming, here and there, a septarian form	100
6. Yellow, ferruginous sand, with bands of ferruginous and micaceous sandstone..	30
7. Great masses of conglomerate, obscurely stratified, containing some large, angular masses both of secondary and tertiary rocks, here and there mixed with, and seeming to pass into, coarse sand and greenish, micaceous sandstone....	80

We have little doubt that the conglomerates (No. 7.) belong to the old, horizontal formation above alluded to. They cannot, however, be so readily separated from these slightly inclined groups, as they were from the highly inclined strata of the Arzt and Untersberg sections*. The marl beds of

* Plate XXXVI. figs. 6 and 9. We before stated, that the horizontal overlying conglomerates were probably formed immediately after one of the most recent elevations of the chain; and that they are not only spread over the edges of the strata descending to the northern plains, but also penetrate within the lateral valleys of the Alps. As a remarkable, additional instance of this kind, we may here mention a horizontal deposit, two or three hundred feet thick, which appears on the left bank of the Isar, below Mittenwald, twenty or thirty miles from the place where the river emerges into the tertiary plains. It consists of a coarse conglomerate of rounded calcareous pebbles irregularly mixed with sand, sometimes cemented into a solid rock, and of strong beds of yellow sand, here and there, containing subordinate, irregular beds of yellowish white, semi-indurated marl, called chalk (*kreidé*), which is worked and exported to Munich and Vienna. The regularity and great thickness of many of these deposits make them very unlike the diluvial formations in our island.

the preceding section occupy the banks of the Lech for some distance to the north of Schöngau; but we did not follow the river in that direction, and the plains stretching northwards are nearly covered with the horizontal conglomerates. The bands of marlstone and calc-grit alternating with the marls and conglomerates of the Peissenberg hills, contain some well-preserved fossil shells; and we found that coal had formerly been worked in the lower strata of these hills at several places near the banks of the Ammer.

Meagre as is the information conveyed by this traverse from Fussen to Schöngau, it is more instructive than any other similar section we are able to offer; and it at least demonstrates the great, and almost incredible, thickness of the newer deposits on the outskirts of the Alps. It further shows that lignite is, by itself, no test of the age of any tertiary deposit; in as much as we have on the northern skirts of the Alps, two, or more, courses of that mineral, one in the lower and another in the higher part of the series, separated from each other by vast sedimentary formations. Without assuming the former continuity of distant deposits of lignite, we think it evident that they were developed through a considerable extent of the lower tertiary groups, between the Lech and the Inn: for, in addition to the localities above mentioned, we find traces of them at Pensberg, a few miles N.W. of Benedict Bayern; at Tölz, on the right bank of the Isar; and at Parsberg, near Miesbach—all which places seem to be nearly on the same parallel.

A level was driving to the Pensberg coal when we visited that district in 1829; but we have not heard whether the works have been since prosecuted. In a mass of bituminous and calcareous shale derived from the excavations, we found many flattened or broken and a few well-preserved fossils, among which were the following genera: Cyclas? two species; a transverse bivalve resembling a Mya; Cardium; Venericardia (?); Cerithium or Potamides, and Calyptræa.

The works at Tölz and Parsberg have been many years deserted; we however visited the latter locality, and found that the place where the lignite bed had been last opened was in a deep ravine, called Sulz-graben, on the left bank of the Leignach, about a mile south of the village. The coal is not, however, confined to this ravine; for it has been traced in several parts of the tertiary hills, which range near the north end of the Tegernsee (parallel to the ridges of secondary green-sand), and are traversed by deep gorges, laying bare their interior structure.

The sections at the Sulz-graben show the following groups in the ascending order.

1. Yellow sands.
2. Yellow sands with beds of pebbles.
3. Greenish, micaceous sandstone.
4. Blue and greenish, arenaceous, shelly marls, with bands of blue, impure, argillaceous limestone, and greenish, micaceous sandstone.
5. Dark, fetid, bituminous marls, with a bed of lignite three or four feet thick.
6. Dark-coloured, shelly, arenaceous marls, with stone bands.
7. Micaceous sandstone, weathering brown, but on fracture exposing a greenish surface.

These groups rise into undulating hills 500 or 600 feet high; and all the subordinate strata have an undeviating dip S.S.W., at an angle of about 60°; and therefore *appear* to plunge under the secondary system of the Alps —a new example of what has been several times noticed in the previous parts of this paper.

The lignite varies in quality; some parts crumble into small, black, cuboidal fragments, and others have almost the external appearance of jet. The argillaceous stone bands, above and below the lignite, contain many fossils, and are extremely fetid under the blows of the hammer. The partings of the stone bands are sometimes almost covered with flattened shells of the genus Cyclas: in the marls many of the shells are in a state of beautiful preservation, but cannot probably be identified with any published species. From some of the groups above mentioned, we collected specimens of the following genera: viz. Melanopsis; Cerithium; Cyclas, very nearly resembling a Cyclas of the Woolwich beds; Lucina, of the same species as one found in the Marzoll marls*; and an unknown bivalve.

We might now proceed to notice the lignite deposits of Pielach near Mölk, and other places on the Danube, but we think it better to postpone their description to a subsequent chapter. We have stated enough to show, that there are many deposits of lignite on the northern skirts of the Eastern Alps, and that they are not all on the same parallel. The one last described is subordinate to the lower tertiary groups, and *may* be of the same age with the deposit of Häring. We offer this merely as a conjecture; for although the fossils of the Häring system unequivocally prove it to have been formed in waters communicating with the sea, they are by no means sufficient to prove that it was contemporaneous with the coal of Parsberg. The difference of mineral structure in the two deposits may, perhaps, be explained by their entire difference of position in respect of the secondary Alpine formations.

The previous details of this chapter prove—that during the successive periods when the lignites were deposited, an ancient sea washed the northern

* Untersberg section. Plate XXXVI. fig. 9.

base of the Alps (then presenting an elevation widely different from what they do at this time)—and that its bays or estuaries in some places penetrated far within the exterior limits of the chain. In this way the details seem to confirm the hypothesis by which we endeavoured (at the end of the former chapter) to account for the presence of the overlying groups of Gosau, so far within the secondary regions of the Alps. In making this remark, we do not assume that the deposits of Gosau and Häring are of the same age; all we contend for is, that what we can prove to have taken place during one period in the history of the Alps, may have taken place during another.

3. *Section from Ortenburg, through Furstenzell, to the Banks of the Inn, &c.*

So far we have described a series of sections which, almost without exception, tend to prove the recent elevation of the Eastern Alps. If, however, we cross the plains of the Danube to the outskirts of the Bohemian chain, we no longer see the secondary and tertiary formations thrown up against it at a high angle; but we find them resting almost horizontally, like the deposits of an ancient shore, among promontories and islets of primary rocks. Such is their position in the section we are about to describe; which extends, in a direction about N.W. and S.E., from the hills near Ortenburg to the Inn, a little to the west of the confluence of that river with the Danube*.

A detailed description of this section would belong to the history of the Bohemian, rather than of the Alpine chain. As it is, at least, geographically connected with the subjects of this chapter, we may give it a passing notice before we quit the north flank of the Alps, and proceed to describe the deposits in the basins of Styria and Vienna.

The section commences, towards the N.W., with a mass of granite, which comes out, as a spur from the Bohemian chain, to the south side of the Danube. It is a small-grained variety of the rock with much black mica. The granite is surmounted by a white cretaceous rock containing black flints and a few fossils: and from the whole of its characters, we could not help regarding it, when seen on the spot, as a true chalk formation. Its planes of stratification are marked by horizontal rows of flints, and it is overlaid by sands, marls, and conglomerates.

The geological sequence appears to be interrupted at the surface of the cretaceous rock: for it is worn down (precisely as in the chalk formation of England) into irregular pits and hollows, which are filled up with yellowish green-sand. Higher up, these sands become regularly stratified, and contain

* Plate XXXVI. Fig. 14.

many fossils, especially large oysters. The oyster-beds are surmounted by beds of pebbles; which are, in turn, surmounted by blue clays and marls with Cerithia and other tertiary shells.

The oysters and other shells are not perhaps specifically the same with the fossils found in the marls and sands immediately overlying the chalk in this country; neither do we venture to affirm that any of the beds of this section are perfectly contemporaneous with our formation of *plastic clay.* They do, however, in their internal structure, their grouping, their fossils, and their position upon the inferior cretaceous rock, present a most perfect analogy to the strata overlying the chalk at Reading, Woolwich, and other well-known places in this country.

The preceding facts seem to prove, unequivocally, that the neighbouring primary mountains of Bohemia have undergone no great movement of elevation since the deposition of the chalk. But the conclusion does not rest here: for, as we pass round the south-western skirts of the chain, we find the Jurassic limestone, on like ground, in an undisturbed, horizontal position: we therefore conclude, that the chain has not been elevated since the period of the Jura limestone.

It will be seen by an inspection of the map *, that the primary chain of Bohemia, and the principal chain of the Alps, converge towards the east: the former ranging from N.W. to S.E; the latter from S.S.W. to N.N.E. According to the comprehensive theory of M. Elie de Beaumont, these two lines of direction indicate two distinct periods of elevation; and he places, theoretically, the elevation of the Bohemian chain in a period immediately subsequent to the deposition of the new red sandstone; while the last great movement of the Eastern Alps is supposed to have taken place after the completion of some of the newest, known, tertiary formations. It is obvious that these grand and general views are in perfect accordance with many of the facts stated in this and the preceding chapters.

There are, perhaps, no physical phenomena, within the limits of the whole region we are describing, more striking than this entire geological separation of the Alpine and Bohemian chains, though ranging at so short a distance from each other.

* Plate XXXV.

CHAP. V.

On the Tertiary Formations of Lower Styria, &c.

INTRODUCTION.

WE here quit the newer deposits on the north flank of the Eastern Alps, and proceed at once to the tertiary formations of Lower Styria. They occupy a region of extraordinary beauty, and are not only of great thickness, but are well exposed in many fine natural sections: and they derive an additional interest from their being the extreme western prolongation of vast groups of strata which form all the lower elevations between the Drave and the Danube, and stretch into the heart of Hungary. As these widely extended groups are continuous, they must have had a common origin; and whatever we can prove respecting one portion of them, may, with proper limitations, be safely predicated of all the others. By help of the clear succession of deposits in Lower Styria we may explain some of the phenomena in the great plains beyond the termination of the Eastern Alps; and in this way we shall endeavour to account for the position and relations of the successive newer groups in the basin of Vienna.

The conglomerate, sandstones, and marls, entering into the composition of the groups we are about to describe, appear to have been formed in a bay of an inland sea; which once filled the basin of Hungary, and extended to the base of the mountains forming the extreme eastern termination of the chain of the Alps. For all these groups are of marine origin, and are nearly horizontal; and at their western extremity, among the older and more elevated formations, they fill an irregular, trough-shaped depression, through which the waters of the Mur, the Raab, and the Drave, make their way to the Lower Danube. From this region they are gradually expanded into the plains on the confines of Hungary *.

The tertiary formations of Styria are bounded, towards the east, by the frontier line of Hungary, and towards the south by the calcareous chain of the Matzel Gebirge, and the great alluvial plain of the Drave. On the south-western side the boundary line is irregular and ill defined. At Marburg it comes up to the ridges connected with the Bacher Gebirge; and, after ascending the Drave for some way, leaves the ridge of the Radlberg to the west, and descends towards Eibeswald. From this place the western boundary ranges at the base of the woody ridges which descend from

* See the accompanying map, Plate XXXV.

the flanks of the Schwanberg Alp and the Pach Alp; passes to the east of Rosen Kogel; and thence, in a sinuous line, bearing in a north-easterly direction, to the valley of the Mur, near Gratz. After doubling the old, calcareous promontory of Gratz, it ranges in an undulating line, bearing on the whole about E.N.E., through the ramifications of the Raab, making a deep bay towards Weiz, which is on the primary system. Doubling the hills to the N.E. of these ramifications, it ranges about N.N.E. into the Safenbach, a few miles to the south of Pöllau; thence to Hartberg, skirting the talcose and micaceous ridges south of Pöllau and Vorau; and from Hartberg, after ranging for some way towards the north, and being deflected by the primary ridge of Friedberg, it passes into the frontiers of Hungary. The accompanying map is on too small a scale to show the several demarcations in any detail, and what we have now given is merely an imperfect sketch; but it is sufficient for our present purpose*.

We entered the tertiary region at Gratz, and descended by the banks of the Raab into the borders of Hungary. We afterwards examined the relations of the trachytic hills between the Raab and the Mur—the sections on the banks of the Mur, from Radkersberg to Ehrenhausen—and the sections laid bare on the banks of the Sulm, and other tributory streams which descend from the Schwanberg Alp. Finally, we crossed the hilly region between the Mur and the Drave, and traced the tertiary strata into contact with one of the spurs of the Bacher Gebirge near Marburg. A second visit to these regions, during the past year, enabled one of the authors to define the northern and north-western boundaries of the tertiary groups; by a traverse from Friedberg to Hartberg, and thence to Gratz, Wildon, Voitsberg, and Lankowitz.

During these various traverses, we not only ascertained the general distribution and relations of the tertiary groups, but also became in some measure acquainted with the structure of the surrounding mountains. For example, we found mica slate in the ridges north of Hartberg—talcose and micaceous rocks near Pöllau and Vorau—primary white limestone at Weitz—ridges, apparently, of transition limestone, on the Mur above Gratz—mica and chlorite slate, with garnets, at Lagist—white, laminated quartz rock at Voitsberg—a rock composed of white, flaky quartz and silvery mica at the Pach Alp—mica schist, at the bottom of some of the deep water channels on the flanks of the Radlberg—&c. &c.

* Plate XXXV. Since this chapter was written, a beautiful, detailed, physical and geological Map of Upper and Lower Styria has been presented to the Society by His Imperial Highness John Archduke of Austria.

To enumerate mere mineralogical facts like these would be to little purpose; but it is important to remark, that all along the western limits of the Styrian basin, the primary and tertiary systems are separated from each other by only one secondary formation. It is well seen in the hills above Eibeswald, and in a succession of broken eminences on the eastern flank of the Schwanberg Alp; where it is clad with forests and intersected by deep ravines and gorges, in which the torrents have sometimes cut their way down to the primary strata. It is chiefly composed of sand and sandstone, generally soft and micaceous, and of a grey, greenish grey, or brown colour. Subordinate to it are beds of indurated shale, and of hard sandstone, occasionally so coarse as almost to pass into a conglomerate form. We obtained no fossils from this formation; and, having other objects in view, our attention was little directed to it: but we have no doubt that it is a prolongation of the system of fucoid grits and green sand, of which we have already sketched the range, from the north flank of the Eastern Alps into Styria.

The beds of the preceding group are all highly inclined, and are generally separated from the nearly horizontal beds of the tertiary system by a longitudinal valley of denudation; once probably occupied by incoherent sandy and argillaceous strata, which have been since washed away. Notwithstanding the minute scale of the accompanying sections, we hope that one of them will give a correct notion of the position of this group between the primary and tertiary systems of Styria*.

The tertiary deposits, within the region of which we have traced the boundary, though generally almost horizontal, and perhaps in no instance very highly inclined, have a prevailing easterly dip; so that in traversing them from west to east we commence with the oldest and end with the youngest strata. They may be conveniently divided into three principal groups: the lowest of which occupies nearly the whole of the finely broken region extending from the neighbourhood of Eibeswald, and the eastern skirts of the Schwanberg Alp to the banks of the Mur. The component strata of this group have yielded to the elements, and been so carved and worn down by torrents as to rival in their miniature outline the serrated peaks of the higher Alps. On this account, the wine-hills and woodlands by the sides of the deep ravines, through which the Sulm and other tributary streams find an escape into the Mur, present a succession of objects of endless complication and beauty; and if such a remark might be permitted in this place, we would add, that the loveliness of the country is reflected in the moral aspect of the inhabitants.

* Plate XXXVI. Fig. 16.

In the valley of the Sulm, and in some other deep ravines, the waters have cut through the whole tertiary series into a formation of transition or primary schist. Indeed the overlying strata, near the western limits of the basin, have been deposited on so uneven a surface, that they never perhaps entirely covered the higher protuberances of the older rocks.

By a comparison of various sections we find that this lowest group admits of the following subdivisions. (1.) Alternating beds of shale and sandstone, with lignite. (2.) Alternations of marl and sand; in some places containing many marine shells. (3.) Beds of sandstone, with bands of sandy shale; and (near the protuberances of the older rocks) with irregular, alternating masses of conglomerate, containing rounded siliceous pebbles, and resembling the shingle of an ancient beach.

The second principal group is characterised by coralline and concretionary limestone of a yellowish white colour: it is finely exposed in the escarpments of Wildon, and in the hills of Ehrenhausen, on the right bank of the Mur. The upper portions of this group occupy a considerable part of a hilly region stretching on the south side of the Mur, in a direction nearly due east and west, and are well exhibited in a succession of fine natural sections on the right bank of the river. They are made up of marls, sometimes so calcareous as to pass into irregular, concretionary masses of white limestone—of beds of shale—and of sand and sandstone, occasionally so coarse as almost to pass into the form of a conglomerate.

The third and highest group contains, like the two preceding, beds of marl and sandstone; but it is distinguished by a great variety of fossils, by beds of indurated, coarse, calcareous sandstone, and especially by beds of limestone, here and there, exhibiting a perfectly oolitic structure. In this group we include the yellowish, micaceous sands, with bands of sandy marl, and occasionally with beds of small pebbles, which occupy a large portion of the surface of the country near the frontiers of Styria and Hungary.

In travelling from the western to the eastern side of Lower Styria we gradually lose some of the grander features seen towards the Alpine boundary; and the country, chiefly composed of low, sandy eminences, becomes much less beautiful and diversified as it sinks towards the neighbouring plains of Hungary. An extensive region, which stretches across the valley of the Raab from Riegisburg to the peaks of the Gleichenberg and the hills of Straden and Poffendorf, offers however a striking exception to this remark. Mountain masses of volcanic breccia, crowned with castellated ruins, flat-topped eminences of basaltic lava, and domes of trachytic porphyry, rising above all the neighbouring tertiary hills, give a new boldness to the outline of this region, and a new interest to its mineralogical details. These phenomena are the more important, from their obvious connexion with the old volcanic operations which are known to have modified the features of a large portion of Hungary.

This introductory sketch will serve, we hope, to explain our views of the structure of Lower Styria; and we now proceed to illustrate and confirm them by two detailed sections—one drawn nearly from west to east, commencing with the hills above Eibeswald, and extending to Radkersberg on Mur, close to the Hungarian border—the other nearly from north to south, commencing at Riegisburg, passing through the volcanic region above mentioned, and ending at Radkersberg, where it crosses the other line of section*.

1. *Detailed Section of the Tertiary Formations between Eibeswald and Radkersberg.*

The accompanying section (fig. 16.) begins at the ridge of the Radlberg, elevated about 2000 feet above the level of the Mur, and passing through the inclined system of secondary green sand (beneath which the primary schists are in several places laid bare), descends to the tertiary groups, which we now proceed to describe, as they appear in the section, in the ascending order.

1. Shale and sandstone with coal.

There are probably several seams of coal among the oldest beds of shale and sandstone: one of the lowest is worked at a place call Pampana, very near Eibeswald, and is about four feet and a half thick. It rests immediately upon the grits and conglomerates of the Radlberg. From this point, a tortuous line drawn along the flank of the Schwanberg Alp intersects several seams of lignite, as at Steierich, St. Tuluri, Sheineck, &c. Of these coal beds, that at Scheineck is the most interesting, on account of its organic remains. Beds of sandy, micaceous marl there occupy the right bank of a little stream called the Weisse-Sulm; and the coal is extracted from the base of an escarpment by horizontal galleries which follow the line of deposit. The coal itself is about three feet in its greatest thickness, but it thins off to a few inches, in the face of the cliff from whence the drift proceeds. It is imbedded in calcareous shale, which contains many large stems of arundinaceous plants, and a considerable number of Gyrogonites,

* Plate XXXVI. Fig. 15 & 16.

among which the *Chara tuberculata* (?) is the most abundant. Opercula of Paludinæ, shells of a Cypris, scales of fish, and fragments of the skeletons of certain species of Mammalia are commonly found associated with the coal. The few specimens of bones which we procured from this place are too imperfect to give any specific information; but a fine jaw of a species of Anthracotherium (?), obtained from the works at Scheineck, is to be seen in the museum at Gratz. These bones have precisely the same mineral character and general appearance as those which occur in a similar deposit at Cadibuona, in Piedmont. The lignite of the two places is undistinguishable, and occurs in both at the base of the respective tertiary systems with which it is associated.

In certain laminæ of the coal-bed of Scheineck a passage is, here and there, seen from wood with a dicotyledonous structure into mineral charcoal; in other laminæ the coal appears to have resulted from the compressed leaves; in those parts which enclose the bones (Anthracotheria ?) it is nearly in a state of jet *.

2. Blue, calcareous shale and sand, &c.

The carboniferous strata are surmounted by sandy, blue and dark-coloured calcareous shales, in which (especially near Kreitzpetter, along the western side of the Sausal-hills) we discovered many well-preserved shells; several

* Lignite, of very different structure and age from that above described, occurs in many parts of Styria. For example, the vast masses of lignite near Lankowitz and Voitsberg cannot in any respect be assimilated to that in the old tertiary deposits, and are moreover entirely cut off from the Gratz basin.

The river Kainach, in its course from the Stub and Pach Alp, flows through narrow gorges of primary rocks, and waters successively several, small, bowl-shaped expansions, on the sides of which the lignites are heaped up: and hence we may perhaps conclude, that these mountain depressions were local and temporary receptacles of great numbers of drifted forest trees, of turf, &c. These lignites are in fact nothing more than brown coal in its first state of carbonization, the woody structure being still preserved; in which respect they resemble the brown coal of the Rhine, of Hesse Cassel, and of Bovey in England. To the Bovey coal they are also analogous in containing no traces of any animal remains, marine, fluviatile, or terrestrial.

The most important of these deposits, at Oberdorf, near Voitsberg, has at one place a thickness of 72 feet, and is worked in a lofty, subterranean chamber 720 feet in length. It is in parts very pyritiferous; and near its base rests upon, and alternates with, unctuous pipe-clay and brick-earth. These clays are found abundantly all round Voitsberg and Oberdorf, deposited at one place on mica schist; at another on white, crystalline, primary limestone; at a third on fucoid shales and coarse grits, the only secondary rocks in the region.

The brown coal occurs at very different levels, being at Lankowitz several hundred feet higher than at Oberdorf; and the beds, or rather heaps, of the mineral at the former place, are horizontal or inclined, according to the nature of the broken surface on which they rest.

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of which, after a careful examination, Mr. J. Sowerby has pronounced to be very nearly, if not quite, identical with species found in *calcaire grossier.* The list is as follows:—

Lutraria convexa, Sowerby. Plate xxxix. fig. 1.
Lucina mutabilis ? *Calc. gross.* Deshayes. *Coq. Fos. des Env. de Paris.* Tab. xiv. fig. 6 and 7.
Lucina renulata. *Calc. gross.* Deshayes. *Coq. Fos. des Env. de Paris.* Tab. xv. fig. 3 and 4.
Pecten (fragments of).
Venus vetula. Basterot. *Mem. Geol. Env. de Bordeaux.* Pl. vi. fig. 7.
Cardium (fragments of).
Cerithium tiara. *Calc. gross.* Lamarck *Ann. du Mus.* Tome 3, p. 343.
——— *scalaria ?*
Nerita.
Bulla elliptica. *Calc. gross.*, London clay, Hordwell Cliff. Min. Con. Tab. cccclxiv. fig. 6.

This shelly, blue marl, though of a thickness very inferior to that of many of the groups we are about to describe, is highly important from its organic remains, which are rare in most of the neighbouring strata.

3. Alternations of sand, marl, and sandstone, with subordinate masses of shingle, here and there, cemented into a millstone conglomerate.

This group is largely developed, occupying the wine-hills of Sausal, and all the broken district extending from thence eastward to the valley of the Mur. It is traversed from W. to E. by the river Sulm, exposing on its banks the old schistose rocks, with cappings, several hundred feet thick, of yellow sands, marls, and conglomerates.

Shelly beds occur, here and there, in this group, of which we remarked a good example at the mouth of the gorge, where the Sulm issues into the broad valley of the Mur near Leibnitz. The inclined chloritic and micaceous schists there rise to the height of about 60 feet above the bed of the Sulm, and are then covered with the following horizontal beds.

a. Breccia of angular fragments of the inferior rocks, cemented, apparently upon the spot, by yellow calcareous matter.

b. Indurated, sandy, concretionary masses, occupying a thickness of about 30 feet, chiefly distinguished by specimens of a very large Ostrea.

c. Arenaceous and calcareous marls of great thickness, but much concealed by vineyards and vegetable soil.

Near Ehrenhausen the group contains thick, subordinate masses of conglomerate, which, in a valley to the W.S.W. of the town, is quarried for millstones. The beds best adapted for this purpose are of a bluish grey colour, and consist of smooth, rounded pebbles of quartz, chlorite, schist, and other primary rocks, varying from the size of a pea to that of a pigeon's egg, held together by a siliceo-calcareous cement. The upper and under beds are more sandy and incoherent, but are equally charged with well-rounded pebbles; and, like the millstones, contain a few fragments and casts of tertiary shells.

Other alternating beds in different parts of this valley consist of rubbly calcareous grit, passing into conglomerate, and of beds of fine yellow sand, separated from each other by bands from two to three feet thick, of very coarse calcareous grit, containing a few ill-preserved shells. These strata form the highest members of the group we are now describing, and dip E. by S. at an angle of about 15° (much above the average dip of the basin) under the coralline, white limestone of Ehrenhausen.

The appearance of the millstone conglomerate so far within the western limits of the basin, is, at first sight, difficult to account for, especially as the two inferior groups contain no similar beds, and seem to have been deposited in a tranquil sea. On examination, however, we find that the primary rocks are not only laid open by the Sulm, but rise from its banks into high ridges protruding through the tertiary formations on the west side of Ehrenhausen. By the degradation of a portion of these ridges, which once existed as shoals or islands in the old tertiary sea, the conglomerates in question were probably formed.

The considerable inclination of the millstone group is also an anomaly in the structure of the basin, in part perhaps explained by supposing the deposits to have taken place on an inclined surface of one of the protruding primary masses. A local movement of elevation would, however, at once account for the position of these beds; and the supposition of some such movement is perhaps countenanced by the presence of trap rocks further to the north, in a corresponding part of the basin.

Had our section commenced at the base of the Pach Alp, and been prolonged by the drainage of the Kainach over the summit of Wildon, it would have crossed a series of beds nearly agreeing with those of the three groups above described. On that line the millstone conglomerates are wanting, but the trap rocks, above mentioned, may be seen in a knoll on the left bank of the Kainach, about three quarters of a mile west of Weiterdorf, among the lower tertiary groups which, by a slight easterly dip, are carried under the south-western escarpment of Wildon*.

* The trap is much concealed in a pine-wood, and the specimens brought away are in a state of decomposition; but they appear to be composed of basaltic greenstone, clinkstone, and clinkstone porphyry. They deserve notice, as the only igneous rocks in this part of the Styrian basin.

4. Coralline, white limestone, calcareous and arenaceous marl, &c.

The finest exhibition of this rock is seen in the tabular elevation of Wildon, situated on the right bank of the Mur, near its junction with the Kainach. This hill, celebrated as one of the astronomical stations of Tycho-Brahe, rises to the height of 600 or 700 feet above the neighbouring plains; and the upper part of it, in thickness more than 400 feet, consists of a horizontal, strong-bedded, yellowish white limestone, here and there charged with many coralline bodies, alternating with some thin wayboards of marl, and with marl containing many irregular calcareous concretions. It is a splendid example of a coralline limestone of a tertiary age, exhibited on a grander scale than the English geologist has been accustomed to see in the secondary coral rag of his own country.

Many of the masses have a mottled appearance, resulting from a number of spheroidal and cylindrical concretions, formed of concentric layers of white carbonate of lime, probably produced in the first instance by organic bodies, the traces of which are now lost. In the harder and thicker beds there are many cavities, originally containing various corallines, of which we now only find the impressions standing out in relief from the interior of the cells*. In the lower part of Wildon the limestone becomes more marly and concretionary, and passes into sandy argillaceous marls, which form the prolongation of beds composing the wine-hills of Sausal.

A line drawn from Wildon about S. by E., at right angles to the prevailing dip of the formations, falls upon the hill of Ehrenhausen, where the castle stands upon a similar coralline and concretionary white limestone†.

The shells we found at Wildon and Ehrenhausen are a Mytilus, a Cardium, two species of Pecten, of which the smaller is the *Pecten infumatus* of Deshayes; one species of Cerithium, *Conus Aldrovandi?* of Brocchi; *Balanus crassus?* of the English crag; small Nummulites, probably of the species *N. complanatus;* many corals of the genera Astrea and Flustra; tubes resembling the cells left by a Teredo or Pholas; club-shaped bodies (Fistulanæ of Lamarck) traversing corals, and the claws of a species of Crab.

* A similar concretionary and coralline structure is seen in the mottled tertiary marble of Costa Lunga, described by one of the authors in a former memoir "On the Tertiary Formations near Bassano," Annals of Philosophy, vol. v. p. 401: and the coralline limestone of Monte Viale in the Vicentine, described by M. Brongniart, may also be cited as an analogous rock. These examples of similar structure do not prove the several rocks to be of the same age. The *leitha-kalk* of the Vienna basin is however not only in structure very like the limestone of Wildon, but is, we believe, exactly on the same parallel.

† Plate XXXVI. fig. 16.

This coralline limestone, which is of such great thickness at Wildon, is less developed and less indurated at Ehrenhausen, where, after occupying the castle-hill on the right bank of the Mur, it passes under saponaceous marls alternating with strong bands of brown, calcareous grit. These masses constitute cliffs which are continually crumbling away in consequence of the decomposing nature of the marls.

4 *a*. White and blue marl with bands of sandstone, white marlstone, and concretionary, white limestone.

Beds of this kind, representing the upper portion of the coral limestone series in its expansion towards the east, are well exposed in a succession of escarpments on the right bank of the Mur below Ehrenhausen. In that part of its course the river is bounded to the north by the great plain of Strass and Mureck, and to the south by a succession of tertiary hills composed of strata like those we have just enumerated.

Descending from Ehrenhausen by the right bank of the river, we find the coral limestone succeeded, and perhaps in part replaced, by light-coloured, unctuous marl, with bands of micaceous calc-grit, which, near the bridge of Strass, are superseded by blue, sandy marls.

We obtain a good transverse section of the district to the south of the river by deviating from the direct line of section, and following the great road to Marburg. This road first conducts us through the hills of Santa Egida, where beds of concretionary, white limestone alternate with marls containing fossils, among which we observed a Scalaria, a Cypræa, *Ostrea Bellovicina*, and many fragments of *Pecten pleuronectes* (?). Still further to the south in the Zirknitz-thal (from which the waters flow into the Drave at Marburg), many fossils have been discovered along the line of a new road: from amongst these we procured a Clypeaster (*Echinanthus marginatus* (?) of Leske); Pectens of gigantic size, one of which is the Pecten figured by Faujas from Maestricht; and *Ostrea longirostra* (Lamarck).

To the west of the valley of Zirknitz, and consequently in the line of bearing of the strata which succeed the coral limestone of Ehrenhausen, the system of white marls, we are describing, assumes so compact a character, that at St. Kunegund and some other places they are extensively quarried as a building stone. This stone much resembles the compact beds of English clunch (or indurated chalk marl), and is remarkable for its dark-coloured blotches, which at a little distance resemble flints in chalk. It is sometimes finely laminated; but it is more frequently thick-bedded, with a dull, conchoidal fracture, and has occasionally been employed in coarse statuary work*.

* The gigantic figures at the mausoleum of the castle of Ehrenhausen are of this stone.

Returning to our former line of section along the right bank of the Mur, between the bridge of Strass and Mureck, we find some slight undulations of the strata; but on the whole the beds are so nearly horizontal, that the same groups of variously coloured, sandy, and unctuous marls continue till the river passes the latter place. Below Mureck a very fine section through the unctuous marls exposes irregular, subordinate bands of a white, concretionary limestone, one range of which is about eight feet thick. The rock is soft in the quarry, but hardens on exposure, and is extracted in large lumps, the outside of which exhibits an earthy texture. The interior is very difficult of fracture, and is made up of a number of small tubular and concentric layers, which at first sight give the rock a pisolitic appearance. Some of the harder masses are traversed by beautiful, contemporaneous veins of crystalline carbonate of lime. The beds in this section dip east at an angle of 6° or 8°.

In the calcareous beds alternating with the various inferior groups, we constantly remarked a tendency to concretionary structure; and in the marls in the upper part of the Sausal-hills, and of Santa Egida, we frequently found balls three or four inches in diameter, made up of a congeries of spheres like clusters of small grapes, which reminded us of some varieties of the magnesian limestone of England. On breaking these balls the spheres were occasionally hollow, but presented, here and there, obscure traces of organic structure.

5. Arenaceous marl and sandstone; concretionary beds of calc-grit and oolitic limestone; micaceous, yellow sand, and small beds of pebbles, &c.

The white marls and concretionary limestone of Mureck, are succeeded on the line of dip by a great, complex deposit forming the highest group of the whole section. The lower members of this group consist of arenaceous, dark-coloured marl alternating with calcareous sandstone, which, opposite to Sixt-Mühle and at other places on the banks of the Mur, contain fossils, of which we may mention the following genera: Cerithium, Modiola, Pecten, and Cardium. From Sixt-Mühle to Radkersberg, the whole system becomes more arenaceous; and at the latter place, where the hills terminate towards the plains of Hungary, the cliff which overhangs the Mur exhibits a good section in the following ascending order.

	Ft.	In.
a. Fine, incoherent, calcareous, grey and blue, micaceous sands and marls, with a great profusion of small Cerithia, of which the most common species very closely resembles the recent species *C. vulgatum*. Associated with it is the *Corbula complanata?* (Sowerby *), a minute Natica, a Nerita, &c. These beds are so disintegrated that their exact subdivisions cannot be determined. Their total thickness from the base of the cliff is about 60 or 70 feet	70	0

* Min. Con. Tab. ccclxii. fig. 7 & 8.

	Ft.	In.
b. Yellowish siliceous limestone, with many casts of shells, among which are *Cerithium pictum*[*] (Bast.); *C. vulgatum; C. pupæforme*[†] (Bast.); and three or four other species: *Turritella incrassata*[‡] (Sow.); *Cardium transversum*[§]; *C. minutum*[‖]; a Sanguinolaria; a Venericardia; *Nummulites variolaria*[¶]? &c. &c. The lower part of these grits compose beds from one to two feet thick, but the higher portions of them are made up of thin slaty layers. The surfaces of the slabs are concretionary, and sometimes oolitic; and some of the masses, when fractured, separate at joints which are stained with black oxide of iron....................	6	0
c. Greenish, calcareous, iron-shot sandstone, with Cerithia................	3	0
d. Thin layer of blue marl	0	2
e. Hard, micaceous calc-grits, of a greenish colour. Some of them exhibit flattened spheroidal concretions, and are quarried for building. They are surmounted by yellowish and greenish sandstone with casts of shells, which finally pass into yellow and blue arenaceous marls	10	0
f. Yellow, micaceous sandstone and sandy marl, with many casts of shells....	30	0
	119	2

Several of the more calcareous beds of this section (especially in the second subdivision marked *b.*), exhibit a tendency to the oolitic structure. As, however, the tertiary oolites are more perfectly developed in beds exactly on the same parallel, which are exposed in the transverse section from Regisberg to Radkersberg, we pass them over without further notice in this place.

Bones of several species of Mammalia have been found in some of the Radkersberg beds; and several interesting specimens of them are placed in the museum at Gratz. This fact is important, as it not only assists us in comparing the upper tertiary systems of the basins of Vienna and Styria, but also establishes an analogy between them and the younger deposits of the Sub-Apennine regions.

We here terminate our description of the section through the successive deposits of the Styrian basin. Though the order of superposition is sufficiently clear, the groups are ill defined; and one or two of them have been adopted in the preceding details, more for the purpose of facilitating the description of the whole series, than from their possessing any very distinctive characters by which they are separated from the other contiguous groups. For the purposes of general comparison, we think (as we have stated in the introduction) that three principal subdivisions of the whole series will be found sufficient. The first comprising all the tertiary strata inferior to the great coralline limestone—the second, all the strata associated with the various forms of the coral-

* Env. de Bordeaux, Pl. iii. fig. 6.

† Ibid. Pl. iii. fig. 18.

‡ Min. Con. Tab. li.

§ See Plate XXXIX. fig. 2.

‖ See Plate XXXIX. fig. 3.

¶ Min. Con. Tab. dxxxviii. fig. 3.

line limestone—and the third, including all the higher deposits which occupy nearly the whole country on the western frontier of Lower Styria.

2. *Section of the Tertiary Groups near Hartberg.*

If a line be drawn (nearly at right angles to the mean direction of the preceding section) from Radkersberg, through the crests of Gleichenberg, to Riegersberg, and be then produced towards the north, it will meet the primary ridges, at the north-eastern boundary of the Styrian basin, in the neighbourhood of Hartberg: and in the whole of this long traverse, it will pass either through strata subordinate to the highest tertiary group (No. 5.) of the general section, or through igneous rocks associated with them.

The tertiary beds, on the north-eastern confines of the basin, rest immediately on the primary system; and are so nearly horizontal, that they probably retain the same relative position, in respect of the Friedberg and the Hartberg ridges, which they had at the time they were deposited. The lower groups are almost entirely made up of alternating laminæ of micaceous sand, and unctuous marl, together forming a good brick-earth. In the ascending order these beds become more indurated, and pass into a group made up of alternating beds of marly limestone and sandstone, containing a few Cerithia. Some of the beds of calcareous sandstone contain fragments of mica schist, small quartz pebbles, &c., mingled with the Cerithia; but in none of them is there a trace of any secondary rock—a proof, in addition to the one offered by the collocation of the beds in natural sections, that no secondary rocks existed in this region at the time the tertiary deposits were forming.

The last-mentioned group is surmounted by a very remarkable calcareous formation, to which the name of *graub-kalk* or *calcaire grossier* has been sometimes given. Mineralogically speaking, such a term may be correct; but as a formation, it is of a much newer age than the *calcaire grossier* of Paris; being, if we mistake not, on the exact parallel of the limestone of Radkersberg and Poppendorf. It is surmounted in the quarries south of Hartberg, by beds of marl and sandstone, some of which resemble those of the inferior groups.

The following descending section from the quarry of Schüldbach, south of Hartberg, will show the nature of the deposits we are here describing.

	Ft.	In.
1. Earthy marls at the surface, of irregular thickness.		
2. Coarse, micaceous grit, with small quartz pebbles	0	6
3. Unctuous marls; part light green, part of a deep ochrous colour	1	0
4. White and grey, micaceous, laminated marl	1	0
5. Greenish laminated, arenaceous marl	3	0
6. Thin layer of sand, with broken shells and black and white quartzose pebbles	0	3

	Ft.	In.
7. Green and yellow arenaceous and micaceous marl; containing geodes, and concretions of hydrate of iron	6	0
8. Green, unctuous marls, separated by thin bands of ferruginous marlstone	7	0
9. Highest bed of shell-limestone, of porous structure, of rusty brown colour, and full of Cerithia	1	0
10. Yellow ochrous coarse-grained limestone: it contains many Trochi and other shells, and is burnt for lime	4	6
11. White limestone, stained by brecciated fragments of greenish marlstone: it contains many Cerithia and other shells; some in good preservation	1	2
12. Coarse, brown limestone, with shells	1	0
13. Fine-grained, strong-bedded, white limestone, with shells on the surfaces of the bed. It splits up into slabs from six inches to a foot thick, and is used in ornamental architecture	4	6
14. Limestone, nearly resembling the preceding	1	3
15. Green, blue, and yellow unctuous marl	2	6
16. White, shelly limestone	1	6
17. Rough, shelly, ochrous bed of porous structure	0	9
18. Sandy bed, obscured by water at the bottom of the quarry	36	11

Geodes and concretions of hydrate of iron (similar to those in No. 7.) occur in all the ferruginous sandy beds, and are also found in the sandy strata under the limestone.

The preceding group is of considerable, economical importance; but its chief geological interest arises from its fossils. Among those we obtained from it are the following:—

Solen.

Cardium—three species.

Pullastra.

Saxicava rugosa? London-clay and crag. Min. Con. Tab. cccclxvi.

Venus or Cytherea.

Mytilus Brardii. Mayence. Fauj. Ann. du Mus. tome 8, pl. lviii. fig. 11, 12.

Cerithium vulgatum; C. pictum (Bast.); *C. plicatum* (Bast.).

Trochus—some specimens of which are not to be distinguished from an undescribed recent species from the Pacific, in the possession of Mr. G. Sowerby. It abounds in the Hartberg limestone.

Turritella incrassata. Crag. Min. Con. Tab. li. fig. 6.

3. *Section in a direction nearly South and North from Radkersberg to Riegisburg, showing the Structure of the Youngest Tertiary Groups of Styria, and their Relations to a Series of Volcanic Rocks*.*

For some miles to the north of Radkersberg, a broad plain of gravel and

* Plate XXXVI. fig. 15.

sand, probably derived from the degradation of the surrounding deposits, is spread out from the left bank of the Mur, to the southern edge of several lofty, serrated ridges of volcanic rocks. Our line of section passes through some of the finest of these volcanic masses, in its range from Hainfeld, on the Raab, through Gleichenberg, to Straden: and had it been drawn a little further to the east, it would have passed over a volcanic ridge stretching southward as far as Klech.

By skirting these volcanic ridges on their western side, we were led along a succession of hills, of the youngest tertiary marine deposits; in some places offering clear, uninterrupted sections; in others, alternating with, or overlaid by, different varieties of the contiguous igneous rocks. At Straden, a hill rises several hundred feet above the plain. It is composed towards its base of calcareous shelly sands, which pass upwards into compacted conglomerates, of well-rounded pebbles, the beds of which incline towards the north, and contain shells similar to those in the escarpment of Radkersberg. The hill is surmounted by a thin cap of dark-coloured basaltic lava, imperfectly columnar, upon which the village and church stand *. This rock is coarse and granular, with a tendency to concretionary structure, contains olivine, and here and there has the rough, open structure of recent lavas.

The tertiary strata of Straden *strike* to the north-west, and are seen in several round-topped eminences, the mineral structure of which may be best understood by the following detailed section of the adjoining hill of Poppendorf.

4. *Section of the Hill of Poppendorf.*

If this hill be ascended from the south, it has the appearance of being divided into three terraces. The lower, on which the castle stands, consists of thin-bedded, calcareous sands, marls, and conglomerates; of blue, grey, and rusty brown colours. They are much concealed by vegetation, but are partially bared on the side of a cross road.

The middle system is, in its general structure, somewhat like the lower, and is imperfectly exposed on the slope of the hills; but a water-course enabled us to observe the following succession of strata:

a. Yellow, micaceous, sandy marlstone.
b. Blue, green, and yellow marl, separated by bands of ferruginous calc-grit.
c. Thin layers of indurated sand.

* The church and principal buildings are made of a beautiful fine-grained oolite, extracted from the adjoining quarries of Freesing and Poppendorf.

d. Greenish, calcareous sandstone, with various casts of shells.

e. Micaceous, thick-bedded, calcareous sandstone, of bluish and greenish colours.

f. Sandy, micaceous, yellow marlstone with casts of a Venericardia; *Cerithium pictum;* a Modiola, of the same species with one found at Sixt-Mühle; a Pecten; a Mactra; a Turbo (?); a Trochus; *Nummulites variolaria* (?); and some other shells similar to those at Radkersberg.

g. Marl, and thinly foliated sandy beds.

h. Yellowish limestone, with casts of shells.

i. Green and white sand.

k. White, sandy, micaceous marl, with calcareous concretions, and many bivalve shells, which fall to pieces on being touched.

l. Finely laminated, sandy marlstone, blue, white, and iron-stained; with casts of shells.

m. Brown and blue, micaceous, argillaceous grit.

n. Bands of light-coloured, calcareous and micaceous sand.

o. Sandy marls.

p. Micaceous and calcareous sandstone, with traces of carbonized wood and plants, passing upwards into a conglomerate.

q. Indurated conglomerate, and micaceous calc-grit, forming the summit of the second terrace, which is obscured by vegetation.

The base of the third and highest terrace is made up, to a considerable thickness, of very micaceous sand, containing some pebbles. It is imperfectly exposed; but near some high vineyards, the sandy beds are cut through in several places for the extraction of a fine-grained, perfect oolite, which is quarried here, at Wasen, and at Freesing; and has been extensively used in the construction of the neighbouring churches and other public buildings. It is an irregular, concretionary rock, formed in the midst of the calcareous sands, marls, and conglomerates; its thickness is consequently variable. In the Poppendorf quarries, the beds of the best building-stone are from four to six feet thick; and their structure is so truly oolitic, that the most experienced geololist on seeing them in hand specimens, or the hewn stone of a building, might confound them with the great oolite of Bath. In the quarries, he would however be soon undeceived by finding casts of Cerithia, and other tertiary shells on the surfaces of the coarser and exterior beds. Amongst the oolitic grains of the coarser beds, and sometimes within them, are minute fragments of bivalves: in the same beds also several species of univalves; for example, a Cerithium, a Murex, a depressed shell resembling a Planorbis, a Natica or Nerita, a Turritella, a Turbo, &c.

Some of the spherules are hollow, but others are arranged about grains of semi-crystalline calcareous matter, or particles of sand. The beds of true oolite are overlaid by irregular, concretionary masses, partially oolitic, which alternate with unctuous sandy marls. Some of these concretions are amorphous; some assume contorted tubular forms; others are finely laminated.

This portion of the rock has occasionally the external appearance and fracture of English cornbrash; and exhibits stellated impressions of black oxide of iron on its broken surfaces.

These quarries are surmounted by white, green, and iron-stained calcareous sands, finely laminated in wavy lines; and above them are repetitions of blue, yellowish, and green, arenaceous marl, similar to that described from a lower part of this section.

The total thickness of all the strata, from the base of the hill, cannot be estimated at less than five or six hundred feet. From the evidence of the organic remains, as well as from the position and *strike* of the strata, there can be no doubt that the group at Poppendorf is of the same or nearly the same age as that of Radkersberg; and thus we find, that one of the last operations in the formation of these great tertiary deposits, was the production of an oolite, undistinguishable in many parts of its structure from the great oolite of England *.

By referring to the accompanying section (fig. 15.), it will be seen, that in the adjoining hill, the shelly sands and marls have not been deposited in the same manner as at Poppendorf; but have been broken in upon by eruptions of volcanic matter. These striking phenomena are seen in the hill of Ferish, between Poppendorf and Gnaess, the base of which (at the point where we examined it, in a little combe on its south-eastern side), consists of a coarse volcanic tufa and breccia, made up of earthy matter, containing many fragments of basaltic lava, scoria, decomposing ancient rocks, quartz pebbles, crystals of vitreous felspar, olivine, and pyroxene, mixed up with broken tertiary shells.

A little above this tufaceous deposit, thick beds of the tertiary calcareous sandstone alternate with a similar volcanic mass; and further in the ascending series, some of the volcanic beds contain many well-preserved shells. Green, micaceous, and calcareous sand of considerable thickness succeeds; and it is surmounted by a regularly bedded, greenish, dark-coloured volcanic breccia, seven or eight feet thick, which is nearly horizontal, and so indurated as to be much quarried for building.

This volcanic rock contains crystals of decomposing glassy felspar; olivine; much scoriaceous and basaltic lava, with olivine and pyroxene; many fragments of shells; and pebbles probably derived from the shingle banks of the tertiary

* Considered as a suite, the shells at Poppendorf and Radkersberg are very nearly the same. For a much more complete account of the fossils at all the localites above mentioned, we must refer to the list at the end of this paper, and to Plate XXXIX. accompanying it.

sea. It is much fissured, and the interstices are coated with crystals of carbonate of lime, and with that variety of the mineral which is sometimes called rock-milk. The building-stone is covered at the top of the hill with finely laminated, micaceous, earthy beds; very much, we believe, resembling the sediments which, in the present day, are occasionally produced, on the shores of the sea, during periods of volcanic eruption.

The phenomena at Ferish and Straden occur on the western edge of the volcanic region. To the east of these places, the tertiary sands are overlaid, or broken through, by ridges of unmixed volcanic rocks. There are, we believe, no traces left of the ancient craters: but from the great predominance of igneous rocks at Gleichenberg, that place may, perhaps, be considered not far from the ancient centre of igneous eruption. The peaks which there rise to the height of eight or nine hundred feet above the surrounding country have all a trachytic character. In the ravines below the castle of Gleichenberg some of the subordinate masses are quarried for millstones; and are, apparently, of a structure quite analogous to the millstone porphyry of Hungary, described by M. Beudant.

The base of this trachytic porphyry is chiefly composed of felspar, with much disseminated black mica; and through it are distributed crystals of felspar, some of which are in a very advanced state of decomposition: its prevailing colours are reddish and greenish grey, with many irregular ferruginous stains.

Between Gleichenberg and Hainfeld, the volcanic peaks diminish in height; and masses, which are within a short distance of each other and seem to form but one group, change their character completely, from a coarse trachyte into a cellular lava, from which they graduate into a basaltic lava, with a tendency to globular structure. Some of these varieties, not however including any true trachyte, occur in the woody cone of Steinberg south of the castle of Hainfeld, and are seen to overlie fine-grained volcanic silt and conglomerate, which repose on the yellow sands that slope away into the valley of the Raab*. We also observed near the basaltic lava at the top of this hill, many fragments of light, cellular scoria.

From Hainfeld towards the north, the tertiary system of yellowish, micaceous sand, marl, and uncemented beds of small pebbles, is uninterrupted for many miles, forming a succession of round, woody hills: but at Riegisburg a magnificent tabular mass of volcanic breccia, crowned by an ancient castle and fortress, appears to cap the tertiary sands. This rock contains quartz pebbles and much detritus of the tertiary groups, mixed up with scoria, and fragments

* Plate XXXVI. fig. 15.

of basaltic lava, containing nests of olivine. The upper part of it is regularly bedded, in which respect, as well as in its whole composition, it bears a close relation to the volcanic conglomerates of Puy en Velay. The summit of the Riegisburg is about four hundred feet above the level of the Raab; and the capping of volcanic conglomerates seems to be from two to three hundred feet thick.

The account we have now given of volcanic rocks associated with the youngest tertiary zone, are quite sufficient to explain the nature of their varied geological relations; we, therefore, merely notice their occurrence at Fehring and Kapferstein, where they are in the form of basaltic conglomerates; at Klausen, where they are basaltic and columnar; and at Seindlberg near Klöch, where they are associated with scoria.

The juxtaposition of the various volcanic rocks, and their passage into each other in some parts of the region last described, make it difficult, and perhaps impossible, to establish any decisive tests of their relative age, founded upon their mineralogical characters. The newest tertiary group is in one place overlaid by prismatic and basaltic lava; in another by coarse granular lava, almost passing into trachyte; in a third by scoria; and in a fourth, alternates with basaltic tufa and conglomerate. All that we can affirm on this subject is, that the whole of these volcanic rocks were probably produced during the formation of the youngest tertiary deposits of the neighbouring region.

In igneous rocks of this age we cannot expect to find continuous streams of lava, traceable to the crater from whence they flowed. The form of the country however seems to indicate, as before stated, that the trachytic domes of Gleichenberg are situated near the principal focus of ancient eruption. Although some of the masses of volcanic rock are so intimately associated with marine deposits, as to leave no doubt of their having assumed their present form under the sea; yet the great abundance of scoriaceous matter, exactly resembling the commonest sub-aerial igneous products, led us to infer, that the principal points of eruption rose above the sea which then occupied the basin of Styria *.

* We did not examine the volcanic region in detail; and we skirted its western extremity almost exclusively for the purpose of ascertaining the relations of the igneous rocks to the upper tertiary groups. The central trachytic region we merely touched upon. In the hill of Ferish, the alternating beds of tertiary sand and volcanic tufa are nearly horizontal; and certainly did not induce us when on the spot to suppose, that the central trachytes of the Gleichenberg were posterior to all the other igneous products. This hypothesis is, however, supported by Dr. Daubeny; who founds his opinion chiefly upon certain inclined strata, on the flanks of the Gleichenberg, which did not fall under our observation. See his "Description of Extinct and Active Volcanos," p. 110.

Conclusion.

1. The slight inclination of the tertiary system at Eibeswald, Hartberg, Marburg, and other places on the confines of the Styrian basin, naturally leads to the conclusion, that the extremity of the Eastern Alps had undergone its chief movements of elevation *before* the existence of the several groups described in this chapter.

2. The formation of the lowest group probably commenced soon after these movements of elevation had ceased; and it is, at all events, newer than any of the inclined strata on which it rests, or against which it abuts. This consideration proves it to be younger than the secondary green sand and fucoid shale, and proves nothing more: for there is nothing in the accompanying details, which positively limits the great movements of elevation, and proves them not to have extended to a period newer than that of the secondary green sand.

3. The age of the lowest tertiary groups of Styria can, therefore, only be determined by their structure and their fossils; and on this evidence (as above stated, p. 387, 388.) we are rather disposed to compare them with the *calcaire grossier* and the London-clay, than with the newer Sub-Apennine formations.

4. Although, as before stated, our subdivisions were in some measure arbitrary, and were adopted chiefly for the convenience of description; yet the tertiary system may be separated into, at least, three natural groups, each of which seems to have been tranquilly deposited during a long period of time—a conclusion justified by the condition of the beds and the distribution and preservation of the fossils. If the lowest group be compared with the *calcaire grossier,* the middle group may, with perhaps more certainty, be compared with a portion of the great Sub-Apennine deposits, or with those of the Bordeaux basin. The highest group seems to be on a parallel with the higher Sub-Apennine strata; but its limits are ill defined; and we may pass it over for the present, as its relations are perhaps better exhibited in the Vienna basin, which we are about to notice.

5. The volcanic forces appear to have been called into action, chiefly during the formation of the most recent group, and were probably continued, with more or less interruption, during a long succession of ages. The varied structure of the different volcanic masses seems to have originated in mere local causes, and we saw no reason for referring the great masses of breccia, of lava, of scoria, and of trachytic porphyry, to distinct epochs of eruption.

6. Respecting the age when the igneous causes ceased, we can offer no conjecture. We find no traces of their action since the sea retired from the

bays of Lower Styria—as no igneous rocks follow the direction of the valleys or inclined planes, presented by the existing surface of the country. On the contrary, they rise in steep insulated masses—formed, evidently, before the rivers drained through their present channels; and they offer most emphatic proofs of the enormous degradation and waste of the country, since the formation of one of the newest regular deposits known in Geology.

5. *Basin of Vienna: Comparison of its Principal Deposits with those of Lower Styria, &c.*

We stated in the first chapter of this paper *, that the central axis of the Alps, in its extreme eastern prolongation, formed the boundary between the basins of Vienna and Styria—and that after partially disappearing under the newer deposits (connected, in point of fact, with both these basins) it again emerged in the neighbourhood of Presburg.

In applying the term *basin*, to the physical regions containing the tertiary formations of Vienna and Styria, we use the customary language of Geology. They were, however, nothing more than two deep bays in the ancient tertiary sea, separated from each other by a great promontory connected with the central ridge of the Eastern Alps †: and we find, as might under such circumstances be expected—that the deposits they contain, are in the same horizontal or slightly inclined position, and that they exhibit very nearly the same succession of phenomena. It is indeed owing to their slight inclination that the lowest tertiary groups in the neighbourhood of Vienna are almost unknown; having been reached only by deep borings for water (through the inferior blue clay called *Tegel*), and by other artificial means.

We subjoin the following synopsis of the successive deposits in the basin of Vienna on the authority of M. Partsch, who has been long employed in working out the most minute details of their structure. Some of the facts were verified by our own observations. The section (partly taken from the borings above mentioned) is in the descending order:

	Average thickness in feet.
1. Alluvial loam called *Löss*, with terrestrial shells, of existing species (of the genera Pupa, Helix, and Succinea), mixed with bones of Elephants of extinct species. The average thickness of this deposit is about 60 feet, but at some places the thickness is much greater	60
2. Gravel and sand, with subordinate, concretionary, calcareous masses, sometimes oolitic. This group contains bones of the Mastodon, Anthracotherium, Tapir, &c.	70

* p. 305. † Plate XXXV.

	Average thickness in feet.
3. Fresh-water limestone—only in patches (as at the Eich-Kogel) containing Lymnææ, Planorbes, Helices, &c	140
4. Great, white coral-limestone (*Leitha-Kalk*), containing large Pectens, Echini, &c.—also bones of the Tapir, Mastodon, Stag, and other Mammalia	150
5. Coarse, calcareous conglomerate, breccia, and calc-grit, forming the base of the white coral-limestone of the *Leitha-Gebirge*	200
6. Superior blue marl (*Tegel*), with a profusion of fossils *	40
7. Yellow sand, with calcareous grits, and many fossils, several of them undescribed—*Cerithium pictum*, and two or three species of Ostrea abound in it.	120
8. Inferior blue marl (*Tegel*)—only known by borings, and some partial excavations; fossils, therefore, little known	300
9. White sands, &c., reached only by boring—thickness therefore entirely unknown.	
Total	1080 feet.

In explanation of this tabular view of M. Partsch, we venture to suggest that Nos. 9. and 8. are on a parallel with the lower tertiary groups of Styria, —that they are, therefore, of an older date than has been generally assigned to any of the tertiary deposits in the Vienna basin—and that they are probably on the parallel of some of the groups of the London and Paris basins.

The preceding supposition is not invalidated by the fact, that the fossils of the yellow sand and superior blue marl (Nos. 6. and 7.), present several analogies to the shells of the Bordeaux basin, and of certain strata in the Sub-Apennine regions †.

It is important to remark, that the great coral limestone (No. 4.) is unequivocally superior to the whole system of marls and sands; as it was at one time, from its mineral structure, confounded with the *calcaire grossier* of Paris. It was

* Most of the organic remains, cited in the instructive memoir of M. Constant Prévost, on a portion of the Vienna basin (*Journal de Physique*, tome 91.), were, we believe, from beds on the parallel of this and the preceding group.

† A collection of fossils from Hirtemberg, in the Vienna basin, which one of the authors owes to the kindness of M. Constant Prévost, has been compared by Mr. J. Sowerby with the fossils of Lower Styria and of some other tertiary deposits, and gives the following results:—

1. None of the Hirtemberg shells are identical with the species found at Kreitzpetter in the lower group of the Styrian basin (*supra*, p. 388.)

2. Considered as a group, they differ much from the fossils of the London-clay; although two species resemble *Cancellaria evulsa* (Min. Con.) and *Fusus complanatus* (Min. Con.)—both of the London-clay.

These results might have been anticipated, because the Vienna fossils are derived from beds which are above the parallel of the lowest tertiary group of Styria.

3. Several of the Hirtemberg fossils seem to be identical with species in the Bordeaux basin and the English crag. For example: *Venericardia Jouanneti* (Bast.); *Arca Diluvii* (Lam.);

examined by M. Partsch and one of the authors (during the summer of 1830), on both flanks of the Leitha-hills, where it dips off from a primary axis, and is seen, at its lower extremity, to pass into the calcareous conglomerate (No. 5.). It was also examined at Loretto (where, besides the casts of numerous shells, the beds contain bones of large land animals; such as the Stag, the Mastodon, &c.), Eisenstadt, and Margarethen *; in the low range called Seegebirge, bordering on the Neusiedler-See; and at Brüner and Willersdorf on the skirts of the Alps; and we are convinced, from its place in the several sections, its structure, and its organic remains, that it is quite identical with the coral limestone in the central group of Lower Styria.

The fresh-water group (No. 3.) is only of partial occurrence in the basin. The best example of it is in the conical hill, called the Eich Kogel, between Baden and Vienna; where it puts on the form of a hard, vesicular, light-coloured limestone, containing shells of the genera, Helix, Lymnæa, and Planorbis; and rests on the calcareous conglomerates of the *Leitha-kalk*, and the inferior system of marls and sand.

Where the fresh-water limestone is wanting, the Leitha-kalk is immediately surmounted by the sand and gravel beds (No. 2.), containing the calcareous concretionary masses and the bones above described. This group is spread over all the low ground about Vienna. It possesses many of the same characters, and appears to be contemporaneous, with the upper group of Lower Styria, which we have shown to be of the same age with the old volcanic eruptions of that region.

Some portions of the preceding group might be confounded with *diluvium*, and considered as due to the last tumultuous operation of the retiring waters of a deluge. But independently of other phenomena (exhibited in certain parts of the group), such a supposition seems to be entirely invalidated by the existence of a still higher group (No. 1.); which is not only of great extent and thickness, but contains delicate shells of living species (such as *Helix hispida*, *Succinea amphibia*, &c.), mingled with the bones, and sometimes with nearly

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Natica tigrina; Trochus patulus, var. (Bast.); *Cerithium pictum* (Bast.); a Cone, resembling *Conus deperditus* (Brug.);—all of which are Bordeaux fossils: and to these we may add, *Natica hemiclausa* (Min. Con.), and *Turritella incrassata* (Min. Con.)—both of which occur in the crag.

4. Some of these fossils are identical with shells found in the upper group of the Styrian basin. For example: *Turritella incrassata* (Min. Con.); *Cerithium vulgatum;* and *C. pictum* (Bast.)—all of which occur at Radkersberg and Hartberg, and the last also at Poppendorf.

* A magnificent section of this group (No. 4.) is exposed in the quarries of Margarethen, where 70 or 80 feet of the thick-bedded massive limestone are laid bare, with scarcely a trace of any *way-board* of division.

entire skeletons of the Mammoth. Such a deposit ill represents the rapid operation of a retiring flood.

It is greatly expanded near Krems and St. Pölten ; reaching occasionally the thickness of 140 feet, and having, near those places, the exact appearance of the old alluvial hillocks in the valley of the Rhine, which have been described by M. Voltz.

Unconformable masses of conglomerate appear (as has been already stated) in several places on the north flanks of the Alps*—apparently produced soon after the last great movements of elevation, which set on edge all the neighbouring strata. We do not however venture rigidly to compare the horizontal conglomerates of Salzburg and Bavaria with any of the upper formations in the basins of Vienna and Styria ; where, as we have seen, all the tertiary groups are nearly horizontal, and where there does not appear to have been any break of continuity between the oldest and youngest of the successive deposits.

To the N.W. of the Wiener-wald appears a similar phenomenon to that already described at Ortenberg (p. 380) : the deposits in this part of the valley of the Danube have, in common with all those on the flanks of the Bohemian chain, escaped the influence of the last movements which dislocated the newest strata on the flanks of the Bavarian Alps. For instance, in several places near the right bank of the Danube (and especially on the banks of the Pielach, just above its confluence with that river at Mölk), are thick stratified masses of marl and sand resembling the *Tegel* and other beds of the Vienna basin, resting horizontally on inclined strata of gneiss and mica-schist†. One of these masses of horizontal, blue marl contains a bed of lignite (too poor to remunerate those who have attempted to work it) ; and many fossil shells, out of which we collected several species of Ostrea, all we believe undescribed, but one resembling *Ostrea flabellula* (Lam.); a Cardium; a Nerita; three species of Cerithium; and several very minute, undescribed bivalves. The lignite, where it has been worked, is about 200 feet above the level of the river ; and in general the system of blue marls, in the little valley of the Pielach, is surmounted by thick beds of yellowish sand without fossils. We have not materials sufficient to define the comparative age of this deposit : but it is obviously much more analogous to the lignites in the Styrian basin, than to any of the formations on the north flank of the Alps described in the preceding chapter.

Lastly, we may notice the structure of the tertiary hills, surrounding the alluvial basin of St. Pölten, on the road from Mölk to Vienna. They are

* Plate XXXVI. fig. 6 and 9.

† The convent of Mölk stands upon the primary strata, which occupy the banks both of the Danube and the Pielach.

made up of three horizontal deposits—the lowest composed of blue marl and sand (*Tegel*), probably the same with the blue marls on the Pielach—the middle deposit made up of yellow, micaceous sand, with concretions of sandstone and bands of coarse grit—the highest consisting of light-coloured loam, with shells of living species, and bones of some animals of extinct species. The analogies of this group to the higher deposits of the Vienna basin are too obvious to require notice.

All these facts are in harmony with each other, and seem to prove unequivocally, that the last great movements of elevation, which dislocated and contorted the newest formations of Switzerland and the Western Alps, and extended their influence into Bavaria and Salzburg, produced little or no effect on the position of tertiary groups near the eastern extremity of the chain.

Before we terminate this chapter, we wish briefly to allude to the great erratic boulders of the chain, apparently independent of all the regular formations above described, but, if we mistake not, confirming by their distribution the conclusion at which we have just arrived.

Every one is aware of the enormous masses of primary rock scattered on the outskirts of some parts of the Swiss and Savoy Alps. Instances of this kind occur also in a part of the chain described in this paper. One of the most striking is seen in a narrow valley below Neukirchen*, where a block of gneiss, as large as a small house, is lying on the surface of the tertiary strata. Similar blocks may be traced along the north flank of the Alps in many other places, particularly between the Inn and the Tegern-see: of these, the well-known "*Grosse-stein*" is perhaps the most gigantic. These phenomena are not, however, confined to the *glacis* of the Alps: for we occasionally find huge, irregular boulders, lodged in recesses and high gorges, midway between the central axis and the outskirts of the chain. A very striking example of such a lodgment occurs to the east of Seefeld in the Tyrol; where many primary boulders of enormous size are surrounded by the bare, lofty peaks of Alpine limestone. These erratic blocks, now in the centre of the calcareous zone, and at the height of more than 5000 feet above the level of the sea, must have come from the south, and must consequently have traversed the space now occupied by the valley of the Inn, which is excavated to the depth of 2000 feet below them.

M. Elie de Beaumont has, we think, proved by most satisfactory details—that the vast boulders of the Swiss and Savoy Alps were sent off by one of the last

* Plate XXXVI. fig. 7.

great movements of elevation, and that these movements propagated their influence in the direction of the Eastern Alps. The facts we have just stated are in accordance with this theory.

Now, if we extend our examination to the eastern limits of the chain, we look in vain for great, erratic blocks like those above described. We are aware of the extreme difficulty of proving a negative proposition: but we may at least venture to assert, that in the plains of Styria, and in parts of the basin of Vienna which come up to the very confines of the Alps, boulders of this kind, if they do exist at all, are almost unknown. To what then are we to attribute their absence? The answer seems to be obvious. The forces of elevation which dislocated and contorted the newest tertiary groups of the Western Alps, have left the tertiary groups of Styria and Vienna almost as horizontal as when they were deposited; and the forces which propelled enormous masses of granite over the mountains of Savoy, exerted little or no influence on the eastern skirts of the chain.

Chap. VI.

Concluding Remarks on the Successive Formations of the Eastern Alps—Different Periods of Elevation—Modifications of the several Deposits since those Periods, &c.

The subjects treated of in the five preceding chapters are so numerous, and at the same time so disjointed, that it seems expedient, before we terminate this paper, to recapitulate some of the leading facts already stated, and to review the conclusions we have drawn from them. Before we proceed to this task we wish to observe, that the accompanying Plate (XXXVI.) exhibits a series, not of ideal, but of real sections. The first figure is indeed partly an exception to this remark; as it merely represents, in a general way, the collocation of the great mineral masses on both sides of the central axis of the chain, without giving the contortions and disruptions on any known transverse line. The other sections are all founded on direct observations; and represent, or are at least intended to represent, the position, dip, and (as far as so minute a scale admits) somewhat even of the external form and relative height of the several groups.

Very few of our conclusions are to be considered as purely hypothetical: they are, for the most part, founded on facts which we have endeavoured, to the best of our power and opportunities of observation, to describe and interpret correctly. In subjects of such extreme complication it would be ridiculous for us to assume that we have fallen into no errors of detail. The facts, however, and the phenomena remain; and the value of the sections, as far as they are true representations of phenomena, is in a great measure independent of the interpretations we may have put upon them.

The chief difference between ourselves and some other writers on the structure of the Eastern Alps (especially Dr. Boué), is in drawing the line of demarcation between certain groups of strata, and determining the limits between the secondary and tertiary systems. Even this difference, though by itself not unimportant, does not affect the general accuracy of the accompanying sections. On this subject we have, however, written so fully in the preceding chapters, that we need not repeat what we have stated; we therefore, without further preface, commence our recapitulation.

1. The general range of the primary axis of the Eastern Alps is seen in the accompanying map*; and has been described in a previous paper†. It is now made to emerge from beneath the tertiary system of the Vienna basin, in the Leitha-gebirge; which thus forms a connecting link between the Eastern Alps and the primary chain commencing near Presburg‡.

2. Stratified rocks, conforming to the common transition type, and with a suite of characteristic transition fossils, are found, though rarely, in the Eastern Alps. Beds of limestone containing organic remains are also found, though still more rarely, associated with highly crystalline rocks of the central axis§. These two facts show the difficulty, or, perhaps, the impossibility, of drawing any exact line of separation between the primary and transition systems of the Alps: and they make it probable, that the crystalline structure of some of the stratified masses of the central axis, has been superinduced after the deposition of the beds. They, however, introduce no confusion between the primary and secondary systems of the chain; which, in general, are clearly separated from each other. We cannot even conceive such a change of mineral structure as could lead us to confound the great zones of Alpine limestone with the gneiss, mica-slate, &c. of the central portions of the chain.

3. The primary and transition systems are surmounted (in some cases unconformably) by red sandstone, *rauchwacké*, red gypseous marls, &c. which sometimes, though rarely, become saliferous. These masses form one large group, supposed to be on the parallel of the new red sandstone. In addition to the localities enumerated in a former paper‖, they have been traced to

* Plate XXXV.

† Phil. Mag. and Annals, N. S., vol. viii. p. 85.

‡ *Supra*, p. 305.

§ *Supra*, p. 306, 307.

‖ Phil. Mag. and Annals, N.S. vol. viii. p. 92.

the flanks of the primary ridge between the basins of Vienna and Styria. In consequence of the enormous derangements of the chain, this group is brought out in some longitudinal valleys within the limits of the secondary zone on the north flank of the Alps; but, in general, it forms, on both sides of the chain, the base of the great escarpments of secondary limestone, and rests immediately on the upper strata of the central system.*

4. The preceding group is surmounted by the great zone of Alpine limestone, which is, in its turn, surmounted by, or passes into, a great series of fucoid shales, green sandstones, and other rocks, referred to the green-sand and cretaceous periods. The Alpine limestone, considered under the most general point of view, is therefore on a parallel with the oolitic series. It is separated, agreeably to the system of M. de Lill, into three great subdivisions. The lowest is supposed to commence (at Bleiberg in Carinthia, and also in the valleys of Abtenau and Gaisau) with beds of the age of the lias. The middle subdivision contains the great, brecciated, saliferous deposits of the Alps, which are, therefore, on a higher parallel than the deposits of rock salt worked in England. The highest subdivision ends with the hippurite-rock, which seems therefore of the age of some of our highest oolitic groups. This last line of demarcation, though artificial, is the best we are able to adopt; for the hippurite-rock seems to be more nearly connected with the Alpine limestone than with the higher groups. But there are, if we mistake not, many places where the upper Alpine limestone graduates insensibly into the next superior group†.

5. To the younger Alpine limestone succeeds a vast series of beds composed of fucoid-shales and grits, green-sands and sandstones, cretaceous marls, &c. &c. They are, as a whole, referred to the green-sand and chalk formations. The fucoid-shales *may* in some cases descend into the upper part of the Alpine limestone; but in general they seem decidedly subordinate to the system we are describing. The upper part of the system, on the north flank of the Alps, contains Nummulites and beds of arenaceous iron ore. On the south side of the Alps, beds of nummulite limestone are in some places (for example between Adelsberg and Trieste) very largely developed, and perhaps descend as low as the Alpine limestone‡.

* *Supra*, p. 307—311. The identification of this group with the new red sandstone was published by Dr. Buckland in 1821; and was, in itself, a step of no ordinary importance; as it at once separated the whole zone of Alpine limestone from the order of transition rocks. About the same time Mr. Bakewell was employed in making a series of independent observations in the Tarentaise, which led him to similar conclusions: they were not, however, published before 1823. See "Travels in the Tarentaise," 2 vols.

† *Supra*, p. 311—318.

‡ *Supra*, p. 320—322, and p. 333, 337, &c.

The fossils of the different secondary groups, above enumerated, can seldom be specifically identified with the fossils of the corresponding formations in this Island. To this remark, however, the organic remains of the transition slate of Bleiberg, as well as the organic remains of some parts of the green-sand and cretaceous groups, may be quoted as partial exceptions.

6. On the north flank of the Alps the nummulitic groups are very largely developed; so as not only to enter into the composition of the green-sand and cretaceous system; but also to rise into a newer order of strata, containing many fossils hitherto unobserved except in tertiary formations, and surmounted by still higher conformable strata with a large suite of unmixed tertiary fossils. As these newer nummulitic deposits are overlaid by no known secondary formation, we regard them as a transition group connecting the secondary and tertiary systems. We place them between the *calcaire-grossier* and the chalk; and do not think that their equivalents are found in any part of England, or in the north of France. This conclusion is founded on the details given in the Arzt, the Kressenberg and the Untersberg sections*.

7. A similar transition is seen among groups of overlying unconformable strata, existing here and there at high elevations within the limits of the secondary system. The most remarkable phenomena of this kind are detailed in the third chapter.

8. The tertiary formations on the flanks of the Salzburg and Bavarian Alps (essentially composed of alternating masses of marl, sandstone, and conglomerate), have a prevailing dip towards the north, but their angle of inclination gradually diminishes as they recede from the outskirts of the secondary system. In their range towards the west the subordinate sandstone (*molasse*) becomes greatly expanded, and they seem gradually to conform to the type of the tertiary deposits of Switzerland†. In many of the low regions, extending towards the plains of the Danube, they are overlaid and almost entirely concealed by horizontal deposits of coarse gravel and conglomerate.

9. There are several deposits of lignite within the limits of these tertiary formations; but not all on the same parallel; as some belong to the lower and others to the higher groups. These deposits are not properly formations of fresh water; but seem to have been drifted mechanically into marine bays or estuaries. The most remarkable of them is at Häring, in the valley of the Inn; and though it has the external characters and structure of a lacustrine formation, it contains some marine shells, resembling those of the older tertiary groups. It also contains many plants; but out of eleven species,

* *Supra*, pp. 337, 341, & 346.

† *Supra*, pp. 324, 329.

examined by M. Adolphe Brongniart, there is not one which is identical with any known tertiary fossil plant in his collection*.

10. All the deposits, so far enumerated, belong to highly inclined systems; but in the basins of Vienna and Styria the tertiary formations are nearly horizontal, and may be subdivided into three groups. The lowest group, in Styria (composed of marl, sand, and sandstone, in some instances passing into a coarse conglomerate form) contains subordinate beds of lignite. It is ill exposed in the Vienna basin. The middle group in both the basins is characterized by the great masses of coralline limestone. In Styria the highest group (essentially composed of sands, small pebble beds, shelly marls, highly calcareous marls passing into concretionary masses of limestone sometimes with a true oolitic structure, &c.) alternates with matter ejected from the old volcanic vents on the confines of Hungary. In the Vienna basin it is unmixed with volcanic ejections; but is in some places separated from the middle group by a deposit of fresh-water limestone. All the three groups contain bones of Mammalia. The lowest we have compared with a portion of the deposits in the London and Paris basins—the middle and upper, with the middle and higher Sub-Apennine formations. The evidence for these several conclusions is given in the details of the fifth chapter. Lastly, the highest regular deposits of the Vienna basin are surmounted by beds of alluvial loam containing bones of extinct Mammalia mixed with terrestrial shells of living species.

Such is a brief synopsis of the successive deposits noticed with greater or less detail in the preceding chapters.

Most of the accompanying sections afford the clearest proofs of the elevations and disruptions of the chain; but they seldom give us any direct indication, either of the nature of the powers employed in producing these effects, or of the exact points on which the principal moving forces have acted. In the section through the ridges near the banks of the Iller we however find, that volcanic dykes have struggled to force a vent through the secondary strata; and that they appear to have driven before them great masses of primary rock among the superincumbent deposits—thereby producing all the ordinary accompaniments of contortion and elevation†. Coupling these phenomena with the appearance of granite, and other undoubted igneous rocks, within the region of the central axis, we have no hesitation in referring all the great movements of the Alpine chain to certain modifications of igne-

* *Supra*, p. 370—375, and p. 377—379.

† *Supra*, p. 333, and Plate XXXVI. fig. 4.

ous action. On this subject, indeed, all controversy seems now to be at an end among practical geologists.

We have repeatedly mentioned phenomena which appeared to harmonize with the theory of M. Elie de Beaumont respecting the recent elevation of the principal chain of the Alps; we have also stated, that the eastern extremity of the chain has not been subjected to the same movement; inasmuch as there all the tertiary deposits rest horizontally on the edges of the older inclined strata. All the western and central portions of the chain described in this paper seem to have partaken of the movements which elevated Mont Blanc, and were propagated along the principal chain of the Alps, in a direction about E.N.E., after the deposition of the *molasse* and other recent, tertiary groups. But the eastern extremity of the chain seems to be connected with the Pyreneo-Apennine system of M. de Beaumont, which was elevated after the deposit, both of the highest portions of the cretaceous system, and of all those peculiar groups which we consider intermediate between the secondary and tertiary series. The high inclination of the *molasse,* &c. on the north flank of the Bavarian Alps*, the direction of the great breaks and fissures in the valley of the Allgau†, the position of the great, erratic blocks noticed in the preceding chapter, and the horizontal position of the tertiary deposits of the Vienna and Styrian basins, all seem to harmonize with this theory.

If these views be correct, a double system of breaks and dislocations (connected with two distinct periods of elevation) must intersect each other somewhere in the line of the Eastern Alps; and by such a supposition the apparently anomalous position of certain groups of strata within the regions above described may be, perhaps, hereafter explained.

The overlying horizontal conglomerates noticed in some of the preceding sections‡, seem to throw some difficulties in the way of this theory, unless, indeed, we can connect them with a part of the horizontal system of the Vienna basin, which, on such a supposition, must extend much further up the Danube than we have hitherto supposed. We wish not to incumber this part of our subject with hypotheses, as our observations were too few and too disjointed to be of much value in establishing any particular theory; but we think ourselves justified in drawing the following conclusions from facts already stated.

1. The old transition rocks of some portions of the Eastern Alps were consolidated and placed in a nearly vertical position before the existence of the

* *Supra*, p. 326, &c. † *Supra*, p. 335. ‡ Plate XXXVI. fig. 6, 9, &c.

new red sandstone group*. How far this fact is general, our observations do not enable us to determine.

2. Some of the primary rocks of the Bohemian chain seem to have undergone no great movement since the deposit of the cretaceous and oolitic series†.

3. The Alpine limestone was solidified and had undergone great movements of elevation before the deposition of the upper cretaceous system, and of the intermediate groups between the secondary and tertiary series. This is proved by the position of the overlying beds of Gosau, and by the conglomerates separating them from the older secondary groups. We may add, that the existence of vegetable fossils in the overlying beds proves them to have been deposited after a part of the chain had risen above the sea.

4. That a portion of the Alpine chain was, at a comparatively ancient period, above the level of the sea, is further proved by the existence of beds of lignite both in the secondary and older tertiary groups. The position and fossils of some of these strata show how much the physical form and vegetation of the Alps must have been changed since the period when these lignites were deposited.

5. The eastern extremity of the chain was elevated *after* the period of the fucoid shales, and also after that of the overlying groups (of the Wand, &c.) between the secondary and tertiary series‡, but *before* the existence of the neighbouring tertiary deposits. We may here observe, that the deposition of the lowest horizontal beds of the Styrian basin probably commenced immediately after this elevation; on which account, as well as for reasons already stated, we are disposed to give them a lower place in the tertiary scale than has generally been assigned to them.

6. A portion of the Bavarian Alps was elevated since the period of the *molasse* of Switzerland, and of the marls and conglomerates by which it is overlaid§. This is the last epoch of elevation here considered; and it seems to correspond to the ninth revolution described in the researches of M. de Beaumont, which includes the chain of the Eastern Alps‖.

Whatever may have been the causes of this last elevation, they seem to have acted with diminished intensity in their continuation towards the east. The newer tertiary marls, sands, and conglomerates, seem to have been formed in a mediterranean sea, which once washed the northern flanks of the Alps, and must, at the time of their formation, have been all nearly at the

* *Supra*, p. 306.; also Phil. Mag. and Annals, New Series, vol. viii. Pl. II. fig. 3.

† *Supra*, p. 380.

‡ See Chap. III. pp. 364, 367.

§ *Supra*, pp. 324, 329.

‖ See *Recherches sur quelques-unes des Révolutions de la Surface du Globe*, p. 156, 311, &c.

same level. But in the south-western parts of Bavaria, where they form the water-shed between the Danube and the Rhine, they are greatly elevated above the corresponding groups further towards the east, and are even at higher levels than the old beds of the Inn and the Salza, many leagues within the barriers of Alpine limestone.

It follows unequivocally from the preceding statements, that the chain of the Eastern Alps has been exposed to many shocks and independent movements of elevation. Some of the most violent of these shocks were followed by the production of conglomerates. Thus we find conglomerates, where they might have been expected, underlying the horizontal deposits of Gosau, and overlying still newer deposits set on edge by the last movement of the chain.

As a general rule, applicable to most parts of the Eastern Alps which we have examined, conglomerates are not only much more abundant, but also of coarser texture in the newer than in the older formations. This again is a result which might have been anticipated. The oldest strata were formed under the sea, perhaps before any Alpine chain existed. The deposits of the middle age were formed on the sides of mountains much less elevated than they are now, and therefore supplying fewer materials for mechanical degradation. But the tertiary groups had their origin in a sea which washed the base of the Alpine chain already greatly elevated, and supplying, not merely by debacles and other extraordinary movements, but by the action of the waves beating on its sides, and by the erosion of torrents wearing their way through its transverse valleys, abundant materials for the masses of conglomerate such as we have described.

The chain of the Eastern Alps has then been exposed, not only to the shocks of elevation above indicated, but, undoubtedly, to many others, of which we have not yet seen the physical trace. Long periods of ages elapsed between the successive greater movements; and during those periods mountain masses of conglomerate were formed, time after time, at the loss of the pre-existing rocks. In such facts as these we have a ready answer to any difficulties suggested by the appearance of the overlying groups (at Gosau, Zlam, &c.) among the high valleys of Alpine limestone. The powers of degradation have been at work ever since the chain first rose above the waters: and in bringing together, in imagination, the disjointed fragments of an ancient deposit, we have no right to look among them for any certain traces of the shores and bays of that sea which beat against the sides of the Alps at the time of their formation; nor are the powers of degradation now suspended. This, at least, is proved by every torrent descending from the chain to the levels of the tertiary plains.

Considered on a great scale the tertiary sand and conglomerates of south-western Bavaria may be described as a series of inclined planes, down which the rivers roll, in nearly undeviating lines, till they mingle themselves with the Danube, presenting, in this respect, a striking contrast to the old sinuous channels and gorges through which the waters struggle to escape from the higher Alps. Some of these rivers run brawling over the surface like the waters of a great land-flood, not having found any well defined course; and ages must yet elapse before they have worked for themselves anything like permanent channels. Under such circumstances the alluvial deposits are coarse in texture, and are spread far and wide, and, in future ages, should the rivers ever change their channels, may be mistaken for diluvial formations.

We do not mean by this remark to assert, that there is no distinction between *alluvium* and *diluvium* (to adopt the technical language now in use, though not perhaps well chosen), or to confound the detritus of river channels with the masses of incoherent matter left on the surface of the land by seas retiring after some period of elevation. What we contend for is, that on the confines of the Bavarian Alps (and the same remark applies to the outskirts of many other mountain chains), the two classes of deposits cannot be easily separated from each other: and in proof of this we may add, that in the parts of Bavaria above described, as well as in other tertiary regions of the flanks of the Alps, bosses of decomposing tertiary conglomerates are often mistaken for patches of diluvial gravel—that where the beds are horizontal, and even in some places where they are considerably inclined, we find it difficult to draw a line between the diluvial gravel and the newer tertiary conglomerates —and that the recent gravel on the banks of the rivers often differs very little from the incoherent matter which caps the neighbouring hills.

That such must be the case is obvious, when we further consider the manner in which the forces of degradation have acted on the newest deposits on the north flanks of the Alps. By a movement of elevation the sea has been driven from the whole region, and the retiring waters have left traces of their ravages on the edges of the uplifted strata. It is to this very action that we have referred the horizontal conglomerates of the Arzt and Untersberg sections*, and other phenomena above noticed. But every movement of elevation must produce a destruction of equilibrium among the waters of inland drainage, and must, in mountain chains, have been necessarily followed by *debacles*, capable perhaps of producing such horizontal masses as those above

* Plate XXXVI. fig. 6. & 9.

those above alluded to. If any of them have been produced by this second mode of action, it cannot be called *diluvium*, except by a use of the word which differs from that for which it was first intended*.

Again, when the southern regions of Bavaria were lifted above the waters, not only would the Alpine torrents be shot down into the Danube along the inclined planes presented to them, but many lakes and pools must have stagnated in the hollows presented by the bottom of the old tertiary sea. Of such expanses of stagnant water, many must have disappeared without leaving a trace behind. But of some we see the marks in low, marshy regions at dead levels, on the sides of which we, here and there, find lines of *travertino* and other indications of the former action of water: and there are still in upper Bavaria many lakes and marshy tracts in such positions as would be unnatural in any country of which the drainage had commenced in a more ancient period.

The inevitable effect of water thus pent up must have been the occurrence of great floods, caused by the bursting of the barriers, differing only in degree from the debacles before spoken of, and modifying the surface of the country wherever they extended. Of this kind of operation there are traces almost innumerable; and we did not ascend a single rivulet which falls through the south-western parts of Bavaria without remarking one or two, and sometimes three or four parallel terraces, indicating (as in the parallel roads of Glen Roy) the residence of nearly stagnant water at successive levels. The banks of the Lech near Schöngau offer some fine examples of these phenomena, but they are so common that it seems needless to refer to instances. By all these causes combined, aided by the diurnal erosion of the elements, has the surface of the country been modified since the last elevation of the Eastern Alps.

* We by no means deny the reality of *diluvial* operations, when the word *diluvial* is used in a limited, and not in a hypothetical, sense. Some of the low longitudinal valleys between the secondary and tertiary deposits—the great breaks of continuity in the same system of strata—the round-topped tertiary hills rising several hundred feet above the mean level of the country—the irregular masses of transported materials, at high elevations, and not along the line of any river drainage—these phenomena we attribute, not to the ordinary erosion of rivers however long continued, but to the action of the retiring waters at the last period of elevation, or to great debacles which soon followed them. By the same kind of action we would explain some of the great erosions near the banks of the Danube. Thus, at the height of several hundred feet above its left bank near Ulm, we find patches of a thick lacustrine deposit sticking on the sides of the secondary hills; and a precisely similar deposit caps some hills, on the Bavarian side, further down the river, and several miles from its right bank. The lacustrine rocks were probably once continuous, forming a part of an extensive formation which has been breached through, and in a great measure carried off, by denuding currents.

Table of Fossils found in the Gosau Deposit and its Equivalents in the Alps.

Class.	*Genus.*	*Species.*	*References.*	*Localities in the Alps.*	*Other Localities.*
Polyparia.	Tragos.		Goldfuss.	Gosau.	
	Nullipora.		Ibid.	Ibid.	
	Madrepora.		Ibid.	Ibid.	
	Cellepora.		Ibid.	Ibid.	
	Lithodendron	granulosum.	Ibid. Tab. 37. f. 12.	Ibid.	Castell' Arquato (Sub-Apennine).
	Fungia	radiata.	Ibid. Tab. 14. f. 8.	Ibid.	
		polymorpha.	Ibid. Tab. 14. f. 6.	Ibid.; Zlam.	Bassano and Dauphiny (oldest Sub-Apennine).
		undulata.	Ibid. Tab. 14. f. 7.	Ibid.	
		discoidea.	Ibid. Tab. 14. f. 9.	Ibid.	
	Diploctenium	cordatum.	Ibid. Tab. 37. f. 16.	Ibid.	Maestricht.
	Turbinolia	complanata.	Ibid. Tab. 15. f. 10.	Ibid.	
		duodecimcostata.	Ibid. Tab. 15. f. 6.	Ibid.	Castell' Arquato (Sub-Apennine).
		lineata.	Ibid. Tab. 37. f. 18.	Ibid.	
		cuneata.	Ibid. Tab. 37. f. 17.	Ibid.	Ibid. (Ibid.)
		aspera.	Sowerby*, Pl. 37. f. 1.	Ibid.	
	Cyathophyllum	rude.	Ibid. Pl. 37. f. 2.	Ibid.	
		compositum.	Ibid. Pl. 37. f. 3.	Ibid.	
	Meandrina	agaricites.	Goldfuss, Tab. 38. f. 2.	Ibid.	
	Astrea	striata.	Ibid. Tab. 38. f. 11.	Ibid.	
		formosa.	Ibid. Tab. 38. f. 9.	Ibid.	
		reticulata.	Ibid. Tab. 38. f. 10.	Ibid.	
		agaricites.	Ibid. Tab. 22. f. 9.	Ibid.	
		grandis.	Sowerby, Pl. 37. f. 4.	Ibid.	
		media.	Ibid. Pl. 37. f. 5.	Ibid.	
		formosissima.	Ibid. Pl. 37. f. 6.	Ibid.	
		ambigua.	Ibid. Pl. 37. f. 7.	Ibid.	
		tenera.	Ibid. Pl. 37. f. 8.	Ibid.	
		ramosa.	Ibid. Pl. 37. f. 9.	Ibid.	
Annulata.	Serpula.		. . . .	Ibid.	
Conchifera.	Teredo.		. . . .	Ibid.	
	Solen.		. . . .	Ibid.	
	Panopæa	plicata?	Min. Con. Tab. 419. f. 3.	Ibid.	Sandgate (lower green-sand).
	Anatina.		. . . .	Ibid.	
	Crassatella	impressa.	Sowerby, Pl. 38. f. 3.	Ibid.	
	Corbula	angustata.	Ibid. Pl. 38. f. 4.	Ibid.	
	Sanguinolaria	Hollowaysii??	Min. Con. Tab. 159.	Ibid.	Bracklesham Bay (London clay).
	Lucina.		. . . .	Ibid.	
	Astarte	macrodonta.	Sowerby, Pl. 38. f. 8.	Ibid.	
	Cyclas	cuneiformis?	Min. Con. Tab. 162. f. 2. & 3.	Ibid.; Flanks of the Wand.	Woolwich (plastic clay).
	Cytherea	lævigata.	Lam. Ann. du Mus. tome 7. p. 134.	Ibid.	Grignon (*calcaire grossier*).
	Venus.		. . . .	Ibid.	
	Venericardia.		. . . .	Ibid.	
	Cardium	productum.	Sowerby, Pl. 39. f. 15.	Ibid.; Marzoll.	
	Isocardia.		. . . .	Ibid.	
	Cucullæa	carinata.	Min. Con. Tab. 207. f. 1.	Ibid.	Blackdown (green-sand).
	Arca.		. . . .	Ibid.	
	Pectunculus	Plumsteadiensis.	Ibid. Tab. 27. f. 3.	Ibid.	Plumstead near Woolwich (plastic clay).
		brevirostris.	Ibid. Tab. 472. f. 1.	Ibid.	Bognor (London clay).
		pulvinatus?	Lam. Ann. du Mus. tome 6. p. 216.	Ibid.	Grignon (*calcaire grossier*); Bracklesham, Sussex (London clay).
		calvus.	Sowerby, Pl. 38. f. 2.	Ibid.; Marzoll; Flanks of the Wand.	

* The figures following the species named by Sowerby refer to the Plates which accompany this Memoir.

Class.	*Genus.*	*Species.*	*References.*	*Localities in the Alps.*	*Other Localities.*
Conchifera.	Nucula	amygdaloides.	Min. Con. Tab. 554. f. 4.	Gosau.	Southend (London clay).
		concinna.	Sowerby, Pl. 38. f. 1.	Ibid.; Hinter Reutter.	
	Trigonia	aliformis. var.	Min. Con. Tab. 215.	Ibid.	Parham Park and Blackdown (green-sand).
	Modiola.		. . . .	Ibid.	
	Inoceramus	Cripsii.	Mantell, Geol. Suss. Tab. 27. f. 11.	Ibid.; Flanks of the [Wand.	Hamsey (chalk marl).
	Avicula.		. . . .	Ibid.	
	Pecten	quinquecostatus.	Min. Con. Tab. 56. f. 4—8.	Ibid.	Lewes (chalk); Chute Farm and Blackdown (green-sand), &c.
	Plicatula	aspera.	Sowerby, Pl. 38. f. 7.	Ibid.; Flanks of the	
	Gryphæa	elongata.	Ibid. Pl. 38. f. 6.	Ibid. [Wand.	
		expansa.	Ibid. Pl. 38. f. 5.	Ibid.	
	Exogyra.		. . . .	Ibid.	
	Ostrea.		. . . .	Ibid.	
	Terebratula	dimidiata?	Min. Con. Tab. 277. f. 5.	Ibid. [Wand.	Halldown (green-sand).
	Axinus?		. . . .	Ibid.; Flanks of the	
	Trigonellites.		. . . .	Ibid. Ibid.	
Mollusca.	Dentalium	grande?	Deshayes Mém. Soc. Hist. Nat. t. 2.	Ibid.; Marzoll.	*Calcaire grossier.*
	Calyptræa?		. . . .	Ibid.	
	Auricula	decurtata.	Sowerby, Pl. 38. f. 10.	Ibid.	
		simulata.	Min. Con. Tab. 163. f. 5—8.	Ibid.; Marzoll.	Barton Cliff (London clay).
	Melania.		. . . .	Ibid.	
	Melanopsis.		. . . .	Ibid.	
	Natica	ambulacrum?	Ibid. Tab. 372.	Ibid.	Ibid. (Ibid.)
		lyrata.	Sowerby, Pl. 38. f. 11.	Ibid.	
		angulata.	Ibid. Pl. 38. f. 12.	Ibid.	
		bulbiformis.	Ibid. Pl. 38. f. 13.	Ibid.; Zlam.	
	Nerita.		. . . .	Ibid.	
	Solarium	quadratum.	Ibid. Pl. 38. f. 17.	Ibid.	
	Trochus	spiniger.	Ibid. Pl. 38. f. 15.	Ibid.	
	Turbo	arenosus.	Ibid. Pl. 38. f. 14.	Ibid.	
	Turritella	angusta.	Deshayes.	Ibid. [stein.	
		biformis.	Ibid. Pl. 38. f. 18.	Ibid.; Bavarian Traun-	
		rigida.	Ibid. Pl. 38. f. 19.	Ibid.	
		læviuscula.	Ibid. Pl. 38. f. 20.	Ibid.	
	Tornatella	gigantea.	Ibid. Pl. 38. f. 9.	Ibid.; Zlam; Meyersdorf; Grünbach; Dreystetten; Heiflau, &c.	
		Lamarckii*.	Ibid. Pl. 39. f. 16.	Gams-Gebirge.	
	Nerinea	flexuosa.	Ibid. Pl. 38. f. 16.	Gosau.	
	Cerithium	reticosum.	Ibid. Pl. 39. f. 17.	Ibid. [Traunstein.	
		conoideum.	Ibid. Pl. 39. f. 18.	Ibid.; Zlam; Bavarian	
		pustulosum.	Ibid. Pl. 39. f. 19.	Ibid.	
	Pleurotoma	prisca?	Min. Con. Tab. 386.	Ibid.; Marzoll.	Ibid. (Ibid.)
		fusiforme.	Sowerby, Pl. 39. f. 20.	Ibid.	
		spinosum.	Ibid. Pl. 39. f. 21.	Ibid.	
	Fasciolaria	elongata.	Ibid. Pl. 39. f. 22.	Ibid.	
	Fusus	intortus.	Lam. Ann. du Mus. tome 2. p. 318. Encyc. pt. 2. 441. f. 16. a. b.	Ibid.	Grignon (*calcaire grossier*); Ronca (tertiary).
		heptagonus.	Sowerby, Pl. 39. f. 23.	Ibid.	
		carinella.	Ibid. Pl. 39. f. 24.	Ibid.	
		muricatus.	Ibid. Pl. 39. f. 25.	Ibid.	
		abbreviatus.	Ibid. Pl. 39. f. 26.	Ibid.	
		cingulatus.	Ibid. Pl. 39. f. 27.	Ibid.	
	Rostellaria	plicata.	Ibid. Pl. 38. f. 22.	Ibid.	

* Presented to the authors by Dr. Boué.

Class.	Genus.	Species.	References.	Localities in the Alps.	Other Localities.
Mollusca.	Rostellaria	costata.	Sowerby, Pl. 38. f. 21.	Gosau.	
		granulata.	Ibid. Pl. 38. f. 23.	Ibid.; Marzoll.	
		lævigata.	Ibid. Pl. 38. f. 24.	Gosau.	
	Nassa	carinata.	Ibid. Pl. 39. f. 28.	Ibid.	
		affinis.	Ibid. Pl. 39. f. 29.	Ibid.	
	Mitra	pyramidella?	Brocchi, tome 2. Tab. 4. f. 5.	Ibid.	Sub-Apennine.
		cancellata.	Sowerby, Pl. 39. f. 30.	Ibid.	
	Voluta	coronata?	Brocchi, Tab. 15. f. 7.	Ibid.	Ibid.
		citharella?	Brong. Terr. de Séd. Tab. 6 f. 9.	Ibid.	Near Turin (tertiary).
		acuta.	Sowerby, Pl. 39. f. 31.	Ibid.	
	Terebra	coronata.	Ibid. Pl. 39. f. 32.	Ibid.	
	Volvaria	lævis.	Ibid. Pl. 39. f. 33.	Ibid.	
	Baculites or Hamites.		. . . .	Ibid.	

Table of Fossils of Lower Styria, referred to in pp. 386, 398.

System.	Class.	Genus.	Species.	References.	Local. in Lower Styria.	Other Localities.
Lower System.	Cryptogamia Vascularia.	Chara	tuberculata?	Lyell, Geol. Trans. 2nd series, vol. ii. Pl. 13. f. 7, 8. p. 94.	Coal of Scheineck.	Isle of Wight.
			medicaginula?	Ad. Brong. Desc. Géol. des Env. de Paris, Pl. 11. f. 7.	Ibid.	Paris and London basins.
	Phanerogamia* (dicotyledonous).			. . . .	Ibid.	
	Crustacea.	Cypris.		. . . .	Ibid.	
	Mollusca.	Paludina.†		. . . .	Ibid.	
	Pisces.‡			. . . .	Ibid.	
	Mammalia.	Anthracotherium.		. . . .	Ibid.	
	Conchifera.	Lutraria	convexa.	Sowerby, Pl. 39. f. 1.	Marls of Kreitspetter.	
		Lucina	mutabilis?	Coq. Foss. des Env. de Paris, Tab. 14. f. 6. & 7.	Ibid.	Grignon (*calcaire grossier*).
			renulata.	Ibid. Tab. 15. f. 3. 4.	Ibid.	Ibid. Ibid.
		Venus	vetula.	Bast. Mém. Géol. Env. de Bordeaux, Pl. 6. f. 7.	Ibid.	Bordeaux (tertiary).
		Cardium.		. . . .	Ibid.	
		Pecten.		. . . .	Ibid.	
	Mollusca.	Bulla	elliptica.	Min. Con. Tab. 464. f. 6.	Ibid.	Barton Cliff, Hants (London clay).
		Nerita.		. . . .	Ibid.	
		Scalaria?		. . . .	Ibid.	
		Cerithium	tiara.	Ann. du Mus. tome iii. p. 343.	Ibid.	Grignon (*calcaire grossier*).
Middle System.	Polyparia.	Flustra.		. . . .	Wildon; Ehrenhausen.	
		Astrea.		. . . .	Ibid. Ibid.	
	Radiaria.	Clypeaster.		. . . .	Zirknitz-thal.	
	Crustacea.§			. . . .	Wildon; Ehrenhausen.	
	Cirripeda.	Balanus	crassus?	Min. Con. Tab. 84. f. 2.	Ibid. Ibid.	Suffolk Crag.
	Conchifera.	Teredo or Pholas.		. . . .	Ibid. Ibid.	
		Fistulana.		. . . .	Ibid. Ibid.	
		Cardium.		. . . .	Ibid. Ibid.	
		Pectunculus.		. . . .	Ibid. Ibid.	
		Mytilus.		. . . .	Ibid. Ibid.	
		Pecten	infumatus.	Lamarck, Fos. Env. Paris. p. 273.	Ibid. Ibid.	
			pleuronectes?	Lam. tome vi. Pt. i. p. 164.	Santa Egida.	Indian Ocean.
			———	Faujas.	Zirknitz-thal.	Maestricht.

* Leaves and fragments of wood.

† Operculæ.

‡ Trapezoidal scales measuring $\frac{1}{3}$rd of an inch by $\frac{1}{4}$th.

§ Claws of a crab.

	Class.	*Genus.*	*Species.*	*References.*	*Local. in Lower Styria.*	*Other Localities.*
	Conchifera.	Ostrea	Bellovacina.	Lam. Ann. du Mus. t. viii. 159.	Santa Egida.	Beauvais.
			longirostris.	Ibid. viii. p. 162.	Zirknitz-thal.	Sceaux.
	Mollusca.	Scalaria.		. . . .	Wildon; Ehrenhausen; Santa Egida.	
		Cerithium.		. . . .	Wildon; Ehrenhausen.	
		Cypræa.		. . . .	Santa Egida.	
		Conus	Aldrovandi?	Brocchi, Tab. 2. f. 5.	Wildon; Ehrenhausen.	Sub-Apennine.
		Nummulites	complanata?	Lam. Ann. du Mus. tome v. p. 242.	Ibid. Ibid.	Paris Basin.
Upper System.	Conchifera.	Solen.		. . . .	Hartberg.	
		Mactra	truncata.			
		Amphidesma	minimum.	Sowerby, Pl. 39. f. 5.	Radkersberg.	
		Corbula	complanata?	Min. Con. Tab. 362.	Ibid.	Royden (Crag).
		Saxicava	rugosa.	Ibid. Tab. 466.	Hartberg.	Suffolk (Crag).
		Sanguinolaria.		. . . .	Radkersberg.	
		Lucina.				
		Cytherea?		. . . .	Hartberg.	
		Venus	obtusa.	Sowerby, Pl. 39. f. 6.	Ibid.	
		Pullastra	nana.	Ibid. Pl. 39. f. 7.	Ibid.	
		Cardium	transversum.	Ibid. Pl. 39. f. 2.	Ibid.; Radkersberg.	
			minutum.	Ibid. Pl. 39. f. 3.	Ibid.; Radkersberg.	
			planicostatum.	Ibid. Pl. 39. f. 4.	Ibid.	
		Cardita or Venericardia.		. . . .	Radkersberg.	
		Mytilus	Brardii.	Fauj. Ann. du Mus. t. viii pl. 58. f. 11, 12.	Hartberg.	Mayence.
		Modiola	cymbæformis.	Ibid. Pl. 39. f. 8.	Ibid.	
			elegans.	Min. Con. Tab. 9.	Ibid.	Bognor (London clay).
	Mollusca.	Planorbis?		. . . .	Poppendorf.	
		Ampullaria.				
		Nerita.		. . . .	Ibid. Radkersberg.	
		Natica.		. . . .	Radkersberg.	
		Trochus	variabilis.	Sowerby, Pl. 39. f. 9.	Hartberg.	Pacific Ocean.
		Turritella	incrassata.	Min. Con. Tab. 51. f. 6.	Ibid. Radkersberg.	Holywell (Crag).
		Cerithium	pulchellum.	Sowerby, Pl. 39. f. 10.	Radkersberg.	
			lineolatum.	Ibid. Pl. 39. f. 11.	Hartberg.	
			disjunctum.	Ibid. Pl. 39. f. 12.	Radkersberg.	
			turritella.	Ibid. Pl. 39. f. 13.	Hartberg.	
			vulgatum.	Lamarck, tome vii. p. 68.	Ibid.; Radkersberg.	Mediterranean (recent).
			pictum.	Basterot, Env. de Bord. Pl. 3. f. 6.	Ibid. Radkersberg; Poppendorf.	Bordeaux.
			pupæforme.	Ibid. Pl. 3. f. 5.	Ibid.	Ibid.
			plicatum.	Brug. Dict. No. 21.	Hartberg.	Pontchartrain and Bordeaux.
		Buccinum	duplicatum.	Sowerby, Pl. 39. f. 14.		
		Nummulites	variolaria?	Min. Con. Tab. 538. f. 3.	Radkersberg.	Stubbington (London clay).

XIX.—*On the occurrence of Agates in Dolomitic Strata of the New Red Sandstone Formation in the Mendip Hills.*

By the Rev. WILLIAM BUCKLAND, D.D., F.G.S. F.R.S. F.L.S.
(PROFESSOR OF GEOLOGY AND MINERALOGY IN THE UNIVERSITY OF OXFORD.)

[Read June 19, 1829.]

HAVING had occasion to visit the cliffs of Cheddar in November 1827, I found in the collections of geodes and calcareous spar which are there exposed to sale, a number of curiously figured agates, such as I had never before seen during my numerous geological investigations of the Mendip Hills, nor in any of the cabinets at Bristol which abound in the products of this district. I was informed that they were ploughed out of the surface of some fields at the base of the Mendips, and collected from holes dug for this purpose to a slight depth where the plough indicated their abundance. I had then no leisure to examine the spot whence they came, but wrote to a geological friend (the Rev. D. Williams of Bleadon, to whom we owe the discovery of vestiges of another hyena's den at Uphill), requesting him to ascertain the exact place whence these agates were taken, and on being informed that it was in the village of Sandford, about two miles east of Banwell, I visited the spot with him in November 1828, and found their matrix to be the dolomitic strata of the new red sandstone formation.

As they are the first examples I have ever met with, of the occurrence of perfect agates in this formation, I send specimens to the Geological Society, in illustration of the present communication.

In external form and size, these agates resemble the ordinary varieties of a common potatoe; they are, in fact, very nearly allied to those geodes, to which the name of potatoe-stones has been generally applied, and which have been long known to abound in the dolomitic beds of the new red sandstone formation around the Mendip Hills. Their exterior is rugged, like that of a truffle, and opaque; but on being broken they present internally, on a larger scale, the same structure and arrangement as the compound agates known in jewelry by the name of bird's-eye agates, being made up of alternating bands of chalcedony, jasper, and hornstone, disposed in irregular and concentric curves: the outermost of these curved bands are conformable to the irregularities of the external surface, whilst a number of minor agates nearly spherical in form, and composed of the same materials as the external case, are dispersed throughout an amorphous mass of chalcedony and hornstone, which occupies the interior of the entire or mother agate.

The prevailing colours of these bands of chalcedony and hornstone are various shades of gray; some are opaque and white, approaching to cacholong; others are red, and pass into red jasper; some of the white bands are filled with minute specks of red oxide of iron, like the specks in bloodstone. The central part is either a cavity lined with crystals of quartz, or a solid mass of semitransparent chalcedony, or of hornstone variously coloured by iron. The chalcedony is sometimes opaque and hydrophanous.

Thus far, considered mineralogically, our specimens differ but little from the common agates of the trap rocks, but their geological relations are entirely different, and the circumstance of their matrix being a dolomitic bed of the new red sandstone formation, presents a novelty worthy our attention, and of which I now proceed to the details.

It has been mentioned in the account of the south-west coal district of England, by Mr. Conybeare and myself, that the Mendip Hills are composed of inclined strata of mountain limestone, and old red sandstone; and that on the sloping sides, and basset edges, and around the base of these inclined strata, we find horizontal beds of dolomitic conglomerate, dolomite, red sandstone, and red marl, which together make up our new red sandstone formation*.

The geodes which are found in many parts of this last formation have been long familiar to mineralogists under the name of potatoe-stones, and are mentioned in the memoir now alluded to (p. 292); these rarely contain pure chalcedony, but are mostly composed of a case or shell of hornstone or quartz, of variable thickness, lined internally, and often very prettily, with crystals of quartz and carbonate of lime, being almost always hollow at the centre; they vary from an inch to a foot in diameter, and have evidently been produced by infiltration into cavities of the matrix, in the same manner as agates are infiltrated into cavities of the trap rocks: these potatoe-stones abound near Wells, and also in the villages adjacent to the agate bed at Sandford, viz., at Hutton, Banwell, Churchill, Winscombe, Burringdon, Compton Bishop, &c. Near Cheddar and Burringdon they assume the character of coarse jasper-agate: nearly pure red jasper-agates occur also in the dolomitic rocks, on the left bank of the Severn, in the villages of Worle and Clevedon.

* Geological Transactions, Second Series, vol. i. pp. 214, 225.

The more perfect agates I am now considering are found in the dolomitic beds of the new red sandstone formation. The spot on which I saw them, lies between the villages of Banwell and Churchill, at the north base of a hill called Sandford Hill, where the junction of the wood with the cultivated land marks the geological junction of the inclined mountain limestone with the horizontal beds of dolomite. Here a shallow pit, which has been opened for the express purpose of digging agates, presents the following section:

1. Yellow clay, mixed with carbonate of magnesia and carbonate of lime	6 inches.
2. Yellow dolomite, used as firestone in lime kilns; it crumbles readily to a soft powder, and is filled with specks of manganese, and contains small veins and minute nodules of chalcedony	6 inches.
3. Yellow clay, falling to powder in water, like fuller's earth, and containing much carbonate of lime and magnesia. In this clay the agates are dispersed irregularly, like nodules of flint in chalk, but not like them in horizontal lines..	6 inches.
4. Yellow clay and earthy dolomite, to the bottom of the pit.................	12 inches.

In the adjacent field is an open well, about twelve feet deep, showing the continuation downwards of the same argillaceous, earthy dolomite which forms the bottom of the agate pit.

These beds of dolomitic clay seem to be decomposed strata of dolomite, in the cavities of which, before its decomposition, the agates may have been formed. The soft, arenaceous, yellow dolomite, No. 2., would, by a very little decomposition, be reduced to a state much resembling the yellow clay of No. 3. In the more solid and crystalline slabs of the stratum No. 2. I found siliceous concretions, which, on being broken, proved to be coarse potatoe-stones; whilst the softer and yellow portions of the same stratum contained thin veins of opaque and white chalcedony, and minute insulated nodules of agate. The substance of these veins and agates is precisely like that of the large agates in the clay immediately subjacent.

This union of potatoe-stones with veins of chalcedony, and with small agates, in the solid dolomite immediately reposing on the clay containing the larger agates, shows that their common origin may be due to an infiltration of siliceous matter into cavities. I do not, however, contend that all these agates and potatoe-shaped concretions have been formed by infiltration into cavities of consolidated rocks: some may have been formed contemporaneously, whilst their matrix was yet plastic, and unconsolidated, and admitted the separation of its siliceous from its calcareous ingredients, in the same manner as contemporaneous concretions of flint have been formed in chalk, and nodules of chert in various limestones, and as Septaria have been formed in beds of clay.

The theory of the formation of agates in trap rocks by infiltration of silex into their cavities is now generally admitted; similar infiltrations of chalcedony occur occasionally in other rocks, and in the cracks and cavities of silicified organic remains. The finest examples of organic remains containing agates are the silicified woods and corals from the tertiary strata of Antigua; in a less perfect state they occur in silicified wood of other formations. The conversion of fossil shells to chalcedony and jasper is due to this same process of infiltration. Remarkable examples occur in the green-sand formation of Devonshire, in shells from the Whetstone pits at Blackdown*, which are turned to limpid chalcedony; and in the shells of the same green-sand at Little Haldon Hill, near Dawlish, which are converted to red jasper†.

I possess two agates from cavities of chert in the green-sand formation at Lyme Regis, one having the structure of a box agate, the other of a fortification agate; and from the same green-sand I have an Echinus, the interior of which is nearly filled with bluish chalcedony. Chalcedony also occasionally assumes the form of agates, in veins and small cavities of primitive and transition rocks; and, indeed, wherever silex is present in a state of sufficiently minute division to be filtrated into any small cavity, there the formation of agates may proceed.

The occurrence of entire beds, as well as nodules of jasper and jasper-agate in the mountains of dolomite near Palermo, which I agree with Dr. Daubeny in referring to our magnesian limestone formation, affords a parallel example of silex assuming the form of agates, jasper, and chalcedony in a formation of the same age with that containing agates in the Mendip Hills.

* In the collection of the present Dean of Bristol there is a specimen from Blackdown, in which a small pond of stratified chalcedony occupies the cavity of one valve of a large Venus; this chalcedony is disposed in parallel and horizontal plates, like the plates at the bottom of a box agate. The shell itself is converted to chalcedony, and must have laid horizontally, when its cavity received in a fluid form the silex, which is become an onyx composed of thin horizontal layers of differently coloured chalcedony.

† The fossils at this place afford the only example I ever saw, of shells converted into red jasper: they are of the same species with those in the not far distant Whetstone Pits of Blackdown, between Honiton and Cullompton, which are usually in the state of light grey coloured chalcedony.

XX.—*On the discovery of Fossil Bones of the Iguanodon, in the Iron Sand of the Wealden Formation in the Isle of Wight, and in the Isle of Purbeck.*

By the Rev. WILLIAM BUCKLAND, D.D., V.P.G.S. F.R.S. F.L.S.

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[Read December 4, 1829.]

WE are indebted to the researches of Mr. Mantell* for our knowledge of the existence of that curious and most gigantic herbivorous reptile the Iguanodon †.

The localities in which he discovered it are limited to the Hastings sand, or Wealden formation in Tilgate Forest, at the west extremity of which district are the quarries of Headfold Wood Common, where was found the enormous femur described by Mr. Murchison in the Geological Transactions ‡, as being three feet seven inches long, and probably derived from this animal.

In the course of this year, 1829, I have ascertained its presence in three other localities, which are important, not only in relation to the history of this singular reptile, but as tending still further to connect the geological structure of those parts of the Isle of Wight and Isle of Purbeck wherein it occurs, with the Hastings sand, *i. e.* the iron sand of the Weald of Sussex and Kent.

1. *Iguanodon at two new localities in the Isle of Wight.*

The first of these new localities is on the south coast of the Isle of Wight, in the iron sand which forms the shore, a little east of Sandown Fort, between high and low water. The most remarkable specimen I possess from thence

* Philosophical Transactions, 1825, Part I. p. 179; also, Illustrations of the Geology of Sussex, with Figures of the Fossils of Tilgate Forest, 1827, p. 71.

† Mr. Mantell has calculated the dimensions of the Iguanodon, on comparing the proportions of eight different bones from various parts of the skeleton with those of the recent Iguana, to be as follows:—

	Feet.
Length from snout to end of tail	70
Length of tail	$52\frac{1}{2}$
Circumference of body	$14\frac{1}{2}$

It does not, however, follow that the proportions of the same parts in different genera are the same.

‡ Second Series, vol. ii. Part I. p. 104, Plate XV. fig. 9.

is the gigantic metacarpal bone about to be described. The form of this bone nearly resembles one in the collection of Mr. Mantell, which Cuvier saw, and pronounced to be the metacarpal bone of the thumb of a reptile; but much exceeds it in size, measuring six inches in length, five inches in width at its largest diameter, and sixteen inches in circumference at its posterior and largest extremity. Its weight is nearly six pounds.

The annexed drawing (Plate XLI. fig. 1. and 2.) being of the natural size, gives an exact representation of it. It is, I believe, the largest metacarpal bone which has been as yet discovered; and if we apply to the extinct animal from which it was derived, the scale by which the ancients measured Hercules ("*ex pede Herculem*"), we must conclude that the individual of whose body it formed a part, was the most gigantic of all quadrupeds that have ever trod upon the surface of our planet. The corresponding bone in the foot of the largest living elephant is less than our fossil metacarpal by more than one-half. The bone represented by Mr. Mantell (Plate XIV. fig. 4. 5. of his fossils of Tilgate Forest), approaches the nearest of all those engraved by him in this work, to our bone from Sandown Bay. He considers his fossil to be most probably a metatarsal bone of the Iguanodon, and states that he has one such bone which measures four inches and a half in length, and thirteen inches in circumference in the largest tarsal extremity. The colossal proportions of a fragment of a femur in his possession, from Tilgate Forest (Plate XVIII. fig. 1. of the same work), which measures twenty-three inches in circumference in the smallest part, sufficiently accord with those of his metatarsal bone last mentioned, as well as of our metacarpal bone from the same formation in the Isle of Wight; and give strong probability to the opinion that all these three fragments of the skeleton of a reptile of such extraordinary stature may be referred to the Iguanodon. It is obvious that these supposed metacarpal and metatarsal bones are much shorter and thicker in their proportions, than the metacarpal or metatarsal bones of any living lizards or crocodiles; but when we consider the enormous weight, which the foot of an animal whose femur was twenty-three inches in circumference must have sustained, a reduction of length and increase of bulk in the bones which supported such a colossal frame, must have been attended with many mechanical advantages*.

* The following are among the reasons which induce me to assign to our bone from Sandown Fort, the place I have given it as the metacarpal bone of the left thumb, or possibly the metatarsal of the left great toe:—

1st. Its want of symmetry in the two sides, as well as its enormous size, forbid us to give it a place among the phalangeal bones of any of the fingers or toes.

2ndly. Its outward curvature towards the right is such as could not have taken place in any other

As large bones of the Megalosaurus are found mixt with those of the Iguanodon in the Wealden formation, and some doubt may arise, from this circumstance, as to the possibility of our large metacarpal being derived from the foot of a Saurian of this genus, I have engraved on the same plate, with my metacarpal bone of an Iguanodon, the metatarsal bone of a Megalosaurus, thirteen inches long (Plate XLI. fig. 5 and 6), and a metatarsal bone of a crocodile (Plate XLI. fig. 7 and 8), both from the oolitic slate of Stonesfield, and now placed in the Oxford Museum. The elongated form and slender proportions of both these bones differ most essentially from the short and thick characters which mark the metatarsus of the Iguanodon. This variation is in due conformity with the difference in the habits of the respective animals; the lighter and more slender structures being more suited to the feet of the carnivorous reptiles, while the more massive and ponderous form was equally adapted to the bulk and babits of a reptile which was herbivorous.

Together with our metacarpal bone, there were found at Sandown Bay some vertebræ and fragments of other bones of smaller reptiles; and in the same place also about four years ago, the Rev. Gerard Smith discovered part of a very large bone, probably a fragment of a coracoid bone, or of the pelvis,

joint than that assigned to it, excepting in the little toe of the right foot, or little finger of the right hand; both these are places for which the flatness of its posterior surface, as well as its vast size, would render it unfit.

3rdly. It cannot be a carpal bone analogous to either of the two carpal bones of the crocodile, (Cuvier's *Oss. Foss.* vol. v. Part II. Plate IV. fig. 13, *c*, *d*,) because both articulating surfaces of these two carpal bones are concave, whereas the anterior surface of our fossil bone is highly convex and nearly semicircular, and must have formed part of a hinge having very considerable power of flexure, such as it may have afforded if it were a metacarpal bone, articulating with the first phalangeal bone of the left thumb.

4thly. The posterior surface of our fossil accords with the metacarpal place thus assigned to it; Its slight degree of concavity would not admit of sufficient flexure for a phalangeal bone, but enough of motion for the articulation of a metacarpal with a carpal bone: see Plate XLI. fig. 3. profile of posterior surface of fig. 2.

5thly. The nearly straight edge by which the posterior surface is bounded towards the left side (Plate XLI. fig. 4, *b*, *c*, where it is drawn reversed,) accords with the supposed juxtaposition of this edge of the metacarpal of a left thumb to that of the straight edge of the metacarpal of a fore finger of the left hand. The circular form of the right portion of the margin could be found only in a bone which came in contact with no other bone on the side so curved outwards, *i. e.* only in a metacarpal of the left thumb, or a metatarsal of a right little toe. The strong markings produced by the origin and insertion of muscles, tendons, and ligaments, which appear at the points *a*, *b*, *c*, *d*, in figs. 1 and 2, would probably be sufficient in the hands of an experienced anatomist to decide with certainty by reference to the muscles to which they had relation, whether the bone formed part of a little finger or little toe of the right side, or is derived from a thumb or great toe of the left side.

which is also in the Oxford Museum. During the last few months Mr. James Vine has made a further discovery of bones, chiefly large vertebræ of the Iguanodon, in the parish of Brook, near the south-west extremity of this same iron-sand formation in the Isle of Wight. They occur along a quarter of a mile of this shore, but most abundantly at a spot called Bull-face Ledge near Brook Point, where the iron-stone is abundantly loaded with prostrate trunks of fossil trees. Many of these vertebræ are as large as those of an elephant, and exceed in magnitude the vertebral dimensions of any other living animal excepting a whale; they possess also that subquadrangular form which Mr. Mantell has marked as characteristic of the vertebræ of the Iguanodon.*

Iguanodon in the Isle of Purbeck.

In the month of September last, 1829, being in the Isle of Purbeck, I found in the Museum of the Rev. F. O. Bartlett of Swanwich, a collection of bones of various reptiles, such as have been found by Mr. Mantell, associated together in the iron-sand of Tilgate Forest; the most remarkable are those of the Iguanodon, together with vertebræ and other bones of more than one large species of Plesiosaurus, and of large and small crocodiles, and fragments of large cylindrical bones resembling those of Megalosaurus, but too imperfect to be identified with certainty.

The most decidedly characterized bones of Iguanodon in this collection, are vertebræ resembling those engraved by Mr. Mantell in his illustrations of the fossils of Tilgate Forest. These vertebræ are nearly as large as those of an elephant, but compressed laterally, and subquadrangular; there are also metacarpal, and toe bones, similar to those which Mr. Mantell refers to the Iguanodon. Nearly all these bones are more or less injured by rolling on the sea-shore, where they were collected by Mr. Bartlett, and Colonel White, in Swanwich Bay, about half a mile north of the village of Swanwich. They fall occasionally from the cliffs of iron-sand and sandy clay, which are undergoing slow but continual destruction by the waves. As this destruction proceeds, the sand and clay are soon dispersed, but the bones remain, being heavy and impregnated with iron. This iron-sand is described by Mr. Webster, in his letters to Sir H. Englefield on the Isle of Wight, (pp. 169, 237, and Pl. XLVII. fig. 2.) as dividing the upper beds of the Purbeck limestone from the green-sand and chalk of Ballard Down. His section of this cliff is copied in fig. 5.

* Mr. Vine's attention was attracted to these bones about a year ago by the fact of their being collected to be broken up for grotto work, in consequence of the very brilliant small crystals of iron pyrites and calcareous spar which fill their cancelli. He has presented this interesting collection to the Museum of the Geological Society.

of the sections in Conybeare and Phillips's Geology of England. As this iron-sand here extends along almost a mile of coast, and through great part of the distance is inclined at an angle varying from 15° to 30° N., its thickness must be very considerable. After making all due allowance for the possible occurrence of faults, I cannot estimate it at less than 500 feet, which is the reputed thickness of this formation in the Weald of Sussex and Kent.

Dr. Fitton, in his excellent paper in the *Ann. Phil.* November 1824, has drawn an interesting comparison between this iron-sand at Swanwich, and the iron-sand of Sandown Bay in the Isle of Wight, and of Tilgate Forest; and has shown that there is a nearly perfect correspondence in the characters of the strata of this formation in Purbeck, with those which they present in the Isle of Wight, and in the Weald of Sussex; and that in each case they are immediately covered by the Weald clay, and contain occasionally the same admixture of the remains of marine animals with those which were inhabitants of fresh water*.

Mr. Conybeare, also, and Mr. Mantell, have considered the argillaceous limestones which lie below these iron-sands in Sandown Bay, and form the lowest strata in the Isle of Wight, to be nearly identical with the shelly *bivalve* limestone beds of Ashburnham, and to afford at both these places an equivalent to the upper freshwater strata of the Purbeck series.

It is satisfactory that in three such important localities as Sandown Bay, Brook, and Swanwich Bay, we have ascertained the presence of an animal so very remarkable as the Iguanodon, whose existence has not till now been traced beyond the Weald of Sussex; and it is still further satisfactory, to find, that in tending to identify the iron-sand of Purbeck and the Isle of Wight with that of Hastings and the Weald, these additional discoveries confirm the opinions of our best geological authorities.

It has been inferred, from the mixed nature of the remains occurring in this formation, that the area on which it was deposited was at that time part of a great estuary; the facts we have been considering show that the extent of this estuary was continuous to the south-west, and west, from the Weald of Sussex, through the districts now occupied by the Isle of Wight, to the Isle of Purbeck in Dorsetshire. The strata of the Purbeck formation at Lady Down near Tisbury, show that it included, also, the south-west extremity of Wiltshire.

We know not what are the fundamental strata of any portion of this district, except at its western extremity, where the Wealden and Purbeck freshwater series rest upon the oolitic marine formation of the Portland stone.

* See Dr. Fitton's Map and Sections, Ann. Phil. 1824, N. S. vol. viii. Pl. XXXIII.

To trace the extent of this ancient estuary, as far as it is indicated by the deposits that were formed within its area, and to ascertain from what more elevated regions of dry land so much detritus has been derived, are objects deserving the careful attention of geologists.

The best indications of the source from whence the materials of the strata have been supplied, would be afforded by pebbles, if any could be found, intermixed with the finer ingredients of this formation. The general absence of such pebbles shows that the lands were distant, from whence the fine particles of sand and clay were transported, that gradually filled up this estuary: and the interposition of the broad belt of the oolitic and new red sandstone formations, between its northern frontier, and the north, and north-western mountain ranges of our own island, would incline us rather to look for these lands either in Devonshire and Cornwall on the west; or in the nearest primary and transition mountains of the Continent, viz., in Normandy and Brittany on the south-west; or in the forest of Ardennes on the south-east. It is not probable that the materials of the Wealden formation have been derived in any great degree from the detritus of the oolitic series, because in such case we should have found among them an admixture of pebbles of oolite; none of which have yet been noticed.

APPENDIX. May, 1835.

The following notices on the habits of modern Iguanas show that some of them, like our Iguanodon, are herbivorous, and that others are omnivorous.

I am informed by my friend William John Broderip, Esq., that in the spring of 1829, he saw a living Iguana, about two feet long, in a hothouse at Mr. Miller's nursery gardens near Bristol. It had refused to eat insects and other kinds of animal food presented to it, until happening to be near some kidney-bean plants, that were placed in the house for forcing, it began to eat of their leaves, and was from that time forth supplied with these plants. When Mr. Broderip saw this animal, it was in good health, and of a beautiful green colour; it suffered itself to be handled, and swallowed some of the leaves in his presence.

I learn further from Mr. Broderip, that in July 1834 a living *Iguana tuberculata* (Seba, 1. 95. 1.—97. 3.—98. 1. C.), in the gardens of the Zoological Society of London, being placed in an inclosure containing a pond, deliberately took to the water, swimming across with the greatest facility, using its tail as the organ of progression, with its fore feet motionless. Cuvier (tom. ii. p. 44.) says of this animal: "Il vit en grande partie sur les arbres, va quelquefois à l'eau, se nourrit de fruits, de grains et de feuilles." The Iguana at the Zoological Garden, after swimming across the pond, generally clambered over the opposite wire fence, and ascended an Acacia tree beyond, on the highest fork of which it would rest. This was its favourite tree, and though others were near, it never mounted any but the Acacia. Cockroaches, &c. were offered to it, and, at Mr. Broderip's suggestion, kidney-bean leaves, but in vain; and it was kept alive, as it was on the voyage, by cramming it with sliced raw potatoes. Its keeper informed Mr. Broderip that he saw it often snap, as it walked on the grass, as if it were taking insects, but he is by no means certain that it actually took any.

Another, kept afterwards for a short time at the Zoological Garden, refused all food; and this was the case with a third from Demerara, which soon languished and died, in the possession of a friend of Mr. Broderip.

I am also informed by Captain Belcher, R. N., that when he was in the island of Isabella, near the gulf of California, in the month of January 1828, he found this island covered with swarms of Iguanas, whose habits appeared to be omnivorous; they fed voraciously on the eggs of birds, particularly of boobies, and frigate pelicans, which build their nests in this island in countless multitudes. When taken on board they fed promiscuously on various kinds of food, and ate greedily the intestines of fowls; they were also insectivorous, and ate cockroaches and flies. The Iguanas occupied the cliffs, and their haunts were filled with egg-shells and bones of birds; they also attack and eat one another.

It is mentioned by Cuvier also (*Règne Animal,* vol. ii. p. 41, ed. 1829,) that he found both leaves and insects in the stomach of an Istiurus (Le Porte-Crête, Lacép.); this animal lives partly in the water, and partly on small trees and shrubs near the water, and eats both seeds and worms. May we not from these analogies infer that the Iguanodon also was omnivorous?

Further discovery of Bones of Iguanodon, and Cones of Zamia, in the Isle of Wight, at Sandown Bay.

In July 1834, a valuable addition was made to the Oxford Museum (through the kindness of the Rev. W. Sewell, of Exeter College, and the Rev. R. Sherson, Rector of Yaverland), of a very large collection of bones from the southern coast of the Isle of Wight, chiefly those of the Iguanodon, discovered in Yaverland, a little east of Sandown Fort, by Mr. John Smith, who has liberally presented them to the University of Oxford.

These bones were found in 1829 by Mr. Smith, near his residence at Yaverland Farm. The following is an extract from his letter to myself, respecting them. "When first I observed these bones, I was passing on the sea-shore, after a week of stormy weather, which had created a heavy sea, and consequently a great tumbling in of its waves on the beach, which swept every moveable object before it, even the shingle and sand, to the depth of two feet, which exposed many fossils lying amongst the large stones on the ground. I frequently visited the same spot during the following winter, and never came home empty-handed; and always found something, until I brought almost all away." The most remarkable bones in this numerous collection are several very large sub-quadrangular vertebræ of Iguanodon, a large portion of a compressed femur, a nearly perfect lower extremity of another large femur, and fragments of the limbs of the same animal; also a considerable number of vertebræ, and many other bones of smaller reptiles. These bones have all suffered injury by rolling among the pebbles amidst which they were found. They had probably fallen long ago, and at intervals, from the low cliff of the Wealden formation, which overhangs the beach, like those found at Swanwich by Mr. Bartlett; and being much impregnated with iron, their weight had caused them to sink deep into the shingle, at the base of the gradually decomposing cliff, from which they were brought to the surface by the extraordinary storm which immediately preceded their discovery.

In the low cliff of grey sandstone interspersed with clay, adjacent to this spot, Mr. Smith found also many curious small cones of Zamia, mixed with fragments of lignite; three of these cones are in one small block, presented by him to the Oxford Museum. Figures of these cones have been published by Professor Lindley, by the name of *Zamia crassa,* in the 14th Number of his Fossil Flora, Pl. 136.

Discovery of Iguanodon in Marine Formation near Maidstone.*

A large proportion of the skeleton of an Iguanodon, discovered in January 1834, in the quarries of Kentish Rag, near Maidstone, and now placed in the splendid museum of Mr. Mantell at Brighton, has verified nearly all his conjectures respecting the insulated bones found in the Wealden formation, which he had assigned to this animal. The two femora measured thirty-three inches each in length, and a tibia and fibula thirty inches each. The position of this skeleton in a marine limestone of the lower green-sand formation must be referred to a carcase drifted to sea not long after the completion of the Wealden estuary deposits.

* See a notice by Mr. Mantell, in the Edinburgh New Philosophical Journal, vol. xvii. p. 200, No. 33, July 1834.

XXI.—*Notice of Two Models and Sections of about Eleven Square Miles, forming a part of the Mineral Basin of South Wales, in the Vicinity of Pontypool, and presented to the Geological Society by* Richard Cowling Taylor, Esq., F.G.S.

[Read June 18th, 1830.]

THE object of the author in preparing the models, was to employ to advantage a considerable accumulation of local details relating to the structure and contour of this district, and thus to exhibit, in the most instructive form, a faithful representation of a part of the South Welsh Coal Field. To avoid confusion, and to convey a distinct illustration of geological arrangement, as well as of natural features and artificial characters, two models appeared indispensable. One of these, therefore, exhibits the external or pictorial characters of the area selected; the other, which is more immediately interesting to the geologist, develops the internal structure, and the position and inclination of the various mineral and coal strata*.

Elevation.—The lowest point shown, is about 350 feet, and the highest 1563 feet above the high-water level of the Usk at Newport. The summit level of the Monmouthshire canal is stated to be 447 feet above the basin at Newport. The Pen Twyn iron-works are situated 179 feet, and the Abersychan furnace 256 feet, higher than the canal summit; and from the latter works to the top of Blaen Sychan the rise is about 900 feet more. The point called *Pen Rhiw Ffranch,* by spirit level was found to be 890 feet, and by barometrical observation 881 feet, above the canal.

The district offers a characteristic specimen, in miniature certainly, of an extensive range of similarly constructed country. Amongst its most striking features are the regular form of the *Pens,* or promontories, which project from the principal mountain ranges, and the deeply eroded ravines which descend into the adjacent valleys, offering to the speculative some elucidation, not the less instructive because on a small scale, of the action of water. The

* Plate XLII. represents the second of these models, but the direction of the ravines being shown by the rivulets, and the form of the *Pens* by the range of the strata, the shading of the hills has been omitted.

It is necessary to premise that the north-east and south-west angles of the models have been filled up from comparatively imperfect observation, the author being in possession of less abundant data. These points must be received as approximations, introduced to preserve the general effect.

streams which these *Cwms*, or deep ravines, contain, have a progressively diminishing inclination as they proceed from their sources. We have shown the profiles of three of these mountain rivers, noting the fall in feet per mile in the respective divisions of each.

Nant Ddû Brook, subdivided into five portions or lengths.

1st or upper portion, has an average inclination of	1040	feet per mile for	$\frac{1}{4}$ mile.
2nd portion	450		$\frac{1}{2}$ mile.
3rd	275		$\frac{1}{2}$ mile.
4th	240		$\frac{1}{2}$ mile.
5th, to its junction with the Afon Llwyd, falls only	110		1 mile.

Bwrgwm Brook.

1st, or upper half mile, descends on a plane of 800 feet in a mile.
2nd, second half mile .... 660 feet per mile.
3rd, three fourths of a mile to the Afon .... 230 feet per mile.

Sychan Brook, in three portions.

1st. —$\frac{3}{4}$ of a mile from its source, descends with a fall of 650 feet per mile.
2nd.—$\frac{3}{4}$ of a mile .... at the rate of.......... 444 feet per mile.
3rd.—$\frac{3}{4}$ of a mile to its junction with the Afon, only .... 230 feet per mile.
The Afon for the succeeding mile proceeds with an inclination of 90 feet only.

Inclination of Strata.—The prevailing dip is about 3 inches' fall in each yard, or from 400 to 450 feet per mile. At Abersychan and Verteg the direction of the dip is nearly west by compass, and consequently the level course is not far from north and south.

Faults.—These of course have been but partially explored in a district which has only been recently penetrated by mining operations. We have traced upon the model the direction of one which was encountered at an early stage of the works at Abersychan, and passes for an unknown distance along the bottom of the Sychan Valley. A level which was conducted along a coal vein suddenly passed into a bed of iron mine, whose proper position was 50 feet above the coal; and thus, for a time, the same level served on one side of the fault for working coal, and on the other, through this change of position, for working the iron ore*.

At Pontnewynydd, and passing upwards in the direction of Nant Ddû Brook, a considerable fault appears, by which all the strata in the promontory called *Pen y Tranch* are brought down, and probably are thrust forward in a mass, somewhat beyond the eastern boundary of the coal field, perhaps more than 300 feet below their proper position. On the south, or opposite side of

* The direction of the fault is shown on the model, but not the nature of the disturbance. See also the Map, Pl. XLII.

this promontory, is a corresponding fault of about 220 feet passing up the ravine in a parallel direction to the fault on the north side of Pen y Tranch.

So far as the present survey carries us, the three or four principal faults pass apparently along the troughs of the valleys. Without entering upon the debatable ground of the origin of valleys, and the agency of existing causes in modifying the earth's surface, we have certain facts, by no means unimportant in the controversy, showing that extensive fissures range along those ravines, or, by a transposition of terms, that the rivers have formed their channels in ancient fissures.

Thickness of Strata.—The series of beds exhibited is probably not less than 1800 feet thick above the limestone. Within this space are about 20 beds of coal, varying in thickness from 1 to 10 feet, and amounting in the aggregate to about 60 feet. Not more than 6 of these are usually worked; the greater portion of the mineral treasures being comprised within an inconsiderable part of the general section. At Abersychan the principal workable beds are contained in a thickness of 119 yards, at the bottom of the series. They consist of 13 beds of bituminous coal, of the aggregate thickness of 42 feet 8 inches, and will readily supply upwards of 30,000 tons per acre. Alternating with the coal-seams are numerous courses of argillaceous iron ore, capable of supplying 15,000 tons of mine per acre.

Almost all these beds, whether of iron ore or of coal, bear different names in different localities. This is not remarkable, when we observe the variations of position and thickness at inconsiderable distances in what are considered to be the same veins. On placing, side by side, several sections derived from iron-works in this neighbourhood, it will be seen that in the thickness of the mineral series, *collectively*, there is a certain agreement; but that in the position of the members of the same series, *individually*, there are frequently striking variations; the coal-beds being often widely separated at some points, and at others, brought either almost into contact, or new veins are introduced. This will be best exemplified by a series of sections, which, when reduced to a common scale, admits of ready comparison.

Aggregate thickness of the strata containing the principal mineral and coal beds, from the "*Bottom Vein Mine*" to the "*Black Pins*" inclusive:

		Yds.	Ft.	In.
At Abersychan and Pen Twyn Works		119	0	2
At Verteg, two miles north	1st section	119	1	5
	2nd section	120	2	6
At Blaen Afon, four miles north		134	0	4
At Coalbrook Vale, six miles north-north-west		127	2	6
At Rumney Vale, ten miles north-west		215	2	2

At the last point a remarkable expansion of the beds occurs, being nearly double the Abersychan section. The intermediate members are so changed in position, and so many additional beds are introduced, that there is a difficulty in recognising the series.

The following summary exhibits the mineral contents of these strata at different points:

	No. of principal beds of Coal.	Thickness of Coal beds. Ft.	In.	Iron ore. Ft.	In.	Beds of Fire Clay.	Thickness of Fire Clay. Ft.	In.
At Abersychan	13	42	8	6	1½	10	47	3
At Verteg { 1st section	14	43	9	0	0	7	45	6
At Verteg { 2nd section	23	46	5½	4	8½	13	42	7
Blaen Afon	22	51	7	0	0	0	24	0
Coalbrook Vale	17	38	8	7	4	5	13	6
Rumney	26	55	1	60 veins		7	28	4

The above sketch will, it is presumed, with the assistance of the models, suffice to convey an adequate knowledge of this district. Newport is the principal port where the coal and iron of this neighbourhood are shipped, averaging upwards of 2000 tons daily. By the official returns of the Monmouthshire Canal Company, it appears that in the year 1829 there were brought down to the wharfs of Newport 104,129 tons of iron, and 513,974 tons of coal.

XXII.—*Some Account of the Remains of the Megatherium sent to England from Buenos Ayres by* WOODBINE PARISH, Jun., Esq., F.G.S. F.R.S.

By WILLIAM CLIFT, Esq., F.G.S. F.R.S.

[Read June 13, 1832.]

THE Remains of the Megatherium described in this paper are part of a collection of fossil bones recently sent from Buenos Ayres by Woodbine Parish, Esq., His Majesty's Chargé d'Affaires in that country *.

They were found in the river Salado, which runs through the flat alluvial plains (the Pampas) to the south of the city of Buenos Ayres †. Their discovery was owing to a succession of unusually dry seasons in the three preceding years, which lowered the waters in an extraordinary degree, and exposed part of the pelvis to view, as it stood upright in the bottom of the river. It appears that this and some other parts of the skeleton, having been carried to Buenos Ayres by the country people, were very liberally placed at Mr. Parish's disposal by Don Hilario Sosa, the owner of the property on which they were found.

In the hope of obtaining the other parts of the skeleton, an intelligent person was subsequently sent to the same spot, who succeeded, after considerable difficulties, in getting out of the mud forming the bed of the river, the remainder of the collection which forms the immediate subject of the present paper.

Further inquiry led Mr. Parish to suppose that similar remains might be met with in other parts of the province of Buenos Ayres, and he applied to the local authorities to assist him in making further search. This aid was given by the Governor, Don Manuel Rosas, and the remains of two other skeletons were found on His Excellency's own properties of Las Averias and

* These Remains, after having been exhibited to the Geological Society, were transferred by Mr. Parish to the Museum of the Royal College of Surgeons in London. Excellent casts of the principal bones have since been prepared under the superintendence of Mr. Chantrey, and have been liberally presented by the College to the Geological Society, the British Museum, the Universities of Oxford and Cambridge, and the Garden of Plants at Paris.

† See Map, Plate XLIII.

Villanueva; the one to the north, the other to the south, of the Salado, but at no great distance from the place where the first had been discovered *.

In these latter instances the osseous remains were accompanied by an immense shell, or case, portions of which were brought to this country, but most of the bones associated with the shell crumbled to pieces after exposure to the air, and the broken portions preserved have not been sufficiently made out to be at present satisfactorily described. Representations, however, of parts of the shell in question are given in the plate annexed†.

It appears remarkable that since the first discovery of bones of so extraordinary dimensions as those of the Megatherium, so long a period should have been allowed to elapse without any further efficient attempts having been made to collect the reliques of so gigantic an animal; especially, since sufficient attention had been in the first instance excited by them as to have occasioned the transmission of the large proportion of the bones which now compose the magnificent, though imperfect, skeleton in the Royal Cabinet at Madrid, where it has remained for the last half century altogether unique.

The jealousies which probably bestrew the path of exploration in a country where the almost all-engrossing subject of search for the precious metals absorbs or blunts all other feelings, together with an apparent indifference in the inhabitants for inquiries of this thriftless nature, offer a combination of obstacles sufficient to account for the little additional light which has during this very long period been elicited.

On whatever causes it may have depended, further research seems to have been almost entirely neglected. Very few additional specimens appear to have been sent to Europe, and no other cabinet, save the solitary one at Madrid, possessed (as far as I have been able to learn), a single intelligible fragment which could with certainty be assigned to this great unknown‡.

* See Plate XLIII. All the bones described in this Memoir were found at the spot marked 1, situated in the southern part of the Map; fragments of small bones, with small portions of the shell, were found at the spot marked 3; and fragments of much larger bones, with larger portions of the shell, including those figured at Plate XLVI., were met with at the spot marked 2. The bones of the Madrid specimen were discovered at the spot marked 4, in the north-western part of the Map.

† Plate XLVI.

‡ Some time after this paper was read, a considerable number of interesting fragments of various parts of the skeleton of a Megatherium were transmitted to England from the country of the Pampas by Mr. Darwin; but the most important of these specimens are in an exceedingly fragile state and are enveloped in an intensely hard concrete of lime and coarse gravel, which will require great care and labour to remove. When that is accomplished, they will very materially add to our present knowledge of the structure of the animal, particularly demonstrating the diminutive size of the brain of this huge creature; the total absence of fangs to the teeth, whose extremities termi-

From the latter circumstance, some naturalists had been induced to believe that the remains of the Megatherium were so exceedingly rare as to render further inquiry almost hopeless, until the laudable and enterprising zeal of Mr. Parish dispelled this disheartening illusion, by teaching us that opportunities not unfrequently occur, if proper advantage be taken of them.

It will be manifest, by the following enumeration of the parts of the skeleton of this stupendous quadruped, sent by Mr. Parish, that although it is, on the whole, much less complete than the specimen preserved in the Royal Museum at Madrid, yet that there are, fortunately, many parts in the present which are deficient in that specimen; and, consequently, the history of this interesting animal will receive considerable and important additions from the remains which that gentleman has, at so much labour and expense, succeeded in introducing, for the first time, to this country*.

These remains include,

The anterior part of the cranium.

Nine teeth, more or less perfect, but none quite entire.

Part of the os hyoides †.

The atlas, and another cervical vertebra entire; with fragments of the dentata, and others.

Two entire dorsal vertebræ, and portions of thirteen other true vertebræ, of which three appear to be lumbar.

The sacrum and pelvis entire with the exception of the right ilium, which was probably broken off in raising the pelvis from the bed of the river.—*The pubis and ischia beautifully perfect.*

Twelve or more of the caudal vertebræ, and ten of the separate chevron bones belonging to them.

Twelve ribs of the left side, including the first; and

Eleven ribs of the right side, more or less perfect; with some smaller portions of ribs.

Two of the bony or pseudo-cartilaginous pieces, which unite the true ribs to the sternum: as is the case also in the Armadillo.

The manubrium or first bone, with *two other bones* of the sternum.

Of the anterior extremities there only remain:

The right scapula, entire, and part of the left.

The left clavicle.

The left radius.

The os naviculare, and five other bones of the carpus and metacarpus.

One middle phalanx, and

Four terminal phalanges, which support the claws.

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nate in a film-like edge surrounding the square cavity which contained the vascular pulp on which each tooth was formed; and that there are four teeth on each side the jaw, as stated by M. Cuvier. —W. C., 1835.

* Plate XLIV shows at one view the comparative state of the two skeletons, and the deficiencies in the one which are supplied by the other.

† The remains printed in Italics in the subjoined list are wanting in the Madrid skeleton.

Of the posterior extremities there are:

The left femur entire, and the extremities of the right femur.
The left tibia, and a portion of the fibula anchylosed to it.
The left astragalus, os calcis, and os naviculare.
Five other bones of the tarsus.

The portion of cranium includes the superior maxillary and intermaxillary bones; a part of the frontal and part of the nasal bones; the vomer, and the remains of two superior spongy bones. There is also, among the loose fragments, apparently a portion of the descending process of the zygoma of one side. The extremities of the intermaxillary and nasal bones are, however, broken off, and the parietal and occipital bones are also deficient.

The maxillary bones include two sockets, and part of the third, on each side. There are many small sinuses at the fractured surface of the os frontis.

The vomer increases in thickness anteriorly, and extends the whole length of the specimen, apparently forming, as in the fossil rhinoceros (*Rhinoceros tichorhinus*, Cuv.), a complete bony septum narium. There are three infra-orbitary foramina, of an oval form, the largest of which measures nine lines in the long diameter, and six in the short.

	Ft.	In.	Lines.
The length of this fragment, measured obliquely from the fractured surface of the os frontis to the end of the protended intermaxillary bones	1	5	0
From the anterior socket to the end of the intermaxillary bone	0	6	6
The greatest breadth at the upper part	0	8	6
Breadth between the orbits	0	7	0
The least breadth	0	5	10
The depth, or vertical diameter of the cranium at the first tooth	0	8	0
The vertical diameter at the fractured end of the specimen, or opposite the third tooth	0	11	0
The palate is very narrow, measuring across, between the first molares	0	1	6
Between the second molares	0	1	0
The depth of one of the sockets is	0	7	0

The thickness of the alveolar partitions from three to six lines.

The teeth are all of one kind, viz. molares, and of similar structure*. Their number, when complete, is, according to Cuvier, sixteen†, there being four on each side in both upper and lower jaws.

Of the nine teeth in the present specimen, six can be identified thus: 1st, 2nd, and 3rd of both sides of the upper jaw. M. Cuvier‡ describes them as being of a prismatic form, but this appears to apply only to the anterior pair; the rest are regularly four-sided, the anterior surface being somewhat

* Plate XLV. fig. 2. † *Ossemens Fossiles*, tom. v. Pl. I. p. 179. ‡ *Ibid.*

convex. From the thinness of the partitions of the sockets, the teeth closely approximate; and from the direction of the sockets, the series on each side is slightly convergent.

The following are the admeasurements of the most perfect teeth:

Upper Jaw.	*First molar.*		*Second.*		*Third.*	
	In.	Lines.	In.	Lines.	In.	Lines.
Length	7	0	9	0	0	0
Circumference	4	0	6	6	6	5
Transverse diameter	1	8	2	0	1	11
Antero-posterior diameter ..	1	4	1	8	1	7

from which it appears that they do not increase in size as they are situated posteriorly, but that the second is at least larger than the third.

Cuvier also describes two fangs to each tooth of Megatherium*, and observes that in this respect it differs from the Bradypodæ, to which it is allied in so many other respects; but as there is not any appearance of fangs in the teeth of the present specimen†, and as the resemblance in every other particular with that on which his description is founded is complete, this cannot be considered as a specific difference, but as depending most probably on the imperfect state of the tooth in the Madrid specimen, from which Dr. Pander's figure is taken; and this is the more probable, as in the original work of Garriga‡, a molar tooth is figured without these fangs; this deceptive appearance being merely owing to a dotted line, by which he has endeavoured to indicate on the surface of the tooth the extent and shape of the cavity for the secreting pulp within: which circumstance may have misled Messrs. Pander and D'Alton, who probably had no opportunity of examining a tooth separated from its socket, as their figure sufficiently implies§.

The teeth ‖, though simple in form, are complex in structure, being composed of a central body of ivory extending across nearly the whole transverse diameter of the tooth, but occupying only the middle two thirds of the antero-posterior diameter. The ivory is surrounded by a thin layer of enamel not exceeding a line, and the rest of the tooth on the anterior and posterior surfaces is made up of cæmentum; hence, from the different degrees of density pos-

[* *Ossemens Fossiles*, tom. v. Pl. I. p. 179. See also *ante*, Note p. 438, on this subject.—W. C. 1835.

† Plate XLV. fig. 2.

‡ Tab. IV. fig. 5. "Descripcion del Esqueleto de un Quadrupedo muy corpulento y raro, que se conserva en el Real Gabinete de Historia Natural de Madrid. Publicala Don Joseph Garriga, Capitao de Ingenieros Cosmógrafos de Estado." Folio. Madrid, 1796; with five folding Plates.

§ Tab. III. fig. 15. "*Das Riesen Faulthier, Dasypus Giganteus*, von Dr. Chr. Pander und Dr. E. D'Alton." Oblong folio. Bonn, 1821.

‖ Tab. IV. fig. 5.

sessed by these substances, the grinding surface of the tooth presents, in consequence of attrition, four facets sloping from the two ridges of enamel which traverse the tooth transversely; the middle surfaces being the worn-down ivory, the outer the worn-down cæmentum.

In the anterior tooth the first facet is very small, from there being but little cæmentum; the second is almost perpendicular; the third proportionally more sloping than the others; the fourth also nearly perpendicular.

In the second and third teeth, the two middle surfaces are nearly equal, and are worn down at the same angle. This is also the case with the two marginal surfaces, which, however, are much smaller than the middle ones.

The secreting pulp, when the formation of the tooth had advanced to a certain extent, appears to have assumed a most regular pyramidal or wedge shape, and to have extended into one half of the length of the tooth. There is no trace of a contraction at the open end of the cavity or root, but it is (as in the incisors of Rodentia) wide open: this structure, therefore, indicates *perpetual growth,* and evidently not a renewal by succession, as in the elephant and mastodon, whose molar teeth are constantly advancing to the front of both jaws and wearing out; so that, though the component parts of the teeth of the megatherium resemble those of the grinders of the elephant, the mode of renewal is different, being like to that of the tusks of the same animal.

Vertebral Column.

The very imperfect condition of the vertebral column is naturally a subject of great regret: the atlas, however, is fortunately entire; and as this affords some data respecting the occiput, the diameter of the spinal chord, and, by the size of the orifices for the vertebral arteries, also an indication of the extent of the brain, it merits a more particular consideration.

It is, as usual, in the form of a ring, being deficient in a body at the anterior part, and having only the rudiment of a spine on the opposite aspect. The articular surfaces for the condyles of the occiput are of an oval form and concave, measuring in their longest diameter three inches three lines. The opposite articular surfaces for the dentata are plane, and nearly circular; and their diameter is two inches six lines. On the anterior part of the spinal canal there is a heart-shaped surface for the rotation of the odontoid process; and on each side is a tuberosity for the attachment of the transverse ligament which confines that process in its situation at the fore part of the spinal canal. Each vertebral artery passed through a tortuous canal at the anterior part of the vertebra, the diameter of which is ten lines. The spinal nerves also passed through a complete foramen on each side, just above the posterior articular process.

	Ft.	In.	Lines.
The greatest breadth of the atlas	1	0	6
From the outside of one condyloid surface to the other	0	6	9
Antero-posterior diameter of the atlas	0	5	7
Antero-posterior diameter of spinal canal	0	3	0
Lateral diameter of spinal canal	0	2	8
Of the dentata there are only fragments, the spinous process of which is bifurcate, and measures in length	0	3	3
In breadth at the tip	0	2	9

Of apparently the third cervical vertebra there are the body and transverse processes, which give the following admeasurements:

	Ft.	In.	Lines.
Greatest breadth from the tip of one transverse process to the other	0	10	0
Antero-posterior diameter of the body	0	2	9
Lateral diameter of the body	0	3	4
Length of the spine, which ends in a tuberosity	0	3	0

The only *entire* cervical vertebra appears to be the fifth; its admeasurements are,

	Ft.	In.	Lines.
Greatest breadth from tip to tip of the transverse processes	0	9	6
From anterior part of body to end of spine	0	8	3
Antero-posterior diameter of the body	0	3	0
Lateral diameter of the body	0	3	8
Antero-posterior diameter of spinal canal	0	3	10
Lateral diameter of spinal canal	0	3	0

Of apparently the sixth cervical vertebra the body measures,

	Ft.	In.	Lines.
In antero-posterior diameter	0	3	0
In lateral diameter	0	4	0

The admeasurements of the only two *entire* dorsal vertebræ are as follow:

	The one which is probably the 4th or 5th.			Probably the 13th or 14th.		
	Ft.	In.	Lines.	Ft.	In.	Lines.
Breadth from the tip of one transverse process to the other	0	9	7	0	11	9
From the anterior part of the body to the end of spine	1	4	0	1	4	0
Antero-posterior diameter of body	0	3	9	0	4	9
Lateral diameter of body	0	3	7	0	5	0
Antero-posterior diameter of spinal canal	0	2	11	0	3	3
Lateral diameter of spinal canal	0	3	1	0	3	3
Length of the spine	0	7	0	0	7	10

Passing over the sacral vertebræ, which will be described with the rest of the pelvis, we come to those of the tail, which being in the Madrid skeleton altogether deficient, merit more particular attention here. Of these, twelve remain; but they are, without doubt, not the entire number; some intermediate, and the extreme ones are evidently wanting. The twelve which are preserved become regularly smaller towards the last. The first eleven are perforated for a continuation of the spinal nerves, and have spinous and articular processes, in addition to the transverse, which the twelfth also possesses.

They have the inferior spines (i. e. the chevron or V-shaped bones), manifesting in this their relation to other Edentata, as the Myrmecophaga and Dasypodæ*.

Their admeasurements, as they at present follow in gradation, are:

1st and 2nd, very imperfect, and their dimensions uncertain.

		Ft.	In.	Lines.
3rd of the caudal vertebræ present.	From the end of one transverse process to the other	1	3	0
	Transverse diameter of anterior articulating surface	0	5	6
	Antero-posterior diameter of ditto	0	5	0
4th of the series.	From the end of one transverse process to the other	0	11	0
5th ———	From ditto to ditto	0	10	6
6th ———	From ditto to ditto	0	9	6
7th ———	From ditto to ditto	0	8	6
8th ———	From ditto to ditto	0	7	7
9th ———	From ditto to ditto	0	6	6
10th ———	From ditto to ditto	0	6	0
11th ———	From ditto to ditto	0	5	0
12th ———	From ditto to ditto	0	3	3

Of the ten chevron or V-shaped bones, or inferior spinous processes:

	Ft.	In.	Lines.
The 1st.—Length	0	10	0
Breadth at the base	0	5	0
Length of its cavity	0	2	2
Breadth of ditto	0	2	3
2nd.—Length	0	9	0
3rd.—Ditto	0	8	0
4th.—Ditto	0	7	0
5th.—Ditto	0	6	0
6th.—Ditto	0	5	0
7th.—Ditto	0	4	0
8th.—Ditto	0	3	2
9th.—Ditto	0	2	9
10th.—Ditto	0	2	6

* Though there are only twelve caudal vertebræ, and ten chevron bones extant, the number of vertebræ composing the tail was probably not fewer than eighteen. The extremity of the tail is incomplete by, perhaps, two vertebræ, and the smallest chevron bone belongs to the fourth or fifth from the tip. Some, also, of the larger chevron bones have not their corresponding vertebræ.

Ribs.

The *first* is nearly straight, and is enlarged and flattened at the sternal extremity.

	Ft.	In.	Lines.
It measures in length	1	2	0
Breadth of the vertebral end	0	3	9
Breadth of the sternal end	0	3	1
Greatest breadth of the rib near the sternal end	0	4	7
Least circumference	0	4	8
Greatest circumference	0	11	0
The length of the *longest rib* following its outer curvature	3	6	0
From the tubercle to the head of rib	0	6	0
Greatest breadth	0	3	6

The true ribs which join the sternum (except the first and last) have a double articular surface at the sternal end, each of which is adapted to two contiguous portions of the sternum*.

Sternum.

	Ft.	In.	Lines.
The *manubrium sterni*, or first bone of the sternum, measures in length	0	9	0
In breadth	0	6	8

It has only three articular surfaces; two for the sternal ends of true ribs, and one for the adjoining bone of the sternum; but it is probable that the clavicles were united by ligaments to the shallow cavities on the inner surface of the manubrium, above those for the ribs.

The *next bone* of the sternum, in the specimen, is very remarkable for the number of its articular surfaces, there being no fewer than ten, viz. one on the anterior and one on the posterior surface for its union with the other bones of the sternum, and four on each side for the double articular surfaces at the sternal ends of the ribs.

	Ft.	In.	Lines.
This bone measures: In length	0	2	6
In breadth	0	4	3
Antero-posterior diameter	0	3	0

The *third bone* of the sternum in this collection is not the third in natural juxta-position, but appears to be the last, for it has but one articular surface for the sternum, and only two inferior costal surfaces (the two being blended together on each side); but there are, as in the preceding, four on the upper part.

	Ft.	In.	Lines.
Its length	0	2	9
Breadth	0	3	4
Antero-posterior diameter	0	3	3

* Most, if not all, of the true ribs had bony articulations to the sternum in lieu of cartilaginous extremities, and a joint at the part where the rib usually terminates and the cartilage begins in most other quadrupeds.

Anterior Extremity.

	Ft.	In.	Lines.
Scapula.			
The greatest extent of the right scapula from the inferior angle to the end of the coracoid process	2	6	6
Greatest breadth from the inferior border of the glenoid cavity to the superior angle	1	5	6
Greatest height of the superior spine	0	5	0
Greatest breadth of the inferior spine	0	4	8
From the root of the spine to end of acromion	2	5	6
Greatest length of the inferior spine	1	4	0
Largest diameter of the glenoid cavity	0	6	6
Shortest diameter of ditto	0	4	6
Length of the base	2	3	6
Supra-spinal aperture formed by the junction of the acromion and coracoid process: Longest diameter	0	6	6
Shortest diameter of ditto	0	4	6
Clavicle.			
Length	1	3	0
Smallest circumference	0	7	6
Humerus, no portion of.			
Ulna, no portion of.			
Radius.			
Length	2	2	0
Smallest circumference	0	9	0
Greatest circumference at lower end	1	8	0
Greatest circumference of upper articular surface	0	3	7
Least diameter of ditto	0	3	3
Circumference of the upper end	1	0	0
Carpal bones, two.			
Metacarpal bones, two.			
Extreme length of the longest metacarpal bone	0	10	8
Circumference of ditto at its posterior extremity	0	10	0
Circumference at its anterior extremity	1	0	11
Ungueal phalanges.			
1st. Length of the largest phalanx	0	10	6
Greatest height near the middle	0	6	0
Circumference at the same part	1	8	0
Breadth at the same part	0	3	0
Length of the bony core of the claw	0	10	0
2nd. Length of the second-in-size phalanx, but imperfect at its point	0	9	0
Greatest height near the middle	0	5	6
Circumference at the same part	1	2	6
Breadth at the same part	0	3	4

	Ft.	In.	Lines.
3rd. Length of the third-in-size phalanx	0	9	3
Greatest height near the middle	0	3	2
Circumference at the same part	0	9	6
Breadth at the same part	0	3	0
4th. Length of the fourth-in-size, or smallest phalanx	0	8	6
Greatest height near the middle	0	3	0
Circumference at the same part	0	9	0
Breadth at the same part	0	2	6

Pelvis.

This most enormous and almost disproportioned part of the skeleton differs chiefly from that of the Edentata in the expansion of the ossa ilia*. In other respects it participates in many of the peculiarities which the pelvis exhibits in that tribe. The ischiadic notch, for example, is converted into a complete foramen on each side, by the anchylosis of the spines of the ischia with the extended transverse processes of the posterior sacral vertebræ.

The deficiency of the pubis in the specimen at Madrid left room for a supposition that the pelvis might be open anteriorly, as Cuvier describes it to be in *Myrmecophaga didactyla*; but the perfect state of the pelvis in this respect in the present specimen shows that the ossa pubis are completely joined at the symphysis, as in the rest of the Edentate order.

Its admeasurements are:

	Ft.	In.	Lines.
From the spinous process of the sacrum to the extreme point of the crest of the ilium	3	0	0
From the extreme point of the ilium to the acetabulum	1	6	0
From the extreme point of the crest of the ilium to the anterior part of the symphysis pubis	3	4	0
From the extreme point of the crest of the ilium to the superior margin of the acetabulum	1	9	0
The antero-posterior extent of the ilium	1	10	6

* If it were allowable to contrast the admeasurements of individual parts in two animals in other respects dissimilar, some of those of the Megatherium are so extraordinary, that when compared with those of an elephant of eleven feet in height, the latter seem to sink into absolute insignificance. Of these, the pelvis, the femur, and the os calcis afford the most striking examples; viz.

	Elephant.		Megatherium.	
	Ft.	In.	Ft.	In.
The expansion of the ossa ilia	3	8	5	1
Breadth of the largest caudal vertebra	0	7	1	9
Circumference of middle of femur	1	0	2	2
Length of the os calcis	0	7½	1	5

	Ft.	In.	Lines.
The lateral extent of the ilium	2	3	8
The diameter of acetabulum from anterior to posterior edge	0	7	3
Ditto, from external to internal edge	0	7	6
From the superior to inferior edge of the ischiadic notch (which is here a complete foramen)	0	7	0
Ditto, its transverse diameter	0	4	5
Length of the dorsal surface of the sacrum	1	6	0
Ditto, on its inferior surface, from its articulation with the last lumbar vertebra to that with the first caudal	1	4	0
From the superior edge of the acetabulum to the symphysis pubis	2	3	0
Depth of the symphysis pubis	0	10	0
Breadth of the pubis from its anterior edge, or brim, to the obturator foramen	0	10	2
Smallest diameter of obturator foramen	0	5	2
From the outer or extreme point of the ilium to the tuberosity of the ischium	3	3	0
Breadth of the ischium, where it joins to the sacrum	1	0	6
From the extreme point of the ilium to the anterior edge of the symphysis pubis	2	8	0
Transverse diameter of the anterior articulating surface of the sacrum, adjoining the last lumbar vertebra	0	6	2
Vertical diameter of ditto	0	5	6
Transverse diameter of the posterior articulating surface of the sacrum, with the first caudal vertebra	0	6	2
Vertical diameter of ditto	0	4	3
The antero-posterior diameter of the pelvic aperture	2	0	0
Transverse diameter of ditto at the brim of the pelvis	1	2	0
Transverse diameter of the pelvic aperture at the outlet	1	6	0
From the posterior part of the sacrum to the anterior part of the symphysis pubis	3	2	6
Transverse diameter of the spinal canal in the sacrum	0	4	2
Antero-posterior diameter of ditto	0	3	3

Posterior Extremity.

Femur.

	Ft.	In.	Lines.
Greatest length from the extremity of the head of the femur to the lower surface of the inner condyle	2	4	0
From the top of the great trochanter to the lower surface of the outer condyle	2	3	0
Greatest circumference of the head of the femur	2	0	0
Circumference of the neck of the femur	1	10	0
Circumference of the upper part of the femur, over the great trochanter	3	2	0
Circumference of the middle of the femur	2	1	10
Circumference above the condyles	3	2	0
Circumference around the condyles	2	10	6
Breadth of the femur at the great trochanter	1	4	0
Ditto, across the middle of the femur	0	11	0
Ditto, above the condyles	2	4	6
Transverse breadth below the condyles	1	0	0
Inter-condyloid space at the middle of the bone	0	3	8

	Ft.	In.	Lines.
Tibia.			
The greatest length along the middle line	1	10	0
Circumference of the head of the tibia, over the anchylosed head of the fibula	2	11	0
Smallest circumference of the tibia at its middle	1	2	2
Circumference of the lower extremity of the tibia and fibula over the malleoli	2	6	3
Length of the interosseous space	0	7	1
Greatest breadth of ditto	0	3	6
Breadth of the superior articulating surface of the tibia	0	11	9
Breadth of the inferior articulating surface	0	8	3
Breadth of the tibia and fibula at the lower end	1	0	6
Astragalus.			
Its greatest breadth	0	9	0
Its greatest height	0	9	0
Os calcis.			
Greatest length on its inferior surface	1	5	0
Circumference around its anterior extremity	2	4	9
Circumference immediately behind the last measured part	1	6	0
Circumference behind its middle	1	7	3
Thence the os calcis gradually tapers to a point backwards.			
Os naviculare.			
Its greatest breadth	0	6	6
Its greatest length	0	4	6
Os cuboides.			
Its greatest diameter	0	5	0

With regard to the relative dimensions of the Madrid skeleton, and the specimen under consideration, on comparing a few of the most certain measurements with those given in a Table constructed by the late justly revered M. Cuvier*, from an admeasurement of the figures published by Messrs. Pander and D'Alton, which are professed to be drawn on a scale of one tenth of the natural size (for, neither Bru†, Garriga, nor Pander having taken the pains to give the real dimensions of the bones in feet and inches, the admeasurements in the Table of the various parts can only be expected to be approximations),—some of the bones in the present specimen are, according to those calculations, somewhat less; but the greater number of our measurements exceed those of the corresponding parts in the Madrid skeleton; consequently, it is fair to infer that the present specimen was, of the two, the older, and somewhat larger individual. From a manuscript memorandum in

* *Ossemens Fossiles*, vol. v. Part I. p. 191.

† M. Bru, from whose description and drawings M. Garriga constructed his work.

a copy of Garriga's work which I have in my possession, made by some person who had compared his Plates with the skeleton in the Royal Cabinet at Madrid, the height of that specimen at the sacrum is stated to be six feet five inches, and its length, from the front of the nasal bones to the setting on of the tail, thirteen feet seven inches.

I cannot conclude my account of this most singular animal without again adverting to the obligations we are under to Mr. Parish for the great zeal and energy he has exerted in collecting and bringing to this country so very interesting a series of fossil remains; and trust his example will operate as a stimulus to others, who may have similar opportunities of exploring distant regions, and excite them to contribute, as he has done, towards the advancement of this important branch of natural history.

XXIII.—*Remarks on the Existence of the Anoplotherium and Palæotherium in the Lower Freshwater Formation at Binstead, near Ryde, in the Isle of Wight.*

By SAMUEL PEACE PRATT, Esq., F.G.S. F.L.S.

[Read November 17, 1830.]

MR. LYELL, in his very valuable work on the Principles of Geology*, has expressed a doubt whether a tooth of an Anoplotherium in the possession of Mr. Allan, and described by Dr. Buckland in the "Annals of Philosophy†", had actually been found in the Isle of Wight, as its label indicated. As this doubt appears to have arisen in consequence of the tooth being the only instance in which such remains had been observed in that locality, it will be satisfactory to geologists to be informed, that during the late summer I discovered at Binstead, near Ryde, among other interesting remains, not only a tooth of an Anoplotherium, but also two teeth of two distinct species of the allied genus Palæotherium; thus, not only removing the chief grounds of Mr. Lyell's doubts, but likewise more fully establishing the identity of the formations of the two basins of the Isle of Wight and Paris.

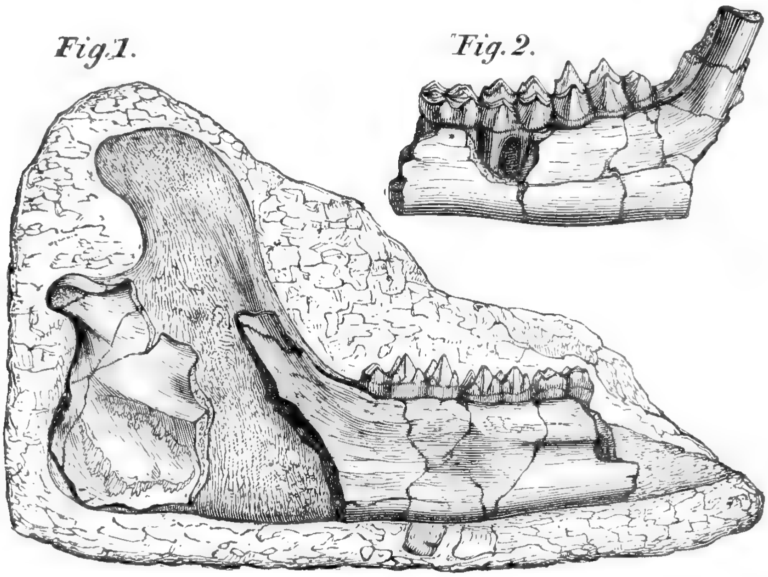
The quarries at Binstead are, as is well known, situated in the lower freshwater formation, and consist of alternating beds of compact siliceous limestone, sand, and whitish shelly marl, composed almost entirely of comminuted freshwater shells. The marls are more or less indurated, and form several distinct beds, separated by thin seams of clay, the lower of which contain the principal part of the fossil remains observed, although indications of the same may be seen in all the beds. These remains consist of numerous fragments of bones, scales, and teeth. Most of the fragments of bone have been rounded, and they are generally so much injured as to make it difficult to class them. One specimen, however, appears to be the head of a humerus, another a bone of a foot, both probably belonging to the Pachydermata above mentioned, as they were found in connexion with the teeth. The greater number of the

* Vol. i. p. 153, note, First Edition. In the subsequent editions the correctness of Mr. Allan's label is acknowledged.

† New Series, November 1825, vol. x. p. 360.

bones may be identified with those of the freshwater turtle, consisting principally of remains of the Carapax; and two genera, at least, the Emys and Trionyx, have been observed, corresponding with those described by Cuvier as found in the Paris basin. Of the teeth, one is a molar of *Palæotherium magnum,* another agrees with the first molar of *Palæotherium minimum,* and the third is apparently part of a molar of *Anoplotherium commune.* Several plates were found, which have proved to be the enamel plates of teeth of the same class of animals, separated from their bony connexion; and, as many of these plates were observed, it is probable that the animals to which they belonged were numerous, although so few of their other remains have been found. This may be partly accounted for from the marls in which they occur being in general extremely fragile, and rarely containing a perfect shell; so that it is difficult to separate the fossils from the marls without destroying the former. I was also informed by a quarryman that he had several times observed large bones, which had not been preserved, in consequence of their rotten state. I have reason, however, to hope that in future such interesting remains will not be lost to science, and that other genera of Mammalia may be discovered. As proof of the justness of this expectation, I will next advert to part of the lower jaw of a species of Ruminantia which was found in the lowest bed of the marl, together with a single molar tooth belonging to another similar animal.

Fig. 1. *Fig. 2.*



This jaw appears to be closely allied to the genus Moschus; but the loss of the anterior portion renders it difficult to class the fossil correctly, and the greater width of the corocoid process distinguishes it from any described species of that order *. This circumstance induced Cuvier (to whom a cast of the specimen had been sent) to suppose it to belong to the genus Anoplotherium, and he had named it *Anoplotherium dichobunes*; but as it was not possible to determine the structure of the fossil from an examination of the cast, I was induced to compare the single tooth above mentioned, with the specimens of the Paris Pachydermata preserved in the Museum of Natural History, and also with the jaws and teeth of all the small Ruminants in the same collection. This was done with the assistance of M. de Blainville, who, after the most careful examination, acknowledged that it was impossible to decide positively without having a more perfect jaw; and he was induced to leave the specimen amongst the Pachydermata, rather because Cuvier had so placed it, than on account of any decisive character. The texture of the tooth approaches, in my opinion, nearer to the Ruminants, while the general form of the jaw gives it the character belonging to the Anoplotherium. It is therefore very desirable to procure more perfect specimens, that this interesting question should be determined, as it is a remarkable circumstance that the teeth of two genera so very different should be so closely allied in form. A species of deer is mentioned by Cuvier, as having been found in the freshwater limestone of Montebusard near Orleans, but it differs essentially from the jaw described, which appears to have belonged to a full-grown animal, from the muscular ridges being well pronounced, although the perfect and little-worn appearance of the teeth seem to indicate that they had not been much used.

* The following observations were made by the author during a visit to Paris in 1833.

XXIV.—*Observations relative to the Structure and Origin of the Diamond.*

By Sir DAVID BREWSTER, K.G.H. LL.D. F.R.S. &c.

[Read February 27, 1833.]

In the year 1820 I communicated to the Royal Society of Edinburgh an account of a very singular fact relative to the structure of the diamond, and I added to this communication some conjectures respecting the origin of this remarkable gem. As these conjectures have been referred to by some late and able writers on the diamond mines of India without sufficiently separating the fact from the conjectures, and as I consider the structure which I discovered around the cavities in this mineral as a leading fact in the natural history of this gem, I have been induced to re-examine it with care, and to make a drawing of the phænomena which it presents.

In order to bring all the facts into one view, I shall make no apology for quoting my original observations.

"Had the diamond not been placed at the head of the mineral kingdom, from its unrivalled lustre and high value as an ornamental gem, it would have attained the same distinction from its great utility in the arts. Separated from all other gems by its remarkable refractive power, and from all mineral substances by its extreme hardness, its chemical composition, and its locality in the crust of the earth, it has always been regarded as an anomalous substance which set even speculation at defiance.

"When Sir Isaac Newton compared the refractive power of several bodies, he remarked that amber and the diamond had a refractive power three times greater in respect of their densities than several other substances, and he conjectured that the diamond was probably an unctuous substance coagulated. This relation between the inflammability of bodies and their absolute refractive power I had an opportunity of confirming and extending by ascertaining that sulphur and phosphorus exceed even the diamond in absolute refractive power, and that these three simple inflammable bodies stood at the head of all other solid and fluid substances in their absolute action upon light.

"In this arrangement, amber stood next to diamond; and as both these substances had a similar locality, and had also carbon for their base, it became of some importance to discover that their general polarizing structure was the same. The analogy, however, to which I wish to direct the attention of the Society is founded on the existence of small portions of air within both substances, the expansive force of which has communicated a polarizing structure to the parts in immediate contact with the air. This structure is displayed in four sectors of polarized light encircling the globule of air, and can be produced artificially either in glass or in gelatinous masses by a compressing force propagated circularly from a point. It is obvious that such an effect cannot arise from any mode of crystallization; and if any proof of this were necessary, it might be sufficient to state that I have never observed the slightest trace of it in more than 200 mineral substances which I have examined, nor in any of the artificial salts from aqueous solutions. It can, therefore, arise only from the expansive force exerted by the included air in the diamond and the amber, when they were in such a soft state as to be susceptible of compression from so small a force. That this compressible state of the diamond could not arise from the action of heat is manifest from the nature and recent formation of the soil in which it is found; that it could not exist in a mass formed by aqueous deposition is still more obvious; and hence we are led to the conclusion rendered probable by other analogies, that the diamond originates, like amber, from the consolidation of, perhaps, vegetable matter, which gradually acquires a crystalline form by the influence of time, and the slow action of corpuscular forces.

"As the preceding results were obtained from flat diamonds, which did not seem to have been regularly crystallized, I was anxious to detect the same structure in those which had a regular crystalline form. With this view I examined several of the diamonds in Mr. Allan's collection, and was fortunate enough not only to detect in a perfect octohedral crystal the same structure which I had observed in the flat specimens, but also an air-bubble of considerable size, which had produced by its expansion the polarizing structure already described."

Since these observations were written, Dr. Voysey has shown that the matrix of the diamonds produced in Southern India is the sandstone breccia of the clayslate formation; and Captain Franklin has found that in Bundel Kund the rocky matrix of the diamond is situated in sandstone which he imagines to be the same as the new red sandstone of England, that there is at least 400 feet of that rock below the lowest diamond beds, and that there are strong indications of coal underlying the whole mass. The following are Captain Franklin's observations on the origin of this mineral:

"There is another circumstance to which I must advert, but I do so with diffidence, and under a hope that it will be considered merely conjectural. Dr. Brewster supposes the diamond to have originated like amber, perhaps from the consolidation of vegetable matter, and that it gradually acquired its crystalline form by the influence of time, and the slow action of corpuscular forces. The late Dr. Voysey adverted to this opinion in his account of the diamond mines of Southern India; and on the occasion of publishing an abstract of that paper in his Journal of Science, Dr. Brewster observed that he saw no reason to alter his opinion. Now, as the rock matrix of the diamond of *Panna* appears, in some respects, though not altogether, to resemble that of *Banganpilli* in Southern India, there would seem to be little chance of any conjecture being useful; still, however, as every opinion regarding the origin of this fine mineral is as yet theoretical, I will not withhold what occurred to me on this subject, though I again repeat that I offer it with great diffidence. The theory of Sir James Hall on the consolidation of strata frequently recurred to me when examining the sandstone in which the diamond is found: I thought that I could discern much in favour of it, and particularly in the gradual changes of its nature from the lower to the upper strata. Now, if the principle of this theory is admitted to be correct, and applicable universally, it follows of course that it must be applied here; and then it may be questioned, how the diamond was preserved under that degree of heat which must have been necessary to form its matrix the gritstone? In answer to this objection, I suggest that the circumstance of calc spar occurring in trap rocks is somewhat analogous; and if it is admitted that compression under the weight of strata and a superincumbent ocean had the effect of resisting the expansion of its carbonic acid, and constraining it to continue in combination with lime, might not the same principle be reasonably enough applied to account for the preservation and detention of the elements of the diamond in the gritstone? And, again, should it be further shown that crystals, such as those with which we are familiar in nature, may be produced by slow cooling, or other processes, according to the above theory, may we not look to it also to account for the crystallization of the gem?

"This conjecture rests upon the truth or fallacy of Sir James Hall's theory, or on a modification of it; and when this theory is considered as the result of long and patient experiment, and the high reputation of its author is taken into account, it will require something more than limited observation or ordinary ability to answer its objections; my part, however, is merely the suggestion of a traveller, and I therefore conclude my paper by expressing a hope that this important mineral may meet with more able investigation."

This discovery of a new matrix of the diamond takes away the foundations of the argument from which I concluded "that the compressible state of the diamond could not arise from heat," for it is possible that the rocky matrix in which it was found had an igneous origin; and Captain Franklin's supposition that it might be fused under compression, is quite conceivable.

But, though I admit the possibility of the diamond having been in a state of igneous fusion, I consider it highly improbable that it was so. In the laborious examination, which I carried on for several years, of the cavities in topaz, quartz, amethyst, chrysoberyl, &c., and in salts formed from aqueous solutions, I had occasion to observe the condition of many thousands of cavities, and in no one case, neither in crystals which exist in rocks known to be of igneous origin, nor in crystals artificially formed, have I been able to discover a single cavity in which the expansible fluid which it contained had compressed the surrounding mass, and communicated to it the polarizing structure existing around the cavities in the diamond.

Now, in glass which is known to have been in a soft state, and in amber, which is generally allowed to be an indurated gum, I have discovered cavities similar to those in the diamond, and surrounded by the same polarizing structure; a structure which could only be produced by a compressing force emanating from these cavities.

As I am desirous that mineralogists should thoroughly understand the nature of this structure, I have made two drawings of the diamond Laske which contains the cavities under consideration.

Fig. 1.

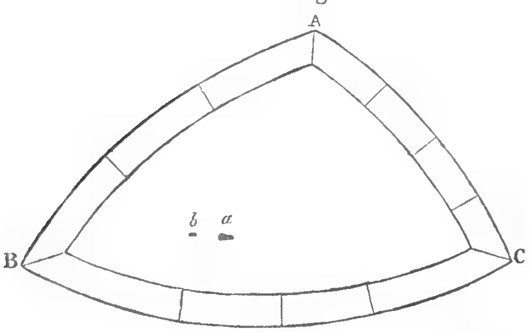


Fig. 2.

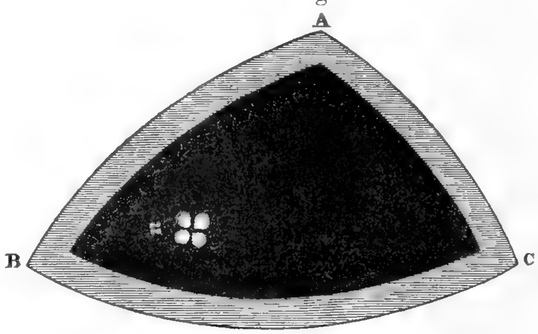


Fig. 1. represents the diamond considerably magnified. At *a* and *b* are seen two minute cavities, which appear perfectly black, as if they were filled with opake matter. This blackness, however, arises from the high refraction which takes place at the concave surfaces of the cavity, as may be proved by the application of a microscope, which exhibits a minute pencil of light transmitted through them. Fig. 2. shows the four luminous sectors around

each cavity, as exhibited by the agency of polarized light. When a plate of sulphate of lime which polarizes a blue tint of the second order of colours in Newton's scale is placed across these sectors, so as to have its axis coincident with the radii of two of the luminous sectors opposite to each other, and perpendicular to the radii of the other two sectors, its blue tint of the second order is depressed, by that which is polarized by the sectors, to a red of the first order in the sectors whose radii are coincident with the axis of the sulphate of lime, and raised to a whitish yellow of the second order in the other two sectors. Hence, it follows that the character of the polarization in the sectors is negative, like that of calcareous spar, and that it has been produced by a compressing force acting outwards from the cavities.

I have, in my former paper, supposed that the compressing force was the expansive power of air included in the cavity; but this, of course, is a conjecture, though it seems quite certain that it must have been a gaseous body. That it was not a fluid is obvious, from there being no fluid in the cavities. This was certainly the case in the cavities in amber and glass; but it is possible that a fluid of very low refractive power may exist in the diamond cavities without my being able to see it, on account of the high refractive power of the gem. If this should be the case, however, it will not be difficult to observe it in larger cavities, if they should ever be discovered.

The existence of a compressed structure round the cavities clearly proves that the diamond has been in a soft state; but it may be shown, from various considerations, that this softness was not the softness produced by igneous fusion, and that it is likely to have been the softness of a semi-indurated gum. I have already stated that no such cavities exist in minerals of igneous origin; a fact which entitles us to separate the diamond from that class of crystals: and it is equally important to observe that its polarizing structure, which I have studied with peculiar care in a great variety of specimens, connects it closely with amber and indurated gum. From such substances, indeed, it differs in having a distinct crystalline form; but in the mineral resin called mellite we have an equally distinct crystalline form, though there can be little doubt, both from its composition and its locality, that it derives its origin from the vegetable kingdom.

XXV.—*Remarks on the Structure of large Mineral Masses, and especially on the Chemical Changes produced in the Aggregation of Stratified Rocks during different Periods after their Deposition.*

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[Read March 11, 1835.*]

§ 1. *Introductory Remarks, &c.*

ALL solid mineral masses must have undergone some change since the time of their first production. Beds of secondary limestone and sandstone did not drop to the bottom of the sea, layer upon layer, in a solid form; and it is equally certain (though not equally obvious) that large unstratified crystalline masses were not created as we now find them. No one supposes that columnar basalt was originally built up of solid parallel jointed pillars, or that the structure of a granitoid rock was effected by a mere fortuitous concourse of the crystalline parts. We believe that these phænomena are the necessary consequences of a certain anterior condition of the materials we examine. Sometimes, indeed, we can imitate these conditions, and then (as the laws of nature are unchangeable) we can do over again that which has been done a thousand times before in the laboratory of nature.

Many large mineral masses appear to have been once in a state of igneous fusion. Such masses, in passing from a fluid (or semi-fluid) to a solid state, necessarily put on a form more or less crystalline. The crystalline form is therefore the first and inevitable change. But there is another effect, arising out of such changes, of great geological importance. The mass which has changed its temperature, and become solid, has also changed its dimensions. Contraction must produce tension on the whole mass; and this tension, acting mechanically, will in many instances produce joints and fissures, and sometimes contortions: these effects will be of greater or less regularity according to the conditions of each particular case.

* The Council has thought it advisable to publish this memoir before its turn, because they consider it to be introductory to other papers by the same author, some of which are already printed, and will appear in the fourth volume, illustrative of the origin and structure of the older stratified rocks.

The original modifications in the structure of an igneous rock *may* have been produced in a comparatively short period of time; and the same remark applies to some *metamorphic* rocks. The saccharoid texture (for example) of limestone, when in contact with trap, *may* have been produced during a very short period; for we know that this effect has been beautifully imitated in a chemical laboratory. In general, when *metamorphic* rocks appear to have been in a state of igneous fusion, it is obvious that all questions, respecting the length of time during which their crystalline structure was elaborated, must come very nearly under the rule that affects igneous rocks.

There is, however, a large class of *metamorphic* rocks, the structure of which can only have been produced by causes acting during long periods of time. I am not now speaking of gneiss, mica slate, and other old formations of crystalline strata. To assume that *all* such rocks are *metamorphic* is nothing better than to beg some of the greatest fundamental questions in geology. But in cases where a new mineral structure appears certainly to have been superinduced by direct igneous action, we sometimes meet with phænomena utterly at variance with the hypothesis of a chemical action continued only through a short period. Rocks, it is well known, are bad conductors of heat; yet among stratified rocks the manifestations of igneous action are sometimes propagated to great distances. Such phænomena may be readily explained. Masses of granite and porphyry were not necessarily protruded instantaneously. They may have been many years in assuming their present relative position among the stratified formations. Again, the effect produced by such protruded masses might be modified, almost indefinitely, by the conducting powers of the materials among which they rose. One mass may have been pushed out into the sea or the open air; another, after its first elevation, may still have been covered up by a vast thickness of badly conducting strata. Nor is this all. It is by no means necessary to suppose that all changes produced by igneous agents on stratified rocks took place only during periods of eruption. We may suppose, for example, that the lower slate formations of Cornwall and Cumberland formed a dome, overhanging the great subterranean fires, for many years, or even for many centuries, before a contraction of the upper surface, or a mechanical action from below, pushed up the great bosses of granite among the altered and half-molten beds. Hence, although it be certain that the structure of altered rocks has in many cases been produced by a sudden action, we are by no means limited in our hypothesis, but may fairly suppose such periods of duration as in each case, are necessary to the elaboration of our phænomena.

My chief object is, however, to describe some of the changes produced on mechanical, stratified rocks by causes acting under a comparatively low temperature, and often during indefinite periods of time. Very few of these changes can be imitated in a laboratory, because it is impossible to imitate the conditions under which they have been brought about. They admit not, therefore, of synthetic proof; but they are unquestionably subordinate to chemical and mechanical laws, which we can study experimentally, and establish on appropriate evidence. By assuming the existence of these laws, and by studying the conditions under which they have acted (not as matters of experiment but of observation), we may gradually ascend towards an explanation of some of the perplexing phænomena presented by sedimentary rocks.

That these rocks are greatly changed since their first origin is too obvious to require any formal proof. Take, for example, a mass of Hertfordshire pudding-stone. There can be no doubt that it once formed a portion of a shingle bank of rolled chalk flints and finely comminuted sand. The materials are now so closely agglutinated by siliceous cement, that a fracture passes indifferently through the sandstone and the imbedded flint pebbles. Again, rocks of this kind are sometimes divided into prismatic masses by cross joints; and these joints pass without any deviation through the imbedded flints, so as to produce a series of smooth surfaces. I merely mention this as an example of a great change produced naturally (and unquestionably without any very high temperature) upon a coarse, mechanical deposit.

Again, every bed of secondary limestone, containing organic remains, gives us an example of somewhat similar changes. We find a mass, hard and solid, which was once comparatively soft and incoherent; we find crystalline structure, and sometimes even regular cleavages, where such an arrangement of the parts could not have originally existed; and, what is more, we find parts originally solid replaced by other solids—a trunk of a tree, for example, replaced by nearly pure silica—a shell by a similar substance, or more commonly by pure carbonate of lime with a regular crystalline structure. The solidification of calcareous beds is easily explained, and the process may be imitated. The replacement of one solid by another requires conditions it is difficult to imitate: but the fact shows that an enormous extent of chemical action, enough indeed greatly to modify the whole aspect of external nature, may take place among the solid parts of bodies without an approach to direct chemical solution.

When we consider even such simple examples as those just quoted, they give us an impressive proof of the powers of nature in producing mineral changes; and when we bear in mind that some of our secondary strata may have rested thousands of years under the pressure of a thousand atmospheres, we need not wonder at the extent to which such changes have been carried.

These examples prove at least two classes of chemical changes in stratified rocks,—the first produced by the penetration of fluids containing some new cementing principle—the second by the long-continued mutual action of contiguous solid parts upon each other. But, besides these chemical changes, most secondary deposits have been modified by two mechanical causes; viz. a contraction of dimensions in passing to a solid form, and a change in the relative position of the component parts, produced during periods of elevation. I shall first endeavour to illustrate some of the chemical changes.

§ 2. *Globular and Concretionary Structure.*

It appears to be an acknowledged principle, that when different substances, in a state of extreme comminution, are mechanically mixed together, they have a tendency to separate and re-arrange themselves in masses more nearly homogeneous. The separation of the pounded flint from the aluminous earth, in the materials prepared for the potteries, has been several times quoted as an instance of this kind of chemical action. If one or more of the ingredients be in a state approaching to chemical solution, a similar segregation will often take place; but the separation of parts will in such case be more complete, and the effect more perfect. I subjoin a few examples of these kinds of segregation.

(1.) *Chalk Flints.*—The position of nodular flints in chalk is two well known to be here described. I merely observe, in this place, that they are, in their origin, unquestionably posterior to the beds in which we find them. What caused them to aggregate on the very points where we find them is not the question. As a matter of fact the free siliceous matter of the chalk formations is not distributed uniformly, but has been accumulated in distinct masses and concretions, and therefore exemplifies the principle for which I am contending.

(2.) *Globular Calciferous Grit, &c.*—Calciferous grit has very often a dull fracture, and the presence of carbonate of lime can hardly be detected except by the use of an acid. In short, we have an irregular mechanical aggregate of earthy parts, and no definite separation produced by crystalline action.

In the next modification of calciferous grit, we always obtain, on fracture, a series of glistening surfaces. The peculiar *chatoyant* lustre of such specimens arises from this cause—that the calcareous matter has crystallized through certain definite spaces in systems of parallel plates. Hence, in turning such specimens about, we first have a reflexion of light from one system, then a dull surface, and then again a bright reflexion for a second system of parallel plates. In this mode of examination we might, I doubt not, sometimes discover a series of planes belonging to some known definite form of carbonate of lime. In the well-known Fontainebleau rhombs, the crystalline forces of the carbonate of lime have had such power over the particles of siliceous sand, as to re-arrange them in regular forms. In the cases I am considering such a change is out of question, because the stratified calcareous grits were probably held together by great pressure, and were partially in a state of solid aggregation at the very time the crystalline plates of carbonate of lime struck in various directions through the intervals of their mass. All that it is important to observe, is the fact, that these plates pass obliquely through the laminæ of stratification, and, consequently, that the structure is one of the numberless instances of chemical changes produced, in stratified rocks, *after* their deposition.

When we examine a weathered surface of calciferous grit, we generally find it exhibiting inequalities, which prove that the crystalline plates of carbonate of lime are not uniformly arranged through the mass. In short, the portions in which these plates are most completely developed are in such cases of the nature of irregular concretions. More rarely the *chatoyant* calc-grit is seen in the form of flattened spheroidal concretions, ranged with more or less regularity on lines parallel to the planes of stratification; and in such cases, the concretions themselves are not unfrequently traversed by these planes. The best examples of this structure may be seen in the neighbourhood of Peterborough among the calcareous flagstones abounding in the upper part of the great oolitic system of Northamptonshire. Thousands of globular concretions of calc grit (generally exhibiting the original laminæ of stratification) lie scattered upon the upland plains on the confines of Huntingdonshire and Cambridgeshire. Whether they have drifted from the calcareous grits of the middle oolite (coral rag), or from the back of the great oolite of Bedfordshire, is not easy to determine. The well-known slates of Stonesfield also exhibit fine examples of this structure.

(3.) *Globular Magnesian Limestone.*—The phænomena accompanying this structure have been described by myself at great length in a paper published in the Transactions of this Society*. It is by far the most beautiful example of a spheroidal structure, superinduced on stratified matter *after* its aqueous deposition, which is to be met with in any of our secondary rocks. This conclusion is controverted by the author of the *Principles of Geology*† on the strength of a supposed analogy between the formation of the magnesian limestone and certain travertines: but as the supposed analogy is wanting in a fact

* Second Series, vol. iii. p. 94—98. † Vol. i. p. 303.

of essential importance (viz. the passage of the laminations of deposit through the globular travertine), I may be pardoned for considering it of no value to the argument. Under such circumstances, however, it may be proper shortly to go over some of the grounds that led me to the conclusion above stated.

1st. The magnesian limestone is sometimes stratified in very thin earthy beds or laminæ; and occasionally (e. g. on the coast of Durham, a few miles north of Hartlepool,) organic remains may be traced in abundance along the lines of such strata, which must, therefore, have been formed by a slow deposition of the successive layers.

2ndly. Globes of various sizes are found in such beds, sometimes appearing as mere semi-indurated lumps, sometimes as hard concentric concretions, sometimes as balls of a radiating crystalline texture: and through such masses (except in the ultimate state of perfect crystallization) we can often trace the laminæ of stratification passing uninterruptedly. This fact alone is decisive, and can be established even by hand specimens.

3rdly. In other places the same limestone is found in thick beds, and is used for building. Such beds are not, however, a momentary product; because we can often subdivide them into smaller beds, and even into laminations. Now we may sometimes discover (especially on producing a fracture with a ponderous hammer,) that portions of such beds are entirely made up of spherical concretions, interfering with each other, and producing solids with trapezoidal faces. These concretions must be contemporaneous; but their centres are found in beds which are not contemporaneous: therefore the concretions must be posterior to the stratified masses in which they are found. This seems to me nothing short of demonstration.

4thly. The formation, though stratified, is often irregularly solidified: portions are solid; other portions are perfectly earthy and pulverulent. Now, we may observe two things: first, the laminæ, when they abut against the earthy portions, are often crystalline; secondly, there are often packed up in the incoherent magnesian earth large spherical concretions of nearly pure carbonate of lime, which do not adhere to or touch any of the solid portions of the surrounding strata. How is such a structure to be explained except by a slow chemical segregation of parts?

I know that travertines sometimes exhibit spherical aggregations. Indeed I saw many magnificent examples of such formations when, in 1829, I visited, along with Mr. Murchison, some deposits of travertine in Bavaria. But the spheroidal portions we saw were fixed to the solid mass, and had no laminæ of deposit passing through them. Whenever such laminations are present, (whatever be the age of the formation,) we may, I think, be certain that spheroidal concretions are not exceptions to, but examples of, the very changes I am attempting to describe.

(4.) *Rocks of Globular Structure subordinate to the Old Slate Formation of North Wales.*—This structure may be often seen in the mountains of Caernarvonshire and Merionethshire, yet I do not remember to have seen a single good example of it in the corresponding formations of the North of England. Tabular masses of porphyry, compact felspar, hornstone, &c. alternate with, and partake of, all the great flexures of the true slate rocks of North Wales. Some of these have, I doubt not, been poured out, in a state of igneous fusion, at many successive times during the long period in which the whole slate series was deposited. Others, on the contrary, seem to have been deposited as a part of the schistose series, and to have been since changed into their present forms by crystalline forces, pushed, probably, into activity by a high temperature. It is in this latter class that I arrange most of the globular rocks I am now noticing.

In the compact felspathic slates we may often see balls of nearly pure quartz. These balls are sometimes as much as three or four inches in diameter, and are arranged with considerable regularity. Their centres are generally compact, but sometimes hollow, exhibiting a tendency to an agate-like structure; and the circumference of these balls is almost always ill defined, gradually blending itself with the prevailing mass of the rock. This, if I mistake not, is one of the modifications produced, in sedimentary rocks, of which the original structure (when they are examined on a great scale) is sometimes not entirely obliterated.

The proportion of quartz varies extremely in other great globular masses, and sometimes it forms nearly the whole rock: in such cases they might be at first sight mistaken for great white quartzose conglomerates. On fracture, the balls are found to be more or less crystalline; not unusually they are hollow, and partially agatized; and, on examination, we find them held together by a rude cement, in which we may sometimes detect a granular structure. Such masses as these could not, I think, be of direct igneous origin. I believe them to be the result of changes produced by slow long-continued chemical action on beds of old stratified sandstone.

These two examples of changed structure differ from all those above enumerated, in as much as they seem to require a high temperature for their completion, and are probably, in all cases, nearly associated with igneous rocks: and if any of these globular masses should appear to have been in a state of igneous fusion, they ought in that case to be removed into another class, and arranged with the orbicular granite of Corsica and other concretionary trappean rocks.

Fine examples of the structure here described may be seen in the hills south of Conway, on the north side of the great road a mile or two east of Bettws y Coed, in the rugged hills east of Beddgelert, as well as in many other parts of the great Welsh chain.

(5.) *Nodular Ironstone, Septaria, &c., in beds of Shale.*—These phænomena are so well described in the fifth chapter of Mr. De la Beche's "Theoretical Researches," that I have little or nothing to add to what he there states; but I may quote him in this place as an authority for the conclusions I am endeavouring to support. He describes calcareous nodules in the lias of Lyme Regis, and tells us "that on fracture they are found of a laminated structure, and that the laminæ of the nodules are precisely parallel to the laminæ of the shale, or marl, in which they are inclosed, and little doubt can exist that they once constituted continuous portions of each other." He considers this structure "as the result of the attraction of certain particles among each other, *after* their deposition;" in which conclusion it is hardly necessary for me to state that I entirely concur with him. Again, he says, "the ironstone nodules of the coal measures seem to have been thus produced." It is true that in such nodules the laminations are seldom visible, and the process of gradual segregation is, therefore, less obvious. But I possess some ironstone nodules from Yorkshire which are perfectly laminated; their origin and mode of segregation can, therefore, admit of no doubt.

Nodular concretions (like those just described), in beds of shale, though very imperfect as mineral phænomena, are very instructive; in as much as they often point out the causes which led to the aggregation of the nodules on the very spots where we find them. The first segregation appears often to have been caused by the presence of some extraneous substance, some fragment of an animal or a vegetable, or, perhaps, some minute and almost invisible granule. This is in exact accordance with what we know experimentally of crystallization and precipitation. Whatever be the health of the patient, if a nucleus be once formed in the bladder, the calculus will go on increasing; and there are numberless instances of the effects of a like principle. The particles in a menstruum may, perhaps, be regarded as in a kind of unstable equilibrium, which is disturbed by the presence of any extraneous body. At all events, as a matter of fact, extraneous substances promote crystalline precipitation; and, therefore, in the great operations of nature, form the centres of concretions segregated from stratified beds. But what cause was it which first determined the chemical nature of the materials forming the nucleus of a nodular concretion, or the lapidifying substance of a petrifaction? If like things tend to aggregate with like, we have a principle which explains, in some measure, why the silica of a chalk flint has struck upon the fibres of bodies allied to sponge; and why the outer substance of the Echinodermata is so frequently changed into carbonate of lime. But how do we explain the fact, that trunks of trees imbedded in siliceous sand are in some places mineralized by carbonate of lime, while other trunks imbedded in limestone are mineralized by silica? that in one limestone country, shells are all petrified by carbonate of lime; while in another, shells of the same species, and even the delicate portions of the internal animal structure (*e. g.* the internal spire of a Spirifer), are petrified by silica? To explain phænomena such as these, or even to classify them rationally, would, I believe, require very extended observations. But, whatever might be the answers given to such questions, the reasoning of this paper would remain unaffected. For, whatever be the mineral composition of a laminated nodule, or of a petrifaction imbedded in any secondary rock, it is equally certain that such rocks must have undergone a great chemical change since the time they were first deposited.

§ 3. *Cleavage, Rocks of Slaty Structure, &c.*

The most striking modifications of structure enumerated in the preceding portion of this paper extend to comparatively short distances from given centres of chemical action: those I am about to notice (especially the transverse cleavage of various slate rocks,) are of a very different character. As the finest examples of slaty cleavage are derived from the great Cumbrian cluster of mountains, and from the chains of North Wales, it may be well, in the first place, briefly to compare the physical structure of the two regions.

The zone of Cumbrian green slate alternates with an indefinite number of tabular or stratified masses of felspathic and porphyritic rocks. The slates are crystalline, and have been so firmly packed in among the alternating porphyries, as to undergo very few contortions or undulations during the period of their elevation. Moreover, they contain no organic remains: such remains being, perhaps, obliterated; or, more probably, organic beings not having propagated in an ocean exposed to continual incursions of felspathic rocks. All the masses alternating with the porphyritic system exhibit in greater or less perfection a *cleavage,* which is in no instance parallel to the true beds. These facts were stated in a former paper*; and I expressed my belief that the felspathic tabular masses were of Plutonic origin, and that even the great alternating beds of slate (especially the more crystalline and chloritic varieties), might, in part, have derived their materials from Plutonic sediment. I also

* See Proceedings, vol. i. p. 400.

imagined (at the time the paper was written) that each great alternating mass of slate had an independent cleavage, produced probably by crystalline forces acting under a high temperature; and this high temperature seemed to be naturally accounted for by the presence of the porphyries.

In the great chain of North Wales we have the same indefinite alternations: but the porphyries are less abundant in proportion to the other masses, and have produced a less impress on the slate system. Some of the slates are crystalline, and some earthy; and in *both varieties* we find (though rarely) traces of organic remains. The whole system of slates and tabular porphyries has been thrown into a number of great undulations, producing through the chain a series of longitudinal anticlinal and synclinal lines*. Lastly, parallel lines of cleavage not merely affect given beds; but sometimes run, without deviation, even through coarse mechanical subordinate strata, affecting whole ranges of mountains, and preserving their parallelism in spite of undulations and anticlinal lines†. These facts have led me to give up the opinion, that the cleavage planes have been materially modified by any action of the alternating porphyries.

Again, among the Cumbrian mountains there is an upper division of slaty rocks, not noticed in the preceding account. It is separated from the green-slate zone by continuous bands of limestone, full of organic remains. It is of much coarser structure than the rocks last described, and has no alternating beds of porphyry; but it contains some deposits of good roofing-slate, alternating with coarse greywacké, and with flaggy beds having no distinct cleavage.

The same description applies, almost word for word, to an upper Welsh system, which occupies a great portion of Denbighshire, the chain of the Berwins, and a considerable part of South Wales: but in some of these regions the alternating felspar rocks occasionally reappear, and true slate rocks are more extensively developed than in the corresponding part of the Cumbrian chain. And it is important to remark, that in Radnorshire and Caermarthenshire large tracts of green chloritic roofing-slate reappear in this upper system, without being accompanied by any masses of tabular porphyry, like those associated with the older chloritic slates of Cumbria and North Wales, and without the presence of igneous rocks in any of the neighbouring country. These facts also induced me to modify my former opinions, grounded on the frequent association of the hard chloritic roofing-slates with the tabular

* See Plate XLVII. fig. 1.

† See Plate XLVII. fig. 4. and 4 *a*.

porphyries. It is evident, after what has been stated, that such an association *may* be purely accidental*.

Leaving all further comparison between the structure of Cumberland and Wales, I return to the description of the most general facts exhibited in slaty cleavage. If we examine a quarry where this structure is well developed, we find a nearly homogeneous mass, easily separable into thin parallel laminæ. But the thickness of these laminæ is not defined by *joints* (*i. e.* by fissures at definite distances); for the cleavage of each part may be carried on indefinitely, or at least so far as the operation is not interrupted by a mere mechanical difficulty. That this arrangement is crystalline it is impossible to doubt, when we examine the planes of cleavage, and see them coated over with flakes of chlorite and semicrystalline matter, which not merely define the planes in question, but strike in parallel flakes through the whole mass of the rock. Were there any doubt of this conclusion, it is further confirmed by the fact, that these planes of cleavage are inclined at various angles to the planes of stratification, and are, perhaps, in no instance coincident with them. This last fact is of great importance, and is now generally admitted by English geologists. But it requires to be made still more prominent; for it is not considered in its proper extent by Continental geologists, and by some of them is actually denied.

Again, some English writers do not always distinguish between a jointed and a slaty structure; and even Dr. M'Culloch (whose general accuracy in the description of primary rocks is above all praise,) seems to consider a lami-

* There is a still lower system of schistose rocks in North Wales (not noticed in the preceding account), which are widely expanded in the Isle of Anglesea (Professor Henslow, Cambridge Phil. Trans., vol. i. p. 365), and occupy the south-west coast of Caernarvonshire from Porthdinlleyn to Aberdaron. They are chiefly made up of chlorite schist, sometimes passing into mica schist; and subordinate to them are calcareous portions, passing on the one hand into a beautiful white saccharoid marble, and on the other into vert antique and serpentine. There is also a lower group in Cumberland, which contains no calcareous beds, and hardly any calcareous matter; and passes in its inferior portion into a rock abounding with chiastolite; and more rarely into a quartzose mica slate, and into a rock which (perhaps improperly) has been described as gneiss. These two lower groups have few analogies of mineral structure, though they seem to occupy nearly the same geological place, and they have no organic remains.

Perhaps some of the lower schists of Cornwall may be on the same parallel with these two groups, however unlike them in structure and composition. It perhaps deserves remark in this place, that the lower schists of Cornwall, though certainly much changed since their deposition, are very distinctly bedded. Near the granite, besides the stratified, they often exhibit a beautifully jointed structure; but in hardly any instance a *true slaty cleavage*, in the sense in which those words are used in this paper.

nated structure, depending on the gradual deposition of the materials (and, therefore, parallel to the stratification), as one of the cases of a slaty structure. Now, I contend that these structures ought never to be confounded. They have very little in common; can, in ninety-nine instances out of a hundred, be distinguished even in hand-specimens; and ought to be designated by separate names.

If the planes of slaty cleavage and stratification be inclined at indefinite angles, some one may suppose that, among other varieties of position, we may find cases of coincidence. I can only state in reply, that I never saw such a case. The planes are, however, sometimes inclined at a small angle, and, from their appearance in a quarry, might easily be supposed parallel; but a careful examination will, I believe, always correct the error. I have seen a slate quarry in Denbighshire where the true fissile laminæ were not inclined to the strata at an angle of more than five or six degrees; and in one of the large quarries near Festiniog these planes are inclined at an angle under ten degrees. Taking, however, the average throughout the Welsh chains, the inclination of these planes is much more considerable, perhaps as much as 30° or 40°; and nearly the same rule may be applied to the slate system of the Cumbrian mountains *. It has, indeed, been said, that the

* I do not know who first published the general fact that true cleavage planes are never parallel to the beds of the finer argillaceous schists. Dr. MacCulloch, in his description of the Western Islands of Scotland, gives a striking instance of a fissile structure oblique to the stratification of clay slate (vol. iii. Plate XXII. fig. 6.). Some years before the publication of that work, Mr. Bakewell stated, "that slaty structure was," he conceived, "the effect of crystallization," and that "in the slate rock of Charnwood Forest the slaty laminæ make an angle of sixty degrees with the principal seam by which the rock is divided," (Introduction to Geology, Second Edition, p. 103); and in the new edition of his work (published in 1833), he generalizes more boldly, and maintains "that slate, unless it be of a soft or coarse kind, invariably splits in a transverse direction to that of the bed, making with that direction an angle of about sixty degrees, and that it has frequently two distinct cleavages." I agree with the most important part of this generalization; but the author is mistaken in supposing that the planes of cleavage and stratification make a constant angle. The angle varies greatly even in the same chain; and in different chains the average angle would, I believe, be very different.

Neither do I know any slate rock with two true cleavages. An ambiguity may, however, arise, if we confound cleavage planes with planes of bedding, and with joints. For example, I entirely agree with Professor Phillips in the account he gives of the flagstone of Horton Scar (Geological Transactions, Second Series, vol. iii. p. 16), though I should endeavour to describe the phænomena in different language. What he calls the *laminæ of false cleavage*, I should call *planes of true cleavage*; and what he calls *laminæ of cleavage*, I should call *laminæ of stratification*. Be it observed, there is no difference between the last-named author and myself, except in language. The rock in question is a fine greywacké flagstone, and rises in beds parallel to the original stracleavage of slate rocks is sometimes at right angles with the planes of stratification: but I doubt the correctness of the statement, as I never observed such a position of the cleavage; and think that a mistake has probably been committed in confounding joints (which are often at right angles to the strata) with true slaty cleavage*.

In some of the largest quarries of Cumberland and Caernarvonshire the cleavage planes dip towards the same point with the strata, but at a greater angle. This rule has, however, too many exceptions to be of value; for the two planes not unusually dip to opposite points of the compass. There is, however, one rule of position to which the exceptions are not, I believe, numerous, viz., where the cleavage is well developed in a thick mass of slate rock the *strike* of the cleavage is nearly coincident with the *strike* of the beds. Where, however, the slate is coarse and thin-bedded, the direction of the cleavage planes is often considerably inclined to the *strike* of the beds; and, ultimately, such planes will appear to pass into an oblique set of cross joints.

Besides the planes of cleavage, we may often find in large slate quarries one or more sets of cross joints, which, combined with the cleavage, divide the rock into rhombohedral solids. Should any one assert that this subdivision of slate rocks into rhombohedral solids implies three planes of cleavage, we might reply, that such solids are not capable of indefinite subdivision into similar solids, except in one direction, viz., that of true cleavage; and in this way (even in hand-specimens) we may generally distinguish the true cleavage planes from the joints. Respecting the angles of such solids, I have no rule to offer that does not appear to be destroyed by the exceptions; but as an approximate rule, there is, I think, one set of joints often nearly transverse to the strike of the beds. If there be any truth in this remark, the prevailing direction of such joints must be north-west, because the prevailing strike of our slate rocks is north-east: but an assumption like this can only be received under proper limitations.

Of all places a slate quarry is often the very worst for determining the

tification; but through these beds there is an oblique "bate", or cleavage, parallel to which the flags naturally break, so as to exhibit regular bevelled edges.

Any one who is anxious to understand the structure of slate rocks would do well to commence his study of them in Charnwood Forest. There is hardly a quarry on the east side of the Forest which does not clearly show the difference between stratification and cleavage; and in all the larger quarries near Swithland, the peculiar stripes marking the stratification of this class of rocks are very well exhibited.

* Researches on Theoretical Geology, p. 108.

stratification of the neighbouring country. The structure of the rock has been so modified that the traces of its original deposition are quite obliterated; and this remark does not apply merely to single quarries, but sometimes to whole mountains. In many slate quarries, and even in hand-specimens of slate, we can, however, discover a number of parallel stripes, sometimes of a lighter, and sometimes of a darker colour than the general mass; and in rocks of the age I am considering, these stripes are universally parallel to the true bedding of the rocks. The proof of this is established by the fact, that the assumption leads to consistent results; and that these stripes are always parallel to true beds, whenever such beds can be discovered, whether by organic remains, by the alternations of dissimilar deposits, or by any other ordinary means. I have seen thousands of examples of the truth of the rule, and not one exception to it, among rocks of the age I am considering. Sometimes all these means fail, and we may ramble for miles among mountains of slate without seeing a single trace of their original stratification.

In examining a formation of greywacké, we may find thick well-defined beds, passing into thin flaggy beds; and these, again, passing into masses, subdivided into very thin laminæ. These thin laminæ often resemble the coarser varieties of slate, and are, indeed, sometimes used for the same purposes. There may, therefore, be cases where, as far as mineral structure is concerned, *slatestones* of cleavage, and *flagstones*, which are thin beds, cannot be separated from each other. These cases are, however, very rare exceptions. A *flagstone* is generally distinguished from a true slate, by slight deviations in its plane; occasionally by what is called the ripple mark; by a dull granular surface; by scattered flakes of mica, entirely unlike the continuous chloritic flakes of a true cleavage; and sometimes by organic remains studded on its surface. By such indications as these, and by the undefinable power acquired by habit, a Welsh quarry-man, accustomed to work in the upper division of the schistose groups, seldom fails to separate the laminæ of deposition from true slates; and in the same quarry he will point out the distinction between the planes of stratification and the planes of cleavage*.

I think it obvious that the contortions of slate rocks are phænomena quite distinct from cleavage, and that the curves presented by such formations are the true lines of disturbed strata. In many cases a cleavage seems to have been the last change superinduced on rocks before they became entirely

* In many parts of Cumberland and Caernarvonshire, where the porphyries interfere with the slates, and where the slaty structure is so completely developed as almost to obliterate the traces of stratification, these distinctions are entirely unknown among quarry-men.

solid; and after that time it is not conceivable that any mere mechanical force, however violent, should have thrown them into such contortions as we often see passing through them. Again, the contorted laminæ, so often seen in formations of argillaceous schist, seem to be removed from all analogy with known modes of crystalline action; whereas the great parallel plates of slaty cleavage (however enormous may be their scale,) are quite compatible with it.

After these remarks, I proceed to notice a few actual sections, and to point out the conclusions we may draw from them.

Plate XLVII. fig. 2.

This section ranges in a direction north-west by west, and south-east by east, through Mr. Penant's great slate quarry on the road to Bangor.

1. Slate rock.
2. Coarse greywacké sandstone.
3. Anticlinal line in slate rock.
4. { Coarse greywacké. In its prolongation it crosses the top of Moel Faban. Sandstone. }
5. Great bed of roofing-slate.
6. Coarse greywacké, prolonged through Fron Llwyd.
7. Bastard slate.
8. Very coarse greywacké, forming the crest of Lider Fawr. The dip of the strata east of the anticlinal line is south-east by east, at about 45°. Enormous excavations have been made in No. 5, but they very seldom show any traces of the true beds. A few stripes are, however, to be seen, just at the top of the great quarry; and these stripes dip exactly with the beds. The cleavage dips south-east by east, at about 80°, and is therefore inclined about 35° to the planes of stratification. This is a very good example for study, as the true position of the beds, when viewed on a great scale, is very obvious.

Plate XLVII. fig. 3.

This section is from a small slate quarry near Harlech.

At the top is a series of hard quartzose sandy beds (*a*), without cleavage, and dipping east by north, at 50°. Below is roofing-slate (*b*), which gives no indication of the true bedding; but the cleavage planes dip about north-east, at 60°.

Plate XLVII. figs. 4, and 4 *a*.

We have here represented two portions of a series of finely contorted strata of hard greenish slate, from the rugged mountains on the left bank of the

Towey, a little below Fanog. Many of the beds are very quartzose, and are obviously of sedimentary origin. The more schistose portions have their beds defined by stripes upon the cleavage planes, and the whole contorted stratification is perfectly obvious. Throughout these sections, which together extend nearly a mile in length, as well as through all the neighbouring chain, the cleavage planes preserve an almost geometrical parallelism, and dip to a point about north-west by north.

Plate XLVII. fig. 5.

This represents the position of the beds, and cleavage planes, in a small escarpment on the north side of the new turnpike, on the banks of Wye, a few miles above Rhaiadr. Near the centre is an anticlinal line, and hard quartzose beds are cracked and shattered at the point of flexure, in such a way as to show that they were partly solidified when the flexure took place. On the surface of some of these hard beds are casts of organic remains. The upper beds on both sides are crystalline and chloritic, and have a slaty cleavage, which preserves a perfect parallelism, and dips nearly north-west. But these planes of cleavage affect also the more solid beds below. Though of coarse mechanical texture, their component parts have been so completely re-arranged, that they will only break in the direction of the slaty cleavage. The length of this section is not a hundred feet, but it is extremely instructive.

Plate XLVII. fig. 6.

This figure represents the arched beds seen in the great slate quarry called Craig y Gribbin, on the road from Llangollen to Ruthin, near the top of the pass. The lower beds are coarse, and have no distinct cleavage. Among the upper beds, those on the left hand of the section have their cleavage planes dipping north-north-east: those on the right hand have a cleavage dipping south-south-west: near the centre the cleavage is nearly perpendicular. This example shows that the dip of the cleavage is sometimes effected by the dip of the beds; I believe, however, that, even in this instance, the cleavages were superinduced after the beds were thrown into the arched position seen in the section.

Plate XLVII. fig. 7.

This section represents a small portion of a calcareous slate rock, with subordinate beds of impure limestone, containing many corals, shells, and trilobites. It is seen in a gorge on the west side of Foel Fawr, about two miles from Llanrhaiadr in North Wales. The beds dip south-east, about 25°, but the cleavage planes dip nearly north-west, at an angle of about 48°. The slaty cleavage affects the limestone beds, which only break freely in that direction. The half-jointed and half-fissile structure of the limestone beds is therefore due to the same cause which produced the true fissile structure in the beds above and below.

Plate XLVII. fig. 8.

We have here the profile of a ridge below Maes Maillyon lime quarry, a few miles south-east of Bala. In a succession of low knolls nothing is at first seen but the cleavage planes dipping west-north-west. The slates are, however, striped; and the stripes dip east-south-east, as represented by the dotted lines. Were there any doubt about the true dip, it is set at rest by the beds of limestone and calcareous schist, full of organic remains, on the left side of the section, which are parallel to the dotted lines; yet the cleavage passes through them, and affects the fracture of thick masses of crystalline limestone.

The preceding sections are sufficient for my present purpose, and they are given, not as exceptions to, but as examples of, the general structure of the regions from which they are taken. A rugged country, more than thirty miles in length, and eight or ten miles in breadth, stretching from the gorge of the Wye, above Rhaiadr, to the upper gorges of the Elan and the Towy, and to the hills west of Llandovery, exhibits, on a magnificent scale, thousands of examples like figg. 4. and 4 *a*. The whole region is made up of contorted strata; and of the true bedding there is not the shadow of a doubt. Many parts are of a coarse mechanical structure; but subordinate to them are fine, crystalline, chloritic slates. But the coarser beds and the finer, the twisted and the straight, have all been subjected to one change. Crystalline forces have re-arranged whole mountain masses of them, producing a beautiful crystalline cleavage, passing alike through all the strata. And again, through all this region, whatever be the contortions of the rocks, the planes of cleavage pass on, generally without deviation, running in parallel lines from one end to the other, and inclining, at a great angle, to a point only a few degrees west of magnetic north. Without considering the crystalline flakes along the planes of cleavage, which prove that crystalline action has modified the whole mass, we may affirm that no retreat of parts, no contraction of dimensions in passing to a solid state, can explain such phænomena as these. They appear to me only resolvable on the supposition, that crystalline or polar forces acted on the whole mass simultaneously, in given directions, and with adequate power. It is not, however, necessary to suppose that these effects were produced in a short lapse of time. In speculating on the time required for the completion of these phænomena, we are free from any unnecessary limitations.

There is, however, at first sight, a difficulty in comprehending the vastness of those forces which nature must have applied in producing effects like those above described. But difficulties of this kind ought to be little thought of, if we can resolve them into any known mode of material action. Now, in a case of crystallization there is something like a definite polarity in each particle, by which it is compelled to turn in a given direction, and group itself with other particles in definite forms. And if this modification of internal structure be carried on through a very large mass of matter, is it not probable that there is an accumulated intensity of crystalline action in each part; so that the whole intensity of crystalline force modifying the mass, is not equal to the sum of the forces necessary to crystallize each part independently; but is some function of that sum, whereby it may be increased almost indefinitely? I see nothing improbable in this kind of accumulated attraction, and it will explain many geological phænomena. Limestone formations, for obvious reasons, are very often crystalline; but in England they are so much subdivided by beds of shale and sandstone, that each part has been left to its own forces of aggregation, and the strata are seldom obliterated. In the Alps, on the contrary, the calcareous zones are generally of enormous thickness, and comparatively uninterrupted by foreign matter; and the structure of each portion is so modified by the general crystalline structure of the mass, that the traces of original stratification and sedimentary origin are very often entirely destroyed.

In the most striking cases of slaty cleavage, since the effects produced through spaces of great extent are nearly uniform, the crystalline forces must have been nearly uniform, at least as to certain directions, which may be regarded as a species of *resultants* from an indefinite number of local attractions. This seems to imply a certain degree of homogeneity in the masses acted on; and as a matter of fact, where the slaty cleavage is very perfectly brought out, the structure of the rocks always makes an approach to homogeneity. Where the quartzose beds of coarse greywacké abound very much, the cleavage is seldom very perfect, or is at least chiefly confined to particular strata. And where the coarse beds predominate (as, for example, in some parts of the western chain of Merionethshire, and in the east end of the Lammermuir chain of Scotland), the slaty structure almost entirely disappears.

All the foregoing remarks in this division of the paper relate to slate rocks, subordinate to formations, parts of which are obviously sedimentary and mechanical, and contain organic remains. But in the centre of Skiddaw Forest, in some parts of Cornwall, in Anglesea, and in the south-western coast of Caernarvonshire (as stated in a preceding note, p. 471), and also in a great portion of the Highland regions of Scotland, we have finely foliated and highly crystalline schists (such as chlorite schist, mica schist, &c.) which contain no organic remains, and (in some instances, at least,) are older than the slaty groups above described. In some of these older groups the cleavage and laminations of mica and chlorite are transverse to the bedding. This is, I believe, the case in some parts of Skiddaw Forest, and it is certainly the case in some parts of Anglesea, as is proved in the beautiful section of Holyhead Mount, published by Professor Henslow, in the Transactions of the Cambridge Philosophical Society*. In general, however, the foliated uneven layers of these older formations belong, I believe, to beds, and not to cleavage planes; and the oldest and most crystalline rocks, designated by the general name of schists, have no true slaty cleavage, in the sense in which I have used the term.

A mechanical rock may appear highly crystalline, because it is composed of crystalline parts, derived from some preexisting crystalline rock. Thus, we have in Scotland masses of sandstone so beautifully recomposed from granite, that it is not always possible to distinguish them from the parent rock†. In the same way, the highly crystalline texture of mica schist *may*, in some cases, originate in causes purely mechanical. I believe, however, that the structure of these old crystalline schists has been greatly changed since their deposition; but the same thing may be asserted of all slate rocks whatsoever, and I do not see why the term "metamorphic" should be applied exclusively to one class of them.

Again, if we apply the term "metamorphic" to the old crystalline schists, and at the same time assume that the changed structure has originated in igneous action, we generalize, I think, a great deal too fast. Such structures sometimes may, and sometimes may not, have been caused by igneous action; and it appears to me rash to limit the great modifying powers of crystalline forces to particular ranges of temperature. At all events, the great parallel cleavage planes, and some other changes, above described, appear to me entirely unlike the altered structures produced by igneous rocks on the masses which are near them. But I do not presume to decide either on the exact temperature, or on the time, necessary to the perfect development of cleavage planes.

Before I conclude this section I cannot help recommending, not a new

* Vol. i. Plate XV.

† Geological Transactions, New Series, vol. iii. p. 140.

nomenclature, but a more systematic use of old terms than we are accustomed to. *Bed* is always applied as the English synonym of *stratum*, and the terms *thick-bedded, thin-bedded, thick-flaggy, thin-flaggy,* and *laminated,* are words in common use, and express, well enough, different modifications of stratified structure. The term *foliated,* again, expresses very well the peculiar structure of mica schist, and the fine glossy undulating layers of greywacké. But it would be well to describe no structure as *slaty* or *fissile* except cases of transverse cleavage, using the term *slate* for a perfect oblique cleavage, and some such term as *flagstone-slate* for imperfect cleavage; and, in like manner, *slaty flagstone* may describe a very thin or laminated structure, parallel to the stratification. In this way, *foliated* as distinct from *laminated,* and *slaty* as distinct from *flaggy,* become terms of a definite meaning.

When a branch of natural history has been placed on a settled basis, it is well to use such classical terms and definitions as may be current throughout the scientific world. But while a science is in progress, and its principles unfixed, the affectation of regular definitions and technical terms of classical etymology may do more harm than good, especially if they be derived from an hypothesis. Were such words as *pyroxene* and *protogine* mere jargon without meaning, we might then retain them as proper names, which, however barbarous, cannot be conveniently parted with. But they have a meaning which proves them to be the offspring of ignorance and error, and on that account they ought to be expelled without mercy from our pages. The pedantry and the gross absurdity of many terms in mineralogy are obvious to every one; and I hope we shall take a lesson from the progress of that kindred science, and not be too hasty in seeking the useless decorations of a too classical nomenclature. Indeed, there already appear in our descriptions some words of doubtful and portentous etymology, with Grecian heads and Gallican tails, which figure but oddly amidst the ordinary staple of our homely pages.

§ 4. *Jointed Structure.*

Many rocks, both stratified and unstratified, are divided into solids of greater or less regularity, by parallel systems of fissures or joints. This gives rise to a jointed structure, and is quite distinct from slaty cleavage. For the joints are at definite distances from each other, and a mass of the rock between them has, generally speaking, no tendency to cleave in a direction parallel to them. The structure in question seems in most cases to have been produced mechanically, either by a strain upon the rock from external force, producing, more or less, regular sets of cracks and fissures, or by a mechanical tension on the mass (produced probably by contraction) during its passage from a fluid or semi-fluid, into a solid state. Cleavage planes are, on the contrary, the results of the ultimate chemical arrangement of the particles of a rock, and appear in most cases to be unconnected with any direct mechanical action.

A slaty and jointed structure are, however, often exhibited together; and cases may arise where it is almost impossible to decide whether a certain set of fissures are to be called joints or cleavage planes. For example, a true slate rock may have been acted on by mechanical forces, producing a set of fissures parallel to the cleavage. In such a case the rock has mechanical fissures and true crystalline cleavage planes coincident with each other. Again, when a cleavage is imperfect, it is sometimes only exhibited by parallel planes at definite distances, in which case it may be difficult to say whether the phænomena are to be classed with joints or cleavages.

Difficulties of this kind are the exception, and not the rule; and they destroy not the reality of the distinctions I am attempting to draw: they only prove how impossible it is for us to constrain the vast and complicated operations of nature by the fetters of a rigid definition. It is the business of a geologist to consider both the resemblances and the differences of the things he describes; and after a broad view of nature's kingdoms, he learns to seize upon those resemblances which are essential to his classification, and to cast from his thoughts those differences which are unessential. In this way he calls by a common name things with a hundred points of difference, and puts in distinct classes, things with a hundred points of resemblance. But on this account his advance is neither unphilosophical nor insecure. He that dwells only on resemblances may be hurried into rash generalizations, which, however, experience will tend to correct: but he who continues to dwell only on the difficulties of geology, and to haggle on mere exceptions and points of difference, should he attempt to advance at all, must stumble at every step.

The jointed structure is best seen in unstratified rocks, such as basalt and certain varieties of granite. The regularly jointed pillars of basalt, and the rectangular prisms composing some parts of the Cornish granite, are good examples of it. When the prisms are very symmetrical, and subdivided by a series of parallel cross joints, the whole configuration is supposed by many to have been produced by the interference of distinct spheroidal corrections. This is a beautiful theory, founded on direct experiment, and quite capable of explaining some cases of prismatic jointed structure; but it has, I think, been pushed too far. If it be true as applied to the granite Tors of Cornwall, we ought, in examining the cuboidal blocks of which they are composed, to see some traces of spheroidal structure in the arrangement of the component crystalline parts; but we look in vain for any such arrangement. The spheroidal blocks into which the Tors decompose, and the concentric crusts which exfoliate on their continued disintegration, are the chief facts in favour of the theory; but they may be explained as well without it. For any homogeneous cuboidal mass of rock will naturally decompose into a spherical form; and the exfoliation of concentric crusts is no proof of globular concretionary structure; because ancient pillars of granite have been known to exfoliate in cylindrical crusts, parallel to the axes of the pillars; and even pillars of oolitic limestone, which unquestionably have no spheroidal structure, sometimes exfoliate (*e. g.* in the second court of Trinity College Cambridge) in crusts parallel to the axes of the several pillars. To what, then, do we refer the prismatic jointed structure of various granitic rocks? We reply, chiefly to a tension on the mass when it passed from a fluid to a solid state; combined sometimes with those great crystalline actions which in argillaceous rocks have produced a true slaty cleavage. This opinion is, I think, fortified by an examination of the prismatic sandstone obtained from linings of old furnaces. These sandstones have been intensely heated, and sometimes partially fused, and their prismatic structure, transverse to the wall of the furnace, is clearly superinduced by the action of heat. They have undergone alterations of dilatation and contraction, which may have produced their several joints; but we do not discover in them the least germ of any globular arrangement.

In the cases just considered, there is a clear distinction between a jointed and slaty structure. Still, even in formations of true granite, we occasionally see imperfect indications of a cleavage, which may sometimes have modified the direction of one set of joints. This kind of cleavage is called the grain of the rock, and is designated in many parts of the North of England by the word "bate", where we are constantly told by quarry-men that no rock is without its "bate". Now the grain has, I believe, in most cases, been produced during the passage of the whole granitic mass into a solid state, by that kind of compound crystalline force which has produced the transverse laminations of argillaceous schist.

Every one has heard of the great vertical, parallel layers composing the central mass of Mont Blanc, and of the conclusions Saussure drew from this structure. On a small scale we have a somewhat similar arrangement of parts in the granitic rocks of St. Austell Moor, which from one end to the other are made up of alternating, parallel masses of granite and schorl rock. In some places the rock is granite, striped by veins of schorl or schorl rock; in other places we have schorl rock, striped by veins of granite; and here and there one rock prevails, to the exclusion of the other. The range of these layers is nearly magnetic east and west, and they are never inclined to the horizon at less than 70° or 80°. On the south side of this moor they generally underlie to the south; but in other places they are very nearly perpendicular, and at Bunney "open-work" they underlie north. The parallel stripes of schorl rock often part in the middle, along very narrow joints traced by oxide of tin. Tin is also disseminated in regular crystals, both in the granite and schorl rock, where we have no appearance of any regular vein distinguished from the rest of the formation. In short, the whole rock has a laminated or veined structure, produced by a peculiar segregation of parts, in passing from a state of fusion into a solid state: and the parallel laminations must have been produced by a crystalline action, very similar, at least, to that which has so completely modified the ultimate structure of our slate rocks*.

The *grain* of certain masses of granite, where we have no external appearance of laminations, *may*, perhaps, have been produced by a similar crystalline action. I have stated above, that the *strike* of the cleavage of large masses of slate, nearly coincided with the *strike* of the beds. A mass of granite has (properly speaking) no *strike*; but it is often protruded upon a given line of direction. If, then, the *grain* of granite rocks be produced by a modification of crystalline action, similar to that which produced slaty cleavage, have we not some reason to expect that the *grain* of such rocks may be traced nearly along their lines of protrusion? I throw this out as a mere conjecture, suggested by an analogy, and by the fact, that the veined structure of the St. Austell granite is nearly parallel to the direction of the Cornish chain.

The *grain* of a rock must evidently have considerable influence in modifying the direction of fissures subsequently produced by mechanical force. Hence the direction of the veins of fissure *may* in some cases be considerably affected by the previous direction of the veins of segregation. It would be well, in a place like Cornwall, to institute a set of direct observations, for the purpose of comparing the *grain* of the granite with the direction of the nearest metalliferous veins.

As so many rocks are intersected by cross joints, nearly perpendicular to their *strike*, we might expect, *à priori*, to find many great "master joints," nearly at right angles to the direction of the granitic ridge of Cornwall. At all events, whether such reasoning be good or bad, there are many great

* Such rocks as those above described must be carefully distinguished from true gneiss; for the parallel, vertical layers are as distinct from true strata as cleavage planes are from beds of slate. A great part of the gneiss of Scotland is undoubtedly stratified; but on the shores of the Pentland Firth there are rocks, commonly described as gneiss, which, if I mistake not, are mere varieties of veined granite, and are formed in the same manner as the granites of St. Austell Moor.

"master joints" or "cross courses" in that country, nearly at right angles to the bearing of the central chain.

I have assumed above, that the veined structure of the St. Austell granite was produced by segregation; but it deserves remark that the several crystals composing each part are by no means universally parallel to the great parallel system of joints, though, on the whole, they rather affect that direction. Mr. De la Beche has well pointed out, that tabular crystals of felspar will sometimes traverse such joints of granite*, so that a part of the same crystal will be on one side of a joint, and a part on the other. He also describes an appearance on the north side of Dartmoor, of which there is a very perfect example in the great open-work of Carglaze, near St. Austell. The alternations of schorl rock and granite above described become more frequent as we approach the junction of the slate, and at last are so frequent and fine-grained, that the rock, on the south side of the open-work, becomes finely laminated, and passes into a true schist. This I noticed many years since, in a paper published in the Cambridge Transactions†. What ought we to infer from a phænomenon like this? That the slate rock in contact with the granite had at one time been nearly in the same condition as the granite; and that both had been modified by a similar crystalline action in passing into a solid state. Now all phænomena of this kind accord perfectly with the igneous theory of granite, and its protrusion among the stratified slates: yet have they been urged as proofs that the slate rocks of Cornwall (including in the list the fossiliferous slates of Tintagel, the coarse greywacké of the south-eastern coast, the shales, the limestones, the beds of greenstone and felspar, &c. &c.) are all contemporaneous with the central granite.

Metalliferous veins and *cross courses, master joints* and fissures, and other similar interruptions to the continuity of great mineral masses, appear in most instances to have originated in mechanical action. The observations applied to certain formations of granite may, however, be applied to rocks of every age. They may, from their mode of aggregation, or *grain,* have a tendency to break in one direction rather than another; and hence one set of joints, though produced by mere rude mechanical action, may still have their directions defined by an internal structure resulting from an entirely independent cause. Thus, in many large formations of semi-crystalline limestone (such, for example, as the great *scar limestone* of Yorkshire, or the limestone of the High Peak of Derbyshire), there may probably be a *grain* bearing a given relation to the direction of the whole mass. If such be the case, the direction of one set of

* Researches in Theoretical Geology, p. 104.

† Vol. i. p. 108.

joints may have a given relation to the meridian of the place; and at the same time, such a given direction may be a mere secondary phænomenon, resulting from the original direction of the mountain chain.

After the experiments of Mr. Fox, it becomes, however, a question of some importance, whether the structure of large mineral masses may not have been affected by the direction of great electrical currents at the period of solidification: and if this be the case, may we not look for certain joints and cleavages, preserving a parallelism through independent chains, and having no fixed relation to the position of the masses they traverse? Such a question requires for its solution a series of observations on different mountain chains, of which the directions are strongly contrasted. As far as my own experience is concerned, I should answer it in the negative, as I believe that all joints and cleavages originating in the structure of a rock are greatly modified by its direction.

In limestone rocks we sometimes see two sets of joints, inclined to each other at angles very nearly equal to those of the primary rhomb of carbonate of lime. Mr. Conybeare has pointed out to me some joints of this kind in the lias. I have seen many examples of them in the mountain limestone of the North of England; and the late Dr. E. D. Clarke brought beautiful primary rhombs of compact limestone from the mountains of Greece. It becomes, then, a question, whether joints like these are mere local phænomena, or affect large masses of strata; and the inquiry ought to be kept in sight by those who compare, on a large scale, the joints of calcareous mountains. At all events, in examining the jointed structure of rocks, not only the directions of the joints ought to be recorded from the compass, but the direction of the mineral masses must also be recorded, otherwise the facts may lead us into entirely false generalizations.

Lastly: there may be in rocks, both stratified and unstratified, distinct sets of parallel joints or fissures, extending through considerable tracts of country, yet of mere mechanical origin, and unconnected with any peculiarity of internal structure. The subject has been lately discussed before the Cambridge Philosophical Society, by Mr. Hopkins; and he has shown, on mathematical principles, that tabular masses of rock elevated by a force from below, must have been exposed to two sets of tensions, which would naturally produce longitudinal and transverse vertical fractures, at right angles to each other. Having solved the problem as a mere abstract question of mechanics, he then showed that the direction of the metalliferous veins, and of certain longitudinal faults in Derbyshire, coincided with the deductions of theory more nearly than might have been expected. I may add, that an examination of

Flintshire during last summer, and of the documents kindly put in my hands by Mr. Taylor, showed, in that county, a still more perfect symmetry and agreement with the mechanical theory. The great parallel *cross courses* range north and south, in the direction of the beds; and the metalliferous veins strike across the calcareous beds, almost mathematically at right angles to the *cross courses*. Whatever may be the true theory of metalliferous veins in some countries, there cannot be a doubt that the great joints and fissures of Flintshire and Derbyshire are of a mechanical origin.

I now terminate what I have to lay before the Society on the changes produced during successive periods in the structure of rocks; and so far from thinking that I have exhausted the subject, I rather wish some parts of this paper to be regarded as mere hints, to be followed out by better and more extended observations.

XXVI.—*Notices and Extracts from the Minute-Book of the Geological Society.*

1.—*Extract from a Letter from* George Gordon, Esq., *addressed to* Roderick Impey Murchison, Esq., P.G.S., *noticing the existence of Blue Clay on the southern side of the Murray Firth.* [Read April 11th, 1832.]

MR. GORDON, after referring to the memoir of Professor Sedgwick and Mr. Murchison on the North of Scotland, in which lias is shown to occur on the northern side of the Murray Firth, points out the existence at Linksfield or Cutley-hill near Elgin, of a stratum of clay inclosing thin bands of limestone, and occupying a position analogous to that of the lias on the northern side of the Firth. Mr. Gordon likewise states, that in making the canal to drain Loch Spynie, a bed of clay was penetrated, containing numerous specimens of Belemnites; and he conceives that a great part of the bay of Lossiemouth belongs to that formation.

2.—*On the Basalt of the Titterstone Clee Hill, Shropshire. By* J. Robinson Wright, Esq., F.G.S. [Read May 30th, 1832.]

THE basalt constitutes the two summits of the hill, one of which is occupied by an ancient British encampment, the western or highest part of it being called the "Giant's Chair," and the other summit is known by the name of the Hoar Edge. The basalt rests partly on old red sandstone, and partly on coal measures, and assumes at the "Giant's Chair," as well as along the western escarpment of the Hoar Edge, a columnar structure, the prisms inclining at an angle of 75°.

The thickness of the basalt under the encampment has not been ascertained, and the author doubts if there be coal beneath it. At the northern or "Far Pit" of the Cornbrook coal-works the basalt is forty yards thick, and a little to the south of it sixty yards. To the west of these pits the coal is entirely "cut out" by an extensive basaltic dyke, ranging apparently in a north-east and south-west direction, or nearly parallel with the Hoar Edge; and the coal is also cut out by it a short distance to the north-west of the Treen pits. In contact with the dyke the coal is injured and said to be sooty. The author suggests that this basalt which the Cornbrook colliers have met with at several points, may be the south-western side of a vast dyke, probably more than 100 yards in thickness; and that the escarpment of the Hoar Edge may be the north-western side. At the "machine," near the village of Cornbrook, the coal is said to have been forced up to the surface, the basalt being found beneath it.

In conclusion, the author points out the resemblance between the basalt of the Titterstone Clee Hills and that of Rowley Regis in Staffordshire. He says, that they agree in assuming a columnar structure, and in the inclination of the prisms; as well as in the hills at both localities being flat-topped, and having their steepest escarpments towards the west.

3.—*On a large Boulder-stone on the Shore of Appin, Argyleshire. By* James Maxwell, Esq.; *and communicated by* William Smith, Esq., F.G.S. [Read May 30th, 1832.]

This boulder-stone consists of a granitic compound of quartz, felspar, and mica, the last mineral being the principal ingredient. Its form is irregular, but the angles have been rounded. The greatest vertical circumference is forty-two feet, and the greatest horizontal, thirty-eight feet. It is supported on three stones, each about six inches thick; one of them being a granite, of a paler colour than that of which the boulder consists, and the other two being composed of argillaceous ironstone; while the formation on which they rest is a slaty calcareous sandstone. Numerous other granitic boulders occur in this part of Scotland, but there is no rock *in situ* from which they could have been derived.

4.—*On the occurrence of Bones in a Coal-mine near Gratz in Styria. By* Professor Anker, *of the Joanneum in Gratz: communicated by* Roderick Impey Murchison, Esq., F.G.S. [Read February 27th, 1833.]

The bones referred to by the author were found in a range of hills, extending in a southerly direction from the foot of the Schwamberg mountains to Scheineck on the Weiss. The hills consist of molasse, alternating with beds of brown coal from 2 to $2\frac{1}{2}$ feet in thickness, and distinguishable from black coal only by geological position, and the occasional occurrence of woody texture. Associated with the coal are beds of bituminous shale, and a grey, bituminous, marly, slaty sandstone, in which are occasionally interspersed pebbles of primary rocks.

The bones were found in the coal itself, forming layers about 2 inches thick. They were for the most part so much shattered that the genus of the animal could not be determined, but from their great number they appear to have been derived from many animals. After long-continued search a jaw-bone with teeth was discovered, and from the inspection of a drawing of it sent with the paper, Mr. Clift considers that it belonged to a hyæna. This specimen is preserved at the Joanneum.

Bones were first found in this mine in the year 1826, in the Joseph adit, fifty fathoms from its mouth. They have been often met with since, in the same adit; and in 1831 bones were also discovered in the Caroline adit of the same mine. Among them was a tooth like that of a shark, together with fragments of bones similar to those from the Joseph adit; but they were principally found in the strata adjacent to the coal.

5.—*Notice of a Machine for regulating High Temperatures, invented by the late* Sir James Hall, Bart., F.G.S.: *drawn up by* Captain Basil Hall, R.N., F.G.S. &c. [Read May 1st, 1833.]

Sir James Hall, in his experiments on the fusion of granite and other rocks, and on the effects subsequently produced upon the fused mass by gradual cooling, conceived that the experimenter required the power of regulating the temperature in such a manner as best to imitate nature; and for this purpose he invented the machine described by Captain Basil Hall.

The principle of the machine is such, that when any change of temperature takes place in that part of the furnace in which the material under experiment is placed, a corresponding change is made in the current of air which maintains the heat.

The furnace was about 3 feet long, 18 inches wide, and 2½ feet deep. From side to side extended a muffle, one end of which was closed with a plug, furnished with a small disk of mica, through which the subject of the experiment could be viewed; and at the opposite end of the muffle was placed the machine.

This instrument consists of a spiral spring coiled in a vertical plane, and facing the muffle. The spring is formed on the principle of Harrison's balance in chronometers, of two metals joined together, but of different degrees of expansibility, so that the spring will either curl or uncurl, according as the heat is raised or depressed. The outer part of the coil is fixed, while the inner end is united to an axle, which, being free, turns round as the spiral winds or unwinds; or as the heat, radiating from the interior of the muffle, is raised or depressed.

To the further end of the axle is bitted a wheel, around the circumference of which is wound a string, carrying at its extremity a small weight, which consequently rises or falls as the spiral curls or uncurls. Under the weight is a little cup, forming one end of a lever, to the opposite end of which a metal disk is suspended, immediately over an aperture of rather smaller dimensions, and near the end of a long iron channel, through which alone air was supplied to the furnace. Directly under this aperture is another of similar size, as well as another disk united to the upper disk by a rod of metal, equal in length to the distance between the two openings. The object of having two apertures is to secure the same amount of current of air both above and below. If there were only one opening, and one disk to close it, the air rushing in would force it down and keep it closed; but by this contrivance the rush of air at the lower opening striking on the under surface of the lower disk, exactly counterbalances that from above, which strikes upon the upper surface of the superior disk. To render the points of contact perfect, and to prevent the interference of small particles of dirt, the disks, when closed, rest upon circular knife-edges.

Besides the wheel, around which the cord carrying the small weight is wound, the axle connected with the spiral is furnished with a long hand, like that of a clock, reaching to a large graduated circle in the same plane with the first wheel, but lying beyond it. This hand is capable of being attached to the wheel carrying the weight, and consequently of indicating changes of temperature with great rapidity.

To preserve uniformity of temperature, the spiral, and as much of the apparatus as possible, were inclosed in a tin case, filled with water kept constantly boiling; so that the only change to which the spiral was subjected, was the heat radiating from the muffle.

The action of the instrument is simply this. The heat of the furnace having been raised to the required pitch, a change in the radiant heat from the muffle effects a change in the action of the spiral, and the string supporting the weight is consequently either lengthened or shortened. If the change in the radiant heat be an increase, then the string is shortened, the weight is removed from the cup at one end of the lever; and the disks at the other end consequently falling, the current of air is checked, as well as the heat within the furnace. If, on the contrary, the change in the radiant heat be a diminution, then a reversed operation takes place, and the current of air being increased, the temperature of the furnace is also increased.

6.—*Extract from a Communication from* Captain Colquhoun, R.A., *addressed to* Roderick Impey Murchison, Esq., F.G.S., *descriptive of Masses of Meteoric Iron found in Mexico and Potosi.* [Read June 12th, 1833.]

The mass of iron principally noticed in this communication is in the street of San Domingo, at Zacatecas in Mexico. Its extreme length is 49 inches, greatest breadth 23 inches, least 15; greatest thickness 13 inches, least 11, and its weight is estimated to be about 2500 lbs. The whole mass appears to be compact; but the surface presents several impressions of a globular form, varying in size: one of them being 7 inches in diameter, and 3 inches deep. This mass has been noticed by Sonneschmid, *Mineralogische Beschreibung der Bergwerks Reviere von Mexico,* p. 192, 8vo, 1804, and by Humboldt, in his *Essai Politique,* vol. ii. p. 385. It is not known where it came from.

Another similar mass of iron stands in the north-west corner of the church-yard at Charcas, between Catorce and San Luis Potosi, and is also noticed by Sonneschmid (p. 288). Its height above ground is 32 inches. In appearance it closely resembles the mass at Zacatecas, and is exceedingly tough.

At Pablazon a Hacienda, to the westward of Catorce, is a third mass. Several small masses, some weighing 20lbs., have been found in the vicinity of the Rancho del Sitio, between Charcas and Pablazon, whence the mass at Charcas is said to have been brought.

7.—*On the Geology of the Banks of the Indus, the Indian Caucasus, and the Plains of Tartary to the Shores of the Caspian By* Lieut. Alexander Burnes: *communicated by* Roderick Impey Murchison, Esq., P.G.S. [Read December 18th, 1833.]

The author has endeavoured in this paper to embody the geological observations which he made on a journey during the years 1831 and 1832, up the river Indus, and across the lofty range of Hindoo Koosh, to the Caspian Sea.

He first describes the province of Cutch, situated near the eastern mouth of the Indus. He states that it is mountainous; that the soil is either rocky or sandy, with masses of lava scattered over its surface; and that sulphur, coal, iron, and alum are found in the district.

Nummulites occur in a ridge near the right banks of the Indus. The delta of the river is composed of a succession of beds of earth, clay, and sand of different colours, sometimes parallel, and sometimes having one stratum dovetailed into another. The sea is described as being discoloured to a distance of three miles by the detritus carried down by the river, with regard to which it may be stated that the base of the triangle of the delta is above 125 miles.

After mentioning a range of hills called the Hala Mountains (about 2000 feet high), which extends in a northerly direction from the sea-shore westward of the mouths of the Indus, and terminates to the north-west of Cabool in the Hindoo Caucasus, and which consists in part of compact nummulitic limestone, the author proceeds to describe the principal geological features which he observed on the banks of this great river. The town of Hydrabad, he states, is built on a finely grained shelly limestone. At Schwan, in lat. 26° 22′, and at Curachee, are hot wells; and the island of Bukhur, in lat. 27° 42′, consists entirely of flint. On the eastern bank of the river, opposite this island, is a precipice of flint, 40 feet high, on which the village of Roree is built. In lat. 28° 55′ the rivers of the Punjab fall into the Indus. Still higher up, in lat. 33°, at Kara Bagh, the river cuts through a range of hills, described by Mr. Elphinstone as the salt range. The salt is found in layers of about a foot in thickness, separated from each other by thin strata of clay. With the exception of this range of hills, which is estimated to be about 1800 feet above the level of the sea, the district of the Punjab is uniformly flat; but the hilly district is intersected by numerous defiles, presenting vertical strata, which terminate in peaked points. Between the river Sutlege and Lahore the country consists of indurated clay, sometimes gravelly.

At Attoch, much higher up, the rocks by which the Indus is confined, consist of a dark-coloured micaceous slate, which is said to extend to the southward, until it meets the salt range above mentioned. Near this place gold is washed out of the sand of the river.

At Lahore, in February 1832, the author experienced a very violent shock of an earthquake. Several valleys were choked up by the masses of rock thrown down from the overhanging precipices, and a great part of the population of Badakhshan was destroyed. In crossing the Punjab the author observed that several buildings of the Mogul Emperors were decaying from the foundations, and were encrusted with an efflorescence of nitre. Proceeding to the westward from the Indus, he found bituminous coal at Cohat, and that the salt range above mentioned extended across the country into this district. The river of Cabool flows through a very narrow defile, the rocks of which rise to a height of 2000 feet, and consist of sandstone, quartz rock, and mica schist, the strata of the latter being vertical. Cabool is situated 6600 feet above the sea*, and the source of the river Cabool 8600 feet, where

* The heights mentioned in the Memoir were determined from the boiling-point of water, 600 feet being allowed for each degree.

snow was first encountered in the valley. The neighbouring hills are covered with rounded pebbles of all sizes, sometimes loose, at others forming a conglomerate. A beautiful white marble is found near Cabool, and the rocks are occasionally covered with asbestus.

From Cabool the author crossed the Hindoo Caucasus to Balkh and the plains of Tartary. This range of mountains is the prolongation of the Himalaya to the westward of the Indus. The height of the passes Hajeeguk and Kaloo is respectively 12,400 and 13,000 feet.

Hindoo Koosh is, properly speaking, the name given to the highest peak in the range, the only part of which that is covered with perpetual snow is the Koh-i-Baba, estimated to be 18,000 feet above the sea, between Cabool and Bameean, from which latter place the waters flow northward into the Oxus. In some of the defiles through which the author passed, the sides rose to a height of 2000 or 3000 feet. The loftiest peak which he observed between Cabool and Hajeeguk consisted of gneiss or granite, sometimes deeply impregnated with iron. These formations were succeeded by blue slates and quartz rock, and precipices of micaceous schist. From the summits of the precipices masses of green granite and other rocks had been hurled into the valley below. Further down is a calcareous conglomerate, succeeded by cliffs of reddish and purple coloured clay, and by ridges of indurated clay mixed with bands of a harder nature. In this ridge great idols have been carved, and caves excavated, for it is easily worked. The neighbourhood of Bameean is described as producing gold, lead, copper, tin, antimony, sulphur, and iron.

The lower passes of Hindoo Koosh consist principally of a light brown splintery limestone, of great hardness, and susceptible of a high polish. This formation is followed by sandstone rocks, in one of which round flint-stones are imbedded at regular intervals. The real peak of Hindoo Koosh lies about a degree to the eastward of this route, and the difficulty of crossing it is very great.

From Khooloom, whence the author descended to Balkh (2000 feet), in the plains of Toorkistan, the country slopes gradually towards the Caspian. It is generally flat, and is watered by the Oxus.

The author then describes the course of the Oxus, from its source in the high plain of Pameer until it is lost in the sea of Aral, after passing through a low and swampy district. He does not believe that the Oxus ever terminated in the Caspian Sea, and concludes that what are called the dry river beds between Astrabad and Khina are the remains of ancient canals. The natives pretend that the waters of the Aral pass by a subterranean communication into the Caspian Sea, and that at a place called Kara-goombuz, between the two seas, the water may be heard gushing beneath. It is, however, remarkable, that in the sandy ridge near this place, water is found near the surface, although further south it cannot be had within a hundred fathoms. The author then fully describes the navigation, course, rise and fall, and inundations of the Oxus; and he mentions that it is frequently frozen over.

The author then notices the effects of the great earthquake of 1832 in the valley of Badakhshan. The roads in this valley were blocked up for several days by the falling of stones and cliffs, and this place seems to have been the centre of the convulsion. Badakhshan is famous for its rubies, which are found imbedded in limestone.

The country which extends from the north of the Oxus towards Bokhara (1200 feet above the sea), is next described. It consists of a succession of low ridges of soft, yellowish limestone, sometimes oolitic, with a superficial coating of loose gravel, alternating with plains of hard clay. Sand-hills of greater or less extent, raised by the winds, also occur in several places on this plain, and in some of the valleys are saline rivulets and deposits of salt.

The author offers some remarks upon the inhabitants, and on the meteorological phænomena which he observed in the neighbourhood of Bokhara; and concludes his memoir with a description of the sandy desert of the Turcomans, between the Oxus and the Caspian Sea.

8.—*An attempt to bring under general Geological Laws the relative position of Metalliferous Deposits with regard to the Rock Formations of which the Crust of the Earth is formed. By* M. Albert Louis Necker, For. Mem. G. S.

The author commences by remarking, that the rules framed by ancient writers for recognising metalliferous districts by the external configuration of the soil were very fallacious; and that the laws which guide the miner in discovering new metalliferous veins in one country, will often not assist him in another. He next observes that, as far as he is aware, Werner and his disciples abandoned the idea of establishing a connexion between formations and metalliferous deposits; and that Hutton considered the connexion of veins and the rocks through which they pass to be purely fortuitous. He then states that he believes Dr. Boué[1] was the first to point out, in a general manner, the

[1] *Mémoire Géologique sur l'Allemagne; Journal de Physique,* Mai 1822, tome xciv. p. 297; *Geognostisches Gemälde von Deutschland,* p. 139—146, Frankfurt, 1829.

relation of metalliferous veins to primary, unstratified formations; and thus to lead to the inference, that the metals were deposited in the former by sublimation from the latter: and he adds, that Baron Humboldt[1] accounts for the association of the mines of the Oural and Altai mountains with granite, porphyry, and syenite, by supposing all of them to be the effect of volcanic agency, taken in its most extended signification.

The doctrine of the sublimation of the metalliferous contents of veins from igneous matter, occurred to the author twelve years ago, from observing the deposition of specular iron on the cooled, lateral edges of a stream of lava flowing down the side of Vesuvius; and he was induced from that circumstance to institute a series of inquiries, in further prosecution of which, he proposes, in the memoir, the following questions:

1st. Is there near each of the known metalliferous deposits any unstratified rock?

2ndly. If none is to be found in the immediate vicinity of such deposits, is there no evidence, derived from the geological constitution of the district, which would lead to the belief that an unstratified rock may extend under the metalliferous district, and at no great distance from the surface of the country?

3rdly. Do metalliferous deposits exist entirely disconnected from unstratified rocks?

With respect to the first of these questions, the author shows, by copious references to works on England[2], Scotland[3], Ireland[4], Norway[5], France[6],

[1] *Essai de Géologie et de Climatologie Asiatique.*

[2] Berger, on the Physical Structure of Devonshire and Cornwall, Geol. Trans., First Series, vol. i. p. 93, 1811. Richard Thomas, Topographical Map and Sections of the country between Redruth and Camborne, 1819. Conybeare and Phillips, Outlines of the Geology of England and Wales, 1822; Ibid., for Cornwall, Map and Sections; and for Derbyshire, p. 448; Greenough's Geological Map, for Northumberland. Henslow, Geological Description of Anglesea, Trans. Camb. Phil. Soc., vol. i. 1822. Berger, Mineralogical Account of the Isle of Man, Geol. Trans., First Series, vol. ii. pp. 8 & 22, 1814. Macculloch, Description of the Western Islands of Scotland, &c., vol. ii. pp. 530 & 574, 1819.

[3] Edinburgh Review, No. 103, p. 54. Boué, *Essai Géol. sur l'Ecosse*, pp. 27, 162, &c. Macculloch, Geol. Trans., Second Series, vol. i. p. 65, and Description of the Western Isles of Scotland, vol. i. p. 68.

[4] Boué, *Essai Géol. sur l'Ecosse*, p. 374—376. Weaver, Geol. Trans., First Series, vol. v. p. 135, *et seq.*

[5] Von Buch, *Voyage en Norvège* (French translation), tome i. p. 112.

[6] De Bonnard, *Géologie de quelques parties de la Bourgogne*, *Annales des Mines*, 1ère Série, tome x. p. 193, *et seq.* Charbaut, *Mémoires sur la Jura*, *Annales des Mines*, 1ère Série, tome iv. p. 579, et tome xiii. p. 177. Cordier, *Annales des Mines*, 1ère Série, tome iv. p. 16. Lucas, *Tableau Méthodique des Mineraux*, Partie II. p. 480. Thierria, *Notice Géologique sur les Environs*

Germany[1], Hungary[2], the southern Alps[3], Russia[4], and the northern shore of the Black Sea[5], that the great mining districts of all these countries are immediately connected with unstratified rocks: and in further support of this solution of the first question, he mentions the metalliferous porphyries of Mexico[6], and the auriferous granite of the Orinoco[7]; but he observes that his knowledge of the mining countries of South America is not sufficient to enable him to state their general geological connexions.

With reference to the second question,—the probable association of metallic veins with unstratified rocks, though the latter are not visible in the immediate neighbourhood of the former,—the author gives a section of the country between Valorsine and Servoz[8], and points out the probable extension of the granite of Valorsine under the Aiguelles Rouges and Breven, composed of protogine, chlorite, and talcose schists, to the immediate vicinity of the mines of Servoz, which are situated in the latter formation. He also refers the reader for further illustration to the metallic deposits of Wanlock-

de Saulnot, Annales des Mines, 1ère Série, tome xi. p. 393. *Annales des Sciences Naturelles,* tome xvi. p. 285. Le Coq et Bouillet, *Vues et Coupes des Formations de l'Auvergne,* pp. 72, 77. *Annales des Mines,* 2ième Série, tome vii., 1830. De Bonnard, *Sur une Formation Métallifère du Départ. de la Charente, Annales des Mines,* 1ère Série, tome viii. p. 491.

1 Héron de Villefose, *Atlas de la Richesse Minerale,* Planches II. et III. Boué, *Mémoire sur l'Allemagne, Journal de Physique,* Mai 1822, tome xciv. p. 297, *et seq.*; *Geognostisches Gemälde von Deutschland,* pp. 120, 125, 140, 143. Von Buch, *Briefe über Südlichen Tyrol,* pp. 172, 188, and Atlas. Sedgwick and Murchison on the Austrian Alps, Geol. Trans., Second Series, vol. iii. p. 301.

2 Beudant, *Voyage Minéralogique et Géologique en Hongrie,* 1822. Elie de Beaumont, *Coup d'œil sur les Mines,* p. 69, *et Dictionnaire des Sciences Naturelles,* tome xxxi. p. 376, *et seq.*, Art. Mines. Boué, *Geognostisches Gemälde von Deutschland,* pp. 117, 118, et Planche VII.

3 Maraschini, *Sulle Formazioni delle Rocce del Vicentino,* p. 145—149. Brochant, *Sur les Roches Granitoïdes du Montblanc, &c., Annales des Mines,* 1ère Série, tome iv. p. 297, *et seq.*

4 Patrin, *Apperçu des Mines de Sibérie, Journal de Physique,* tome xxxiii. p. 81, 1788. Hermann, *Versuch einer mineralogischen Beschreibung der Uralischen Erzgebürger,* 1789. Elie de Beaumont, *Coup d'œil sur les Mines,* pp. 79, 128, and *Dictionnaire des Sciences Nat.,* tome xxxi. p. 385, *et seq.*, Art. Mines. Patrin, *Notice Minéralogique de la Daourie, Journal de Physique,* tome xxxviii. p. 225, 1791. Engelhardt und Parrot, *Reise in die Krym und den Kaukasus,* vol. ii. pp. 187, 264. Kupfer, *Rapport fait à l'Académie des Sciences de Pétersbourg sur son Voyage à l'Elbrouz,* 1830.

5 Pallas, Second Voyage, French Trans., tome ii. p. 278—286.

6 Humboldt, *Essai Politique sur le Mexique,* 4to, tom. ii. pp. 494, 516, *et seqq.* Elie de Beaumont, *Coup d'œil sur les Mines,* p. 67, and *Dict. des Sciences Nat.,* tome xxxi. p. 371, *et seq.*, Art. Mines.

7 Humboldt, *Relation Historique du Voyage,* 8vo, tome vi. p. 264.

8 *Journal des Mines,* tome i. No. 5. pp. 32, 33, *et seq.* L. A. Necker, *Mémoire sur la Vallée de Valorsine, Mém. de la Société de Physique et d'Hist. Nat. de Genève,* tome iv.

head, the Lead-hills, and Northumberland[1]; to the mines of Huelgoet and Poullavaen in Brittany[2]; to those of Macagnaga and Allayna at the foot of Mount Rosa[3], of Sardinia[4], Corsica[5], and Elba[6]; to the metalliferous veins of the Vosges[7], near Brescia[8] in the Alps, and the Altai chain[9];—all of which occur in districts where unstratified rocks are known to exist.

The author, however, states, that besides the evidence thus afforded of the connexion of igneous rocks with metalliferous deposits, it is necessary to have a knowledge of the stratification of the formations in which mines are worked before any legitimate conclusion can be drawn.

In reply to the third question,—Do metalliferous deposits exist entirely disconnected from unstratified rocks?—the author enumerates the mines of the Netherlands[10]; those of quicksilver at Idria; the lead mines of Poggau in the valley of the Mur; Pezay and Macoz in the Tarentaise; the copper slate of Mansfeld and Thuringia; and the veins of galena in the inferior oolite near Frome[11], in the magnesian limestone of Durham[12], and the mountain-limestone of England.

The author then gives, as a general illustration of his subject, a sketch of the countries between the Alps and the western extremity of England, and shows that igneous rocks and metallic deposits are totally wanting in the whole of the districts extending from the foot of the Alps across the valley of Lac Leman, the Jura chain, the plains of Franche Comte and Burgundy; in the oolitic, green-sand, chalk, and tertiary formations of the north-west of France, and in the tertiary and secondary formations of England as far as Devonshire; but that, on the contrary, when the unstratified rocks recommence in the last-mentioned district, metallic veins reappear.

[1] Conybeare and Phillips, Outlines of the Geology of England, pp. 443, 444, 445, and 447.

[2] D'Aubuisson, *Journal des Mines*, tome xxi. p. 81.

[3] Saussure, *Voyages dans les Alpes*, § 2132 *et seq.*, et § 2151. Von Wellen, *Der Monte Rosa*, pp. 55, 56, 1824.

[4] Marmora, *Mém. du Museum*, tome xi.

[5] Gueymard, *Annales des Mines*, 1ère Série, tome ix. p. 123.

[6] Pini, *Journal de Physique*, tome xii. p. 413. Edinburgh Philosophical Journal, vol. ii. p. 177.

[7] Elie de Beaumont, *Coup d'œil sur les Mines*, p. 33, *et seq.*; *Dictionnaire des Sciences Naturelles*, tome xxxi. p. 388. Art. Mines.

[8] Brocchi, *Sulle Miniera del Dipartimento della Mella*, tomo ii. pp. 248, 273, 274, 275.

[9] Renovaz, *Mineralogische Nachrichten von den Altaischen Gebürgen.* Elie de Beaumont, *Coup d'œil sur les Mines*, pp. 77, 78; *Dictionnaire des Sciences Naturelles*, tome xxxi. p. 382 *et seq.*, Art. Mines. Patrin, *Journal de Physique*, tome xxxiii. p. 81.

[10] D'Omalius d'Halloy, *Mémoire Géologique sur la France et quelques Pays voisins.*

[11] Philosophical Magazine, New Series, vol. ii. p. 234.

[12] Sedgwick, Trans. Geological Society, Second Series, vol. iii. pp. 77, 78, 105, 108.

Lastly, the author compares the relative connexion of igneous deposits with metallic accumulations, and states that ores are more abundant in granite, certain porphyries, syenites, amygdaloids, and trap, which he calls underlying, unstratified rocks, than in the newer porphyries, the dolerites, and the true volcanic formations, which he distinguishes by the term of overlying, unstratified rocks; and he alludes to the assistance which the practical miner would derive from attending to this distinction, as well as to the principal object of the paper,—the connexion of igneous with metalliferous deposits.

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31.	Untersuchungen über den Magnetismus der Erde, von C. Hansteen. Uebersetzt von P. Treschow Hanson. Erster Theil. Die mechanischen Erscheinungen des Magneten. 1819.	H. C. White, Esq. F.G.S.

1831.	BOOKS.	DONORS.
Jan. 14.	Transactions of the Society for the Encouragement of Arts, Manufactures and Commerce, vol. 48, part 1.	The Society of Arts.
18.	Proceedings of the Astronomical Society of London, No. 30.	The Astronomical Society.
	Occultations of Planets and Fixed Stars by the Moon.	....
	On the Fossil Organic Remains found in Canada.	Lt. Baddeley, Roy. Eng.
	Mineralogical Examination of the Sulphate of Strontian from Kingston, and on the Red Colour of Flame as produced by Strontian and as characteristic of Minerals of that Genus, by Lieut. Baddeley, Roy. Eng.	....
20.	Proceedings of the Committee of Science and Correspondence of the Zoological Society of London, No. 1.	The Zoological Society.
28.	Catalogue of the Hunterian Collection in the Museum of the Royal College of Surgeons, part 4, comprehending the Human and Comparative Osteology.	The Royal College of Surgeons.
	Journal of the Royal Institution of Great Britain, No. 2.	The Royal Institution.
Feb. 11.	Proceedings of the Committee of Science and Correspondence of the Zoological Society of London, No. 2.	The Zoological Society.
	Versuch einer geognostischen Eintheilung seiner Versteinerung-Sammlung, von Herrn F. W. Hoeninghaus, erster Theil.	The Author.
12.	Manual of Analytical Chemistry, by Henry Rose, Professor of Chemistry at Berlin, translated from the German by Mr. Griffin.	The Translator.
19.	Real Museo Borbonico. Officina de' Papiri descritta dal Canonico Andrea de Jorio. Napoli, 1825.	H. T. De la Beche, Esq. F.G.S. &c.
	Plan de Pompei, de M. le Chanoine D. André de Jorio, 1827.	....
	Synopsis Reptilium, or Short Descriptions of the Species of Reptiles, by John Edward Gray, Esq. F.G.S. part 1, Cataphracta, Tortoises, Crocodiles, and Enaliosaurians.	The Author.
	The Zoological Miscellany, by John Edward Gray, Esq. F.G.S. No. 1.	....
Mar. 10.	Proceedings of the Committee of Science and Correspondence of the Zoological Society, No. 3.	The Zoological Society.
12.	Address of Earl Stanhope, President of the Medico-Botanical Society, at the Anniversary Meeting, Jan. 16th 1831.	The Medico-Botanical Society.
14.	Researches about Atmospheric Phænomena, by Thomas Forster, Esq. M.B. F.L.S. Third edition. 1823.	The Author.
	Illustrations of the Atmospherical Origin of Epidemic Diseases, by T. Forster, Esq. M.B. F.L.S. Second edition. 1829.	....
30.	Proceedings of the Royal Society of London, Nos. 1 & 2.	The Royal Society.
April 5.	Edinburgh Journal of Natural and Geographical Science, New Series, No. 4, conducted by Henry Cheek, Esq. F.L.S.	The Conductor.
11.	Proceedings of the Committee of Science and Correspondence of the Zoological Society, No. 4.	The Zoological Society.

1831.	BOOKS.	DONORS.
April 13.	Meeting of the Cultivators of Natural Science and Medicine at Hamburgh, in September 1830, by F. W. Johnston, M.A. From the Edinburgh Journal of Science, N.S. vol. 4.	The Author.
	On the Occurrence of the Remains of Elephants and other Quadrupeds in the Cliffs of frozen Mud in Eschscholtz Bay, within Beering's Strait, and in other distant parts of the shores of the Arctic Seas, by the Rev. William Buckland, D.D.	The Author.
18.	Studien des Göttingischen Vereins Bergmännischer Freunde. Im Namen desselben herausgegeben von J. F. L. Hausmann, For. Mem. G.S.	The Author.
	The Utility of the Knowledge of Nature considered with Reference to the Introduction of Instruction in the Physical Sciences into the General Education of Youth, by E. W. Brayley, Jun. Esq.	The Author.
19.	Histoire des Végétaux Fossiles, ou Recherches Botaniques et Géologiques sur les Végétaux renfermés dans les diverses Couches du Globe, 4 livraisons, par M. A. Brongniart.	Frederick Page, Esq. F.G.S.
	Natur-Historie des Schweizerlandes, von Johann Jacob Scheuchzers.	H. J. Brooke, Esq. F.G.S.
25.	Mémoires de l'Académie Royale des Sciences de l'Institut de France, tome 10.	The Royal Institute of France.
26.	On the Diluvial Theory, and on the Origin of the Valleys of Auvergne, by Dr. Daubeny, F.G.S. (From the Edinburgh New Philosophical Journal, No. 20, 1831.)	The Author.
27.	On the probable Connexion of Rock-Basins, in Form and Situation, with an Internal Concretionary Structure in the Rocks in which they occur, by E. W. Brayley, Jun. A.L.S.	The Author.
	Philosophical Transactions of the Royal Society of London; parts 1 and 2, 1830; part 2, 1828; part 3, 1830.	The Royal Society.
	Proceedings of the Royal Society, Nos. 2 and 3.	....
	Notice sur les Puits Artésiens, ou Observations sur les diverses Tentatives exécutées dans le Midi de la France, par M. Marcel de Serres.	The Author.
	De la Simultanéité des Terrains de Sédiment Supérieur, par M. Marcel de Serres.	....
May 6.	Proceedings of the Royal Astronomical Society of London, Index to vol. 1, parts 2 and 3 of vol. 2.	The Astronomical Society.
	Charter and Bye-laws of the Astronomical Society.	....
9.	Recueil de Planches de Pétrifications remarquables, par M. Léopold de Buch, For. Mem. G.S., premier cahier.	The Author.
11.	Abhandlungen der Königlichen Akademie der Wissenschaften zu Berlin aus dem Jahre 1827, nebst der Geschichte der Akademie in diesem Zeitraum.	The Royal Academy of Berlin.
16.	Catalogue of the Library of the Royal College of Surgeons in London, 1831.	The Royal College of Surgeons.

1831.	BOOKS.	DONORS.
May 16.	Catalogue of the Contents of the Museum of the Royal College of Surgeons in London, part 4, fasciculus 1, comprehending the First Division of the Preparations of Natural History in Spirit.	The Royal College of Surgeons.
19.	Quarterly Mining Review, No. 5.	The Editor.
25.	Examination of the Objections made in Britain against the Doctrines of Gall and Spurzheim, by J. G. Spurzheim, M.D.	S. Underwood, Esq. F.G.S.
	Journal of the Royal Institution of Great Britain, No. 3.	The Royal Institution.
June 7.	A Descriptive Outline of the Roman Remains in Norfolk, accompanied by a Map of the County, by S. Woodward, Esq. From the Archæologia, vol. 23.	The Author.
8.	Description of the Fossil Bones of the Megalonyx discovered in White Cave, Kentucky, by Dr. Harlan. From the Journal of the Academy of Natural Sciences of Philadelphia, vol. 6.	The Author.
	A newly illustrated Road Book of the Route from London to Naples, by William Brockedon, Esq., part 1, containing Route from London to Paris.	The Author.
	Annual Report of the Yorkshire Philosophical Society and List of Members and Contributors for 1830.	The Yorkshire Philosophical Society.
	Reports of the Auditors of the Accounts of the Zoological Society for the year 1830.	The Zoological Society.
	Proceedings of the Committee of Science and Correspondence, No. 6.	....
	Proceedings of the Royal Society, No. 4.	The Royal Society.
	Transactions of the Cambridge Philosophical Society, vol. 4, part 1.	The Cambridge Philosophical Society.
	Histoire des Végétaux Fossiles, par M. Adolphe Brongniart, 5me livraison.	Frederick Page, Esq. F.G.S.
21.	Proceedings of the Royal Society, No. 5.	The Royal Society.
27.	Catalogue of the Organic Remains of the County of Wilts, by Miss Etheldred Benett, 4to.	The Author.
	Catalogue of Wiltshire Fossils, by Miss Etheldred Benett, fol.	....
July 3.	A Critical Review of Mr. Montgomery's Poem of "Oxford," by the Reviewer of the Keepsake for 1831.	The Author.
15.	The Fossil Flora of Great Britain, or Figures and Descriptions of the Vegetable Remains found in a Fossil State in this Country, by John Lindley, Esq. F.G.S. and William Hutton, Esq. F.G.S. No. 1.	J. Lindley, Esq. F.G.S.
18.	Remarks on the Formation of Alluvial Deposits, by the Rev. James Yates, F.G.S. &c. From the Edinburgh New Philos. Journal for July 1831.	The Author.
20.	Manual of Geology, by H. T. De la Beche, Esq. F.G.S. &c.	The Author.
	Transactions of the Royal Irish Academy, vol. 16, part 1, 1830.	The Royal Irish Academy.
26.	Proceedings of the Royal Astronomical Society of London, vol. 2, No. 6.	The Royal Astronomical Society.

1831.	BOOKS.	DONORS.
July 28.	A Description of a Fossil Tree discovered in the Quarry at Craigleith, near Edinburgh, in the Month of November 1830, by Henry Witham, Esq. F.G.S. From the Transactions of the Natural History Society at Newcastle, vol. 1.	The Author.
30.	Ninth and Tenth Annual Reports of the Council of the Leeds Philosophical and Literary Society, for 1829 and 1830.	The Leeds Philosophical and Literary Society.
Aug. 3.	Journal of the Royal Institution of Great Britain, No. 4.	The Royal Institution.
12.	Proceedings of the Committee of Science and Correspondence of the Zoological Society, for April, May, and June 1831, No. 7.	The Zoological Society.
	Catalogue of the Contents of the Museum of the Royal College of Surgeons, part 5, comprehending the Preparations of Monsters and mal-formed Parts, in Spirit, and in a Dried State.	The Royal College of Surgeons.
28.	Proceedings of the Royal Society of London, Nos. 5 and 6.	The Royal Society.
	Monthly American Journal of Geology and Natural Science, conducted by G. W. Featherstonhaugh, Esq. F.G.S., July 1831.	The Conductor.
29.	Additional Observations on the Geology and Organic Remains of New Jersey and Delaware, by G. Morton, M.D.	The Author.
	Notice of the Academy of Natural Sciences of Philadelphia, Second edition.	The Academy of Sciences at Philadelphia.
	List of Portraits in possession of the Royal Society.	The Royal Society.
	Transactions of the Royal Irish Academy, vol. 16, part 2.	The Royal Irish Academy.
Sept. 5.	Description of the Skeleton of the Fossil Deer of Ireland, *Cervus Megaceros*, by John Hart, Esq. M.R.I.A. Second edition, with an Appendix.	The Author.
7.	A Letter to Dr. David Boswell Reid in Answer to his Pamphlet, entitled "An Exposure of the Misrepresentations in the Philosophical Magazine and Annals of Philosophy," by R. Phillips, F.G.S. &c.	The Author.
12.	Transactions of the Royal Society of Edinburgh, vol. 11, part 2.	The Royal Society of Edinburgh.
25.	Bulletin de la Société Géologique de France, tome 1er.	The Geol. Soc. of France.
29.	American Journal of Science and Arts, conducted by Benjamin Silliman, M.D. For. Mem. G.S., vol. 19, 20.	The Conductor.
Oct. 5.	On a peculiar Class of Acoustical Figures, and on the Forms of Fluids vibrating on Elastic Surfaces, by Michael Faraday, Esq. F.G.S. &c. From the Philosophical Transactions, 1831, p. 299.	The Author.
	Proceedings of the Committee of Science of the Zoological Society for the Meetings held July 16th and Aug. 9th.	The Zoological Society.
	Table of the Logarithms of the Natural Numbers from 1 to 108,000, by Charles Babbage, Esq. M.A.	The Author.

1831.	BOOKS.	DONORS.
Nov. 5.	Rapporto sulle Ossa Fossili di Mardolce e degli altri contorni di Palermo.	Dr. Christie, F.G.S.
	A newly illustrated Road Book of the Route from London to Naples, part 2, containing Route from Paris to Turin, edited by William Brockedon, Esq.	The Editor.
	Verzeichniss der von F. W. Hoeninghaus in Crefeld dem Museum der Universität Bonn, zur Beförderung grösseren Nutzens in den Naturwissenschaften überlassenen Petrefacten-Sammlung.	F.W. Hoeninghaus, Esq.
	Caspari Georgii Caroli Reinwardt, Oratio de Augmentis, quæ Historiæ Naturali ex Indiæ investigatione accesserunt, habita Leidae, A.D. 3 Maji, 1823.	The Author.
	Over eenen Hoorn en Gedeelte des Bekkeneels van Bos. Primigenius, in Februarij, 1825, bij de Eembrugge gevonden, door N. C. de Fremery.	C. G. C. Reinwardt, Esq.
9.	Fragmens de Géologie et de Climatologie Asiatiques, par Alexandre de Humboldt, For. Mem. G.S., tomes 1er et 2me.	The Author.
	Notice sur l'Hypersténe et la Siénite Hypersténique de la Valteline, par M. L. A. Necker, For. Mem. G.S. Lué à la Société de Physique et d'Histoire Naturelle de Genève, le 16 Avril, 1829.	The Author.
	Sur quelques Rapports entre la Direction Générale de la Stratification et celle des Lignes d'égale Intensité Magnétique dans l'Hémisphère Boréal, par M. L. A. Necker, For. Mem. G.S. Communiqué à la Société de Physique et d'Histoire Naturelle de Genève le 4 Fev. 1830.	....
	Note sur la Gismondine de Carpi, et sur un nouveau Minéral des Environs de Rome, par M. L. A. Necker, For. Mem. G.S. Luë à la Société de Physique et d'Histoire Naturelle de Genève, le 20 Jan. 1831.	....
	Petrificata Suecana Formationis Cretaceæ, descripta et Iconibus illustrata a S. Nilsson. Pars prior, Vertebrata et Mollusca sistens.	H. T. De la Beche, Esq. F.G.S. &c.
22.	A Geological Nomenclature for North America; founded upon Geological Surveys taken under the Direction of the Honourable Stephen van Rensselaer.	The Hon. Stephen van Rensselaer.
	Beiträge sur Petrefactenkunde, von Hermann von Meyer. (This volume contains Von Meyer's memoirs on *Orthoceratites striolatus, Calymene? æqualis, Mastodon arvernensis,* Aptycus, Rhacheosaurus, Plagiosaurus, Pleurosaurus, Macrospondylus and Pterodactylus.)	The Author.
	Journal of the Royal Geographical Society of London, vol. 1.	Royal Geographical Society.
Dec. 1.	The Horticultural Register and General Magazine of all Useful and Interesting Discoveries, No. 1 to 6, conducted by Joseph Paxton, F.L.S. and Joseph Harrison.	The Conductors.

1831.	BOOKS.	DONORS.
Dec. 3.	Description of the Fossil Bones of the Megalonyx discovered in White Cave, Kentucky, by R. Harlan, M.D. From the Journal of the Academy of Nat. Sciences at Philadelphia, vol. 6.	The Author.
3.	Description de Coquilles Caractéristiques des Terrains, par M. G. P. Deshayes.	H. T. De la Beche, Esq. F.G.S. &c.
9.	The Philosophical Transactions of the Royal Society of London, for the year 1831.	The Royal Society.
13.	American Journal of Science and Arts, vol. 21, 1831, conducted by Benjamin Silliman, M.D. For. Mem. G.S.	The Conductor.
18.	Memoirs of the Royal Astronomical Society, vol. 4, part 2.	The Royal Astronomical Society.
	Tableau Mnémonique des Terrains Primitifs, destiné au Géologue Voyageur, avec son Explication, par M. Nérée Boubée.	The Author.
31.	Eléments de Géologie, par M. J. J. D'Omalius D'Halloy.	H. T. De la Beche, Esq. F.G.S. &c.
	The Magazine of Natural History and Journal of Botany, Zoology, Mineralogy, Geology, and Meteorology, for 1831, by J. C. Loudon, F.G.S. &c.	The Conductor.
	The Philosophical Magazine and Annals of Philosophy, for 1831, conducted by R. Taylor, Esq. F.G.S. and Richard Phillips, Esq. F.G.S.	Richard Taylor, Esq. F.G.S.
	Principles of Geology, by C. Lyell, Esq. F.G.S. vol. 2.	The Author.
1832.		
Jan. 7.	The Fossil Flora of Great Britain, by J. Lindley, F.G.S. and William Hutton, F.G.S., parts 2 and 3.	The Authors.
12.	An Estimate of the Philosophical Character of Dr. Priestley, by William Henry, M.D. F.R.S. Hon. Mem. G.S. Read to the first meeting of the British Association, 1831.	The Author.
16.	Histoire des Végétaux Fossiles, ou Recherches Botaniques et Géologiques sur les Végétaux renfermés dans les diverses Couches du Globe, par M. Adolphe Brongniart, 6me livraison.	F. Page, Esq. F.G.S.
17.	Proceedings of the Committee of Science of the Zoological Society for Nov. 1831.	The Zoological Society.
24.	Proceedings of the Royal Society, No. 7.	The Royal Society.
25.	Transactions of the Literary and Historical Society of Quebec, vol. 2.	The Literary and Historical Society of Quebec.
	Programme d'un Concours pour le Percement de Puits Forés suivant la Méthode Artésienne, à l'effet d'obtenir des Eaux jaillissantes applicables aux Besoins de l'Agriculture, suivi de Considérations Géologiques et Physiques sur le Gisement de ces Eaux, par M. le Vicomte Héricart de Thury, 1828.	The Author.
	Considérations Géologiques et Physiques sur la Cause du jaillissement des Eaux des Puits Forés ou Fontaines Artificielles, &c., par M. le Vicomte Héricart de Thury, 1829.	....

1832.	BOOKS.	DONORS.
Jan. 25.	Recherches sur l'Origine ou l'Invention de la Sonde du Fontenier-Sondeur, et Considérations sur le Dégré de Probabilité du Succès des Puits Forés ou Fontaines Artésiennes dans les hautes Plaines des Départemens de la Champagne, de la Beauce, de la Picardie, de la Normandie, &c. &c., par M. le Vicomte Héricart de Thury, 1829.	The Author.
	Rapport de M. le Vicomte Héricart de Thury sur le Concours ouvert pour le Percement des Puits Forés. Séance Publique du 18 Avril 1830.	....
	Rapport sur le Concours pour le Percement des Puits Forés, &c., par M. le Vicomte H. de Thury, 1831.	....
	Programmes des Prix proposés par la Société Royal et Centrale d'Agriculture dans sa Séance Publique du 10 Avril 1831, pour le Desséchement des Terres argilleuses et humides au moyen de Puisards artificiels, de Sondages et de Coulisses ou Rigoles Souterrains, par M. le Vicomte Héricart de Thury, 1831.	....
	Notices sur le double Puits Foré au Port Saint-Ouen par MM. Flachat frères et Cie; luës à la Société Royale et Centrale d'Agriculture de Paris, dans les Séances des 18 Février et 3 Mars 1829, par M. le Vicomte Héricart de Thury.	....
Feb. 3.	Sacred Poems, Poetical Illustrations of Scripture, by the Rev. C. F. Watkins.	The Author.
9.	List of Portraits in possession of the Royal Society.	The Royal Society.
	List of Instruments and Apparatus belonging to the Royal Society.	....
10.	Remarks on Thermal Springs and their Connexion with Volcanos, by Charles Daubeny, M.D. F.G.S. From the Edinburgh New Philosophical Journal, Jan. 1832.	The Author.
11.	An account of the Beulah Saline Spa at Norwood, Surrey, by George H. Weatherhead, M.D.	The Author.
16.	A Letter to a Friend containing Observations on the Comparative Merits of Canals and Railways, occasioned by the Reports of the Committee of the Liverpool and Manchester Railway, by Frederick Page, Esq. F.G.S.	The Author.
23.	Micrometrical Measures of 364 Double Stars with a Seven Feet Equatorial Achromatic Telescope, taken at Slough in the years 1828, 1829, and 1830, by J. F. W. Herschel, Esq. F.G.S. From the Memoirs of the Royal Astronomical Society, vol. 5, part 1.	The Author.
24.	A Geological Manual, by H. T. De la Beche, Esq. F.R.S. F.G.S. &c. 2nd Edit.	The Author.
25.	First Report of the Proceedings, Recommendations and Transactions of the British Association for the Advancement of Science, 1832.	The British Association.

1832.	BOOKS.	DONORS.
Feb. 25.	Dictionnaire Géographique de la Province de Liége, précédé d'un Fragment du Mémorial de l'Etablissement Géographique de Bruxelles, fondé par Ph. Vander Maelen.	M. Vander Maelen.
Mar. 3.	Proceedings of the Committee of Science and Correspondence of the Zoological Society of London, No. 1, 1830–31.	The Zoological Society.
7.	The British Magazine and Monthly Register of Religious and Ecclesiastical Information, No. 1.	The Editor.
	Catalogue of German Books and Maps which have been published from July to December 1831 by Messrs. Black, Young and Young.	Messrs. Black and Co.
12.	Proceedings of the Royal Asiatic Society, for Feb. 1832.	The Royal Asiatic Society.
	Ittiolitologia Veronese del Museo Bozziano ora annesso a quello del Conte Giovambattista Gazola e di altri Gabinetti di Fossili Veronesi con la Versione Latina.	Rev. D. Pettiward, F.G.S.
26.	A History of Mountains, Geographical and Mineralogical, by J. Wilson, Esq., 3 vols. 4to, and the Picturesque View of the Principal Mountains of the World.	Samuel Luck Kent, Esq. F.G.S.
28.	First Annual Address of the Geological Society of Dublin, Feb. 1832, by the Rev. Bartholomew Lloyd, D.D. P.G.S.D.	The Geological Society of Dublin.
	List of Indian Woods collected by N. Wallich, M.D. F.G.S., drawn up by Arthur Aikin, Esq. F.G.S. Sec. to the Society of Arts. From the 48th vol. of the Transactions of the Society of Arts.	Dr. Wallich, F.G.S.
April 1.	Transactions of the Society for the Encouragement of Arts, Manufactures and Commerce, vol. 48, part 2.	Society of Arts and Sciences.
10.	First Appendix to the Third Report of the Select Committee of the House of Commons on the Coal Mines of India.	Henry H. Goodhall, Esq. F.G.S.
	Experimental Researches in Electricity, by Michael Faraday, Esq. F.R.S. F.G.S. From the Philosophical Transactions, 1832.	The Author.
	American Journal of Science and Arts, conducted by Benjamin Silliman, M.D., vol. 22.	The Conductor.
	On the Vitality of Toads inclosed in Stone and Wood, by the Rev. Prof. Buckland, D.D. F.G.S. From the Zoological Journal.	The Author.
16.	Sketch of the History of Van Diemen's Land; and an Account of the Van Diemen's Land Company, by James Bischoff, Esq.	The Author.
18.	Proceedings of the Royal Asiatic Society, March 1832.	The Royal Asiatic Society.
24.	Proceedings for January and February of the Committee of Science and Correspondence of the Zoological Society.	The Zoological Society.
May 1.	Transactions of the American Philosophical Society, vol. 4, part 1. New Series.	The American Philosophical Society.

1832.	BOOKS.	DONORS.
May	1. Observations on the Genus Unio, together with Descriptions of new Genera and Species in the Families Naïades, Melaniana and Colimacia, by Isaac Lea, Esq. From the Transactions of the American Philosophical Society held at Philadelphia. New Series, vols. 3 and 4.	The Author.
	3. On Mineralogy, considered as a Branch of Natural History, by M. L. A. Necker, For. Mem. G.S. From the Edin. New Phil. Journal, April 1832.	The Author.
	4. Remarks on the Mineralogy and Geology of the Peninsula of Nova Scotia, by Charles T. Jackson, Esq. and Francis Alger, Esq. From the Memoirs of the American Academy.	The Authors.
	Proceedings of the Royal Society, No. 8.	The Royal Society.
	6. An Address delivered at the Anniversary Meeting of the Geological Society of London, on the 17th of February 1832, by Roderick Impey Murchison, Esq. F.R.S. L.S. President of the Society.	The Author.
	Proceedings of the Royal Asiatic Society, April 1832.	The Royal Asiatic Society.
	21. Annual Report of the Council of the Yorkshire Philosophical Society, for 1831, presented to the Annual Meeting, February 7th 1832.	The Yorkshire Philosophical Society.
June	4. Descrizione dell'Etna, con la Storia delle Eruzioni e il Catalogo dei Prodotti, dell'Abate Francesco Ferrara.	Marquis of Northampton, F.G.S.
	I Campi Flegrei della Sicilia e delle Isole che le sono intorno, o Descrizione Fisica e Mineralogica di queste Isole, dell' Abate Francesco Ferrara.	....
	Zoologia Adriatica, ossia Catalogo Ragionato degli Animali del Golfo e delle Lagune di Venezia, preceduto da una Dissertazione sulla Storia Fisica e Naturale del Golfo, e accompagnato da Memorie ed Osservazioni di Fisica Storia Naturale ed Economia, dell' Abate Giuseppe Olivi. Bassano, 1792.	....
	6. On the Free Motion of Points, and on Universal Gravitation, including the Principal Propositions of Books 1 and 3 of "The Principia"; the First Part of a new Edition of a Treatise on Dynamics, by William Whewell, M.A. F.G.S. 1832.	The Author.
	7. On the Investigation of the Orbits of Revolving Double Stars: being a Supplement to a Paper entitled, "Micrometrical Measures of 364 Double Stars, by Sir J. F. W. Herschel, K.G.H. F.G.S. F.R.A.S., &c." From the Memoirs of the Royal Astronomical Society, vol. 5, p. 171.	The Author.
	8. The Eleventh Report of the Council of the Leeds Philosophical Society, at the Close of the Session 1830–1831.	The Leeds Philosophical Society.
	13. On the *Lepidodendron Harcourtii*, by Henry Witham, Esq., F.G.S. From the Transactions of Nat. Hist. Soc. of Newcastle-upon-Tyne.	The Author.

1832.	BOOKS.	DONORS.
June 18.	On the Economy of Manufactures, by Charles Babbage, Esq. A.M.	The Author.
20.	Proceedings of the Royal Asiatic Society, for May 1832.	The Royal Asiatic Society.
	Report of the Council to the Annual Meeting held June 7, 1832.	....
28.	Observations on the Theories which have been proposed to explain the Vitrified Forts of Scotland, by S. Hibbert, M.D. F.G.S.	The Author.
	Description of the Shetland Islands, by Samuel Hibbert, M.D. F.G.S.	....
	History of the Extinct Volcanos of the Basin of Neuwied on the Lower Rhine, by Samuel Hibbert, M.D. F.G.S.	....
	Notice of the Discovery of very extensive Vitrified Remains at Elsness, in the Island of Sanday, Orkney, by Samuel Hibbert, M.D. F.G.S.	....
29.	Anniversary Address, Report and List for 1832 of the Royal Society of Literature.	The Royal Society of Literature.
July 3.	Transactions of the Royal Asiatic Society of Great Britain and Ireland, vol. 3, part 1.	The Royal Asiatic Society.
12.	The Monthly American Journal of Geology and Natural Science for August 1831, conducted by G. W. Featherstonhaugh, Esq. F.G.S.	The Conductor.
	Description of the Fossil Bones of the Megalonyx discovered in the White Cave, Kentucky, by R. Harlan, M.D. From the Journal of the Academy of Natural Sciences at Philadelphia, vol. 6.	The Author.
	List of Premiums for the years 1831, 1832, 1833 and 1834, offered by the Society for the Encouragement of Arts, Manufactures and Commerce.	The Society of Arts.
	Rapport sur les Travaux de la Société Géologique de France pendant l'Année 1831, par M. Jules Desnoyers, Secrétaire pour la France.	The Author.
28.	On certain new Phenomena of Colour in Labrador Felspar, with Observations on the Nature and Cause of its changeable Tints, by David Brewster, LL.D. F.G.S. From the Transactions of the Royal Society of Edinburgh, vol. 11.	The Author.
Aug. 6.	On the Osteological Symmetry of the Camel, by Walter Adam, Esq. M.D. From the Transactions of the Linnean Society, vol. 16, page 525.	The Author.
15.	Proceedings of the Committee of Science and Correspondence of the Zoological Society for March, April, May and June 1832.	The Zoological Society.
18.	Mémoires de l'Académie Royale des Sciences de l'Institut de France, tome 11, 1832.	The Royal Academy of France.
23.	Bulletin de la Société Géologique de France, tome 2, feuilles 23 et 24.	The Geological Society of France.

1832.	BOOKS.	DONORS.
Aug. 23.	Memoir on the Pearly Nautilus, drawn up by Richard Owen. Published by the Direction of the Council of the Royal College of Surgeons.	The Royal College of Surgeons.
27.	Transactions of the Royal Society of Edinburgh, vol. 12, part 1.	The Royal Society of Edinburgh.
Sept. 2.	Sketches of Vesuvius, with short Accounts of its principal Eruptions from the Commencement of the Christian Era to the present Time, by John Auldjo, Esq. F.G.S.	The Author.
	Verhandlungen der Kaiserlichen Leopoldinisch-Carolinischen Akademie der Naturforscher, 13ter Bänd.	The Royal Leopold Society of Bonn.
19.	On the Stratiform Basalt associated with the Carboniferous Formation of the North of England, by William Hutton, Esq., F.G.S. From the Transactions of the Nat. Hist. Soc. of Newcastle-upon-Tyne.	The Author.
26.	Report of the Proceedings of the Fourth Annual Meeting of the Subscribers to the Oriental Translation Fund of Great Britain and Ireland.	The Committee of Oriental Translation Fund.
	Fossil Flora of Great Britain, No. 6, by John Lindley, Esq. F.G.S. and William Hutton, Esq. F.G.S.	The Authors.
11.	Proceedings of the Royal Society, Nos. 8, 9, 10, 1832.	The Royal Society.
15.	Journal of the Asiatic Society, No. 1, January 1832.	The Editor.
Oct. 31.	De Origine Saxorum per Germaniæ Septentrionalis Regiones arenosas dispersorum Commentatio, Auctore Jo. Frid. Lud. Hausmann. Recitata in Consessu Societatis Regiæ Scientiarum d. 25 Aug. 1827.	The Author.
	De Hispaniæ Constitutione Geognostica, Auctore Jo. Frid. Lud. Hausmann, For. Mem. G.S.	....
	Essai sur les Orbicules Siliceux et sur les Formes à Surfaces courbes qu' affectent les Agates et les autres Silex, par M. Alex. Brongniart, For. Mem. G.S. From the Annales des Sciences Naturelles, 1831, tome 23, page 166.	The Author.
	The American Journal of Science and Arts, conducted by Benjamin Silliman, M.D. For. Mem. G.S. vol. 9, No. 1.	Henry Brooke, Esq. F.G.S.
	Transactions of the American Philosophical Society held at Philadelphia for promoting Useful Knowledge. New Series, vol. 4, part 2.	The American Philosophical Society.
	Taschenbuch für die gesammte Mineralogie, mit Hinsicht auf die neuesten Entdeckungen, von Karl C. von Leonard, Bände 1 bis 8 und 10 bis 12.	George B. Greenough, Esq. F.G.S.
Nov. 2.	Twelfth Report of the Council of the Leeds Philosophical and Literary Society at the Close of the Session 1831–1832.	The Leeds Philosophical Society.
16.	Eighth and Ninth Annual Reports of the Bristol Institution, 1831–1832.	The Bristol Institution.
20.	Journal of the Royal Geographical Society of London, vol. 2.	The Royal Geographical Society.
21.	Mémoires de la Société de Physique et d'Histoire Naturelle de Genève, tome 5.	The Natural History Society of Geneva.

1832.	BOOKS.	DONORS.
Nov. 24.	Introduction au Rapport fait à l'Académie Royale des Sciences sur le Voyage à l'Ile Julia en 1831 et 1832, par M. Constant Prevost, chargé par cette Académie de recueillir les Observations Géologiques relatives à l'Apparition de la nouvelle Ile Volcanique de la Méditerranée.	The Author.
29.	Proceedings of the Committee of Science and Correspondence of the Zoological Society of London, for July, August, September and October 1832.	The Zoological Society.
	Some Remarks on an Error respecting the Site and Origin of Graham Island, by Captain W. H. Smyth, R.N. From the Philosophical Transactions, 1832, page 255.	The Author.
30.	Ueber den Haytorit, von Weiss.	The Author.
	Ueber das Dihexaëder, dessen Flächenneigung gegen die Axe gleich ist seinen ebenen Endspitzenwinkel; nebst allgemeineren Betrachtungen über Invertirungskörper, von Weiss.	....
	Ueber das Staurolithsystem, als abgeleitet aus dem regulären Krystallsystem, von Weiss. From the Trans. of the Berlin Academy, 1831.	....
Dec. 1.	De redigendis ad unicam Seriem comparabilem meteorologicis ubique factis Observationibus Conventio proposita et Tabulæ supputatæ, ab Equite Nicolao Cacciatore, 1832.	The Author.
	Statuti dell' Accademia delle Scienze e Belle Lettere di Palermo, 1832.	The Academy of Palermo.
6.	A Popular Guide to the Observations of Nature, by Robert Mudie, Esq.	The Author.
12.	Bulletin de la Société Géologique de France, tome 2, feuilles 25–30.	The Geological Society of France.
19.	Fossil Shells of the Tertiary Formations of North America, illustrated by Figures drawn from Nature, by T. A. Conrad, vol. 1, No. 1. 1832.	The Author.
	Cataloghi Sistematici e Descrittivi degli Oggetti di Storia Naturale esistente nel Museo di Giuseppo de Cristofori e Prof. Giorgio Jan: Sezione Quarta, Prima Divisione, Mineralogia, Fascicolo 1.	
31.	The American Journal of Science and Arts, vol. 23, No. 1, conducted by Benjamin Silliman, M.D. For.Mem.G.S.	The Conductor.
	The London and Edinburgh Philosophical Magazine and Journal of Science, conducted by Sir D. Brewster, K.H. F.G.S., R. Taylor, Esq. F.G.S. and Richard Phillips, Esq. F.G.S., for the year 1832.	The Conductors.
	The Horticultural Register and General Magazine of all Useful and Entertaining Discoveries, conducted by J. Paxton, F.L.S. and H. Harrison, for the year 1832.	The Conductors.
1833.		
Jan. 1.	Hints for collecting Animals and their Products, by William John Broderip, Esq. F.G.S. V.P.Z.S.	The Author.

1833.	BOOKS.	DONORS.
Jan. 10.	Transactions of the Cambridge Philosophical Society, vol. 4, part 3.	The Cambridge Philosophical Society.
	The Charter and Bye-Laws of the Cambridge Philosophical Society.	....
14.	Philosophical Transactions of the Royal Society of London, for the year 1832.	The Royal Society.
	Addresses delivered at the Anniversary Meetings of the Royal Society on Thursday, Nov. 30, 1831, and Friday Nov. 30, 1832, by His Royal Highness the Duke of Sussex, K.G. &c., the President.	....
19.	A Catalogue of the Mammalia and Birds observed in Dukhun, East Indies, by Lt.-Col. W. H. Sykes, F.G.S. From the Proceedings of the Committee of Science and Correspondence of the Zoological Society of London, for July 1831, and April, September and October 1832.	The Author.
30.	Proceedings of the Royal Asiatic Society for June, July and December 1832.	The Royal Asiatic Society.
Feb. 1.	Transactions of the Society for the Encouragement of Arts, Manufactures and Commerce, vol. 49, part 1.	The Society of Arts.
	Principles of Geology, by Charles Lyell, Esq. For. Sec. G.S. Second edit. vols. 1 and 2.	The Author.
	Coup Théorique des divers Terrains, Roches et Minéraux qui entrent dans la Composition du Sol du Basin de Paris, par MM. Cuvier et Brongniart.	M. Clerget.
	Annales des Sciences et de l'Industrie du Midi de la France. Publiées par la Société de Statistique de Marseille, tome 1, Nos. 1, 2, et 3.	M. Donati.
22.	Mémoires présentés par divers Savans à l'Académie Royale des Sciences de l'Institut de France, (Sciences Mathématiques et Physiques,) tome 3.	The Royal Academy of France.
26.	Handbuch der Geognosie, von H. T. De la Beche. Nach der zweiten Auflage des Englischen Originals bearbeitet von Heinrich von Dechen, For. Mem. G.S. 1832.	The Translator.
	Proceedings of the Royal Asiatic Society, January 5th, 1833.	The Royal Asiatic Society.
	Élémens de Géologie mis à la portée de tout le Monde, par M. L. A. Chaubard.	The Author.
27.	Histoire des Végétaux Fossiles, par M. Adolphe Brongniart, 7e livraison.	Fred. Page, Esq. F.G.S.
Mar. 4.	An Historical and Practical Treatise upon Elemental Locomotion by means of Steam Carriages on Common Roads, by Alexander Gordon, Esq. 1832.	The Author.
	Journal of Elemental Locomotion, Nos. 1 to 5, for October, November and December 1832, and January, February and March 1833, edited by Alexander Gordon, Esq.	The Editor.
11.	Theory of the Formation of Chalk and Flint, by W. Man, (2 copies).	The Author.

1833.	BOOKS.	DONORS.
Mar. 11.	Transactions of the Royal Geological Society of Cornwall, vol. 4, 1832.	Davies Gilbert, Esq. Pres. R.G.S. of Cornwall.
	Die Dendrolithen in Beziehung auf ihren inneren Bau, von C. Bernhard Cotta.	The Author.
21.	American Journal of Science and Arts, conducted by Benjamin Silliman, M.D. For. Mem.G.S. vol. 23, No. 2.	The Conductor.
	Proceedings of the Royal Asiatic Society, February 2, 1833.	The Royal Asiatic Society.
	Astronomy and General Physics considered with Reference to Natural Theology, by the Rev. William Whewell, M.A. F.G.S.; being No. 3. of the Bridgewater Treatises.	The Author.
	Transactions of the Linnean Society of London, vol. 16, part 3.	The Linnean Society.
23.	On the Economy of Machinery and Manufactures, by Charles Babbage, Esq. A.M. Third edit. 1832.	The Author.
27.	An Account of some Fossil Shells of Maryland, by Thomas Say, Esq. From the Journal of the Academy of Natural Sciences, vol. 4.	J. Finch, Esq.
	Fossil Flora of Great Britain, by John Lindley, Esq. F.G.S. and William Hutton, Esq. F.G.S. No. 8.	The Authors.
April 1.	Annual Report of the Yorkshire Philosophical Society, for 1832.	The Yorkshire Philosophical Society.
2.	Proceedings of the Committee of Science and Correspondence of the Zoological Society of London, for October and November 1832.	The Zoological Society.
4.	Transactions of the Royal Academy of Berlin, for 1830 and 1831.	The Royal Academy of Berlin.
19.	Abstracts of the Papers printed in the Philosophical Transactions of the Royal Society of London, from 1800 to 1830, 2 vols.	The Royal Society.
	Proceedings of the Royal Society, No. 11.	. . . .
25.	Proceedings of the Natural History Society of Ile Maurice.	The Natural History Society of Ile Maurice.
	Mémoire sur la Relation des Ophites, des Gypses, et des Sources Salées des Pyrénées, et sur l'Epoque à laquelle remonte leur Apparition, par M. Dufrénoy, For. Mem. G.S. From the Annales des Mines, Third Series, vol. 2, page 21.	The Author.
	Mémoire sur les Caractères particuliers que présente le Terrain de Craie dans le Sud de la France, et principalement sur les Pentes des Pyrénées, par M. Dufrénoy, For. Mem. G.S. From the Annales des Mines, Second Series, vol. 8, pages 175, 321, and Third Series, vol. 1, page 3.	. . . .
	Sur la Nature et la Position Géologique des Marbres désignés sous le Nom de Calcaires Amygdalins, par M. Dufrénoy, For. Mem. G.S. From the Annales des Mines, vol. 3, page 179.	. . . .

1833.	BOOKS.	DONORS.
April 25.	Proceedings of the Royal Asiatic Society, March 1833.	The Royal Asiatic Society.
	Fragmens Géologiques tirés de Stenon, de Kazwini, de Strabon et du Boun-Dehesch, extrait et traduit par M. Elie de Beaumont, For. Mem. G.S. From the Annales des Sciences Naturelles, vol. 25, page 337.	M. Elie de Beaumont.
	Memoirs of the Royal Astronomical Society of London, vol. 5.	The Royal Astronomical Society of London.
30.	Atlas et Déscription Minéralogiques de la France, par MM. Guettard et Monnet. Publiés par M. Monnet d'après ses nouveaux voyages. Première Partie, comprenant le Beauvoisis, la Picardie, le Boulonnais, le Flandre Française, le Soissonnais, la Lorraine Allemande, une Partie de la Lorraine Française, le Pays Messin, et une Partie de la Champagne. 1780.	W. H. Fitton, M.D. F.G.S.
	The Natural History of Lancashire, Cheshire, and the Peak in Derbyshire: with an account of the British, Phœnician, Armenian, Greek and Roman Antiquities in those Parts, by Charles Leigh, M.D. Oxford, 1700.	....
	Fragments of Voyages and Travels, by Capt. Basil Hall, R.N. F.G.S. Third Series, 3 vols.	The Author.
	Recueil d'Itinéraires pour servir de Guide au Minéralogiste, au Conchyliologiste, et au Géologue dans toute la France, publiée par M. Nérée Boubée. 1er, 2de et 3me demi-livraisons.	The Author.
	Bulletin de Nouveaux Gisemens en France d'Economie Industrielle, Animaux, Végétaux, Minéraux, et Roches à exploiter; pour servir à la Statistique Générale de la France; divisé en huit sections, publié par M. Nérée Boubée. 1er demi-livraison.	....
	Proceedings of the Zoological Society, January 8th, 1833.	The Zoological Society.
May 3.	Principles of Geology, by Charles Lyell, Esq., For. Sec. G.S. vol. 3.	....
11.	Philosophical Transactions of the Royal Society of London, from 1801 to 1807, and for 1812 part 2, 1813 part 2, 1823 part 2, and the years 1824, 1825, 1826, 1827 and 1828.	The Royal Society.
14.	The Geology of the South-east of England, by Gideon Mantell, Esq. F.G.S.	The Author.
	Systematisches Verzeichniss der Petrefacten-Sammlung des verstorbenen wirklichen Geh.-Raths Freiherrn von Schlotheim.	Messrs. Perthis and Besser.
	Bulletin de la Société Géologique de France, tome 3, feuilles 6–9.	The Geological Society of France.
14.	Report of the Committee of the Atheneum, for the year 1833.	Committee of the Atheneum.
17.	A continuation to the Alphabetical Index of the Matter contained in the Philosophical Transactions of the Royal Society of London, from vol. 111 to 120, (1821 to 1830 inclusive).	The Royal Society.

1833.	BOOKS.	DONORS.
May 17.	Proceedings of the Royal Society, No. 12.	The Royal Society.
18.	Summary of the Proceedings of the Plymouth Institution; with a List of the Lectures from the Commencement to March 14th, 1833.	Plymouth Institution.
20.	On the Lacustrine Basins of Baza and Alhama, in the Province of Granada in Spain, by Col. Charles Silvertop, F.G.S. From the Edinburgh New Philosophical Journal, Oct. 1830 and Jan. 1831.	The Author.
	An Outline of the Geology of Norfolk, by Samuel Woodward.	The Author.
	American Journal of Science and Arts, conducted by Benjamin Silliman, M.D. For. Mem. G.S. vol. 24, No. 1.	The Conductor.
31.	Transactions of the Cambridge Philosophical Society, vol. 5, part 1.	The Cambridge Philosophical Society.
June 3.	Experimental Researches in Electricity, Third Series, by Michael Faraday, D.C.L. F.G.S. From the Philosophical Transactions for 1833, page 23.	The Author.
4.	Bulletin de la Société Géologique de France, tome 3, feuilles 10–13.	The Geological Society of France.
8.	Proceedings of the Royal Society of Literature, vol. 1, No. 2. 1833.	The Royal Society of Literature.
12.	Observations on Lakes, by Col. J. R. Jackson.	The Author.
	A Treatise on Astronomy, by Sir John Herschel, Knt. Guelp., LL.D. F.G.S.	The Author.
	The London and Edinburgh Philosophical Magazine and Journal of Science, conducted by Sir D. Brewster, K.C.H. F.G.S., Richard Taylor, Esq. F.G.S. and Richard Phillips, Esq. F.G.S., from Jan. to June 1833.	The Conductors.
	The Horticultural Register and General Magazine of all Useful and Interesting Discoveries, conducted by Joseph Paxton, F.L.S., from January to June 1833.	The Conductor.

II. *Donations to the Collections of Maps, Drawings, &c.*

1829.	MAPS, &c.	DONORS.
July 14.	Gisement du Terrain d'Arkose à l'Est du Plateau Central de la France, par M. Lacordaire. (2 copies.)	M. Lacordaire.
18.	Carte Géologique du Terrain entre le Lac d'Orta et celui de Lugano, par M. Leopold de Buch, For. Mem. G.S.	M. Leopold de Buch, For. Mem. G.S.
Dec. 12.	Cartes des principales Sondes du Lac Leman, par H. T. De la Beche, Esq. F.G.S.	The Author.
1830.		
Mar. 3.	Lithographic Print of *Isocardia Humboldtii* and *Calymene Macrophthalma.*	M. F. W. Hoeninghaus.
	Map of the Suffolk Crag District, by Richard C. Taylor, Esq. F.G.S.	The Author.
April 16.	Section of the Coal-field at Rummey, in Glamorganshire, and of the Monmouthshire Coal-field.	Alfred Thomas, Esq. F.G.S.

1830.	MAPS, &c.	DONORS.
May 8.	Lithographic print of Puy en Velay, drawn by Mrs. Murchison.	Mrs. Murchison.
Nov. 2.	Eight sheets of the new atlas of India in preparation under the orders of the Honourable the Court of Directors of the East India Company.	The Honourable the Court of Directors of the East India Company.
3.	Geognostische Karte von dem Odenwald und einigen angraenzenden Gegenden entworfen von Dr. A. Klipstein.	Dr. A. Klipstein.
1831.		
Jan. 19.	Section of a proposed rail-road from London to Birmingham.	Henry C. White, Esq. F.G.S.
26.	A copy of the geological map of Styria drawn under the superintendence of His Imperial Highness John Archduke of Austria, For. Mem. G.S.	His Imperial Highness John Archduke of Austria, For. Mem. G.S.
	A portrait of His Imperial Highness John Archduke of Austria, For. Mem. G.S.	Rev. Professor Sedgwick, F.G.S. and Roderick I. Murchison, Esq. P.G.S.
	Allgemeine geognostische Umrisse von dem Felsgebäude der Karparthen.	M. Von Lille von Lilienbach.
Mar. 10.	A map of five miles round the city of Bath, coloured geologically by Mr. W. Smith in the year 1799.	Mr. William Smith.
	General map of the strata found in England and Wales, 1801.	....
	Table of the strata of England dictated by Mr. Smith in 1799.	....
16.	Copy of a lithographic print of remains of *Felis Spelæa* found in July 1829 by Sir Philip de Malpas Grey Egerton, Bart. F.G.S., in the cave of Gailenruth.	Sir Philip Egerton, Bart. F.G.S.
30.	A lithographic print of a fossil fish from the slate of Engi in the Canton of Glarus, Switzerland, in the possession of Viscount Cole, M.P. August 1829.	Viscount Cole, M.P. F.G.S.
April 5.	Print of the Ichthyosaurus in the Museum of the Royal College of Surgeons.	William Clift, Esq. F.G.S.
11.	Carte hydrographique de la province du Chocó, esquissée d'après le plan de Don Juan Donoso, et les matériaux communiqués par le Gouvernment de la République de Colombia, par M. le Baron Alexandre de Humboldt, For. Mem. G.S.	J. B. Pentland, Esq.
	Plan hypsométrique du volcan de Pichincha, esquissé sur les lieux par M. le Baron Alexandre de Humboldt, For. Mem. G.S.	....
	Esquisse hypsométrique des nœuds de montagnes et des ramifications de la Cordillère des Andes, depuis le Cap de Horn jusqu'à l'Isthme de Panama et à la chaine littorale du Venezuela, par M. le Baron Alexandre de Humboldt, For. Mem. G.S.	....
	Carte géologique d'Europe, dressée par M. Ami Boué, For. Mem. G.S.	M. Ami Boué, For. Mem. G.S.
13.	Print of the cavern of Makoo near Mount Ararat.	T. Alcock, Esq.
May 6.	Map of canals in the counties of Lancaster, York, Derby and Chester, by G. Bradshaw.	Frederick Page, Esq. F.G.S.

1831.	MAPS, &c.	DONORS.
May 6.	Map of canals, navigable rivers, rail-roads, &c., in the midland counties of England, by G. Bradshaw.	....
June 8.	Engraved portrait of John Taylor, Esq. F.R.S. Treas. G.S.	Mrs. Taylor.
	A lithographic print of the Valley of Gosau, drawn by Mrs. Murchison.	Mrs. Murchison.
Aug. 18.	A geological section exhibiting the strata across the coal-field of Lancashire, by Elias Hall.	Mr. Hall.
Sept. 30.	An impression of a lithographic drawing of the animals of the Jura formation.	M. F. W. Hoeninghaus.
Dec. 13.	A lithographic drawing of a Plesiosaurus found in the lias at Bitton near Bristol.	Thomas H. Holdsworth, Esq. F.G.S.
14.	Engraved portrait of the late William Phillips, Esq. F.R.S. G.S.	Mrs. Phillips.
1832.		
Feb. 6.	Carte physique de l'Isle de Téneriffe, levée sur les lieux par M. Leopold de Buch, For. Mem. G.S.	M. Leopold de Buch, For. Mem. G.S.
	Map of the Crimea, in ten sheets.	Sir Alexander Crichton, F.G.S.
17.	The sheets of the Ordnance Survey not previously in the possession of the Society.	The Master-General and Board of Ordnance.
April 10.	The 55th sheet of the Ordnance Survey.	....
June 8.	A lithographic drawing of the skeleton of the whale exhibited in London in 1831.	Mr. G. Scharf.
Oct. 31.	Sheet No. 42 of the Ordnance Map in continuation of the trigonometrical survey of Great Britain.	The Master-General and Board of Ordnance.
Nov. 24.	A lithographic print of Ile Julia.	M. Constant Prevost, For. Mem. G.S.
	A lithographic print of the portrait of George Bellas Greenough, Esq. F.G.S. R.S. &c.	DecimusBurton,Esq.F.G.S.
1833.		
Feb. 1.	Sheets Nos. 36 and 61 of the Ordnance Map in continuation of the trigonometrical survey of Great Britain.	The Master-General and Board of Ordnance.
Mar. 27.	A set of the charts containing surveys mostly executed in the Indian seas, by officers in the Honourable Company's Marine Service.	The Honourable the Court of Directors of the East India Company.
	A series of charts of the Indian seas, constructed by Capt. James Horsburgh.	Capt. James Horsburgh.
April 25.	A lithographic drawing of the *Plesiosaurus macrocephalus* discovered in the lias at Bitton, Gloucestershire.	Joseph Parker, Esq.
May 11.	Townland survey of the county of Londonderry, consisting of 49 sheets, and index sheet.	Lt.-Col. Colby, by order of His Excellency the Lord-Lieutenant of Ireland.
22.	Sheet No. 73 of the Ordnance Map in continuation of the trigonometrical survey of Great Britain.	The Master-General and Board of Ordnance.

III. *Donations to the Cabinet of Minerals.*

1829.		SPECIMENS.	DONORS.
May	15.	Fossil wood from Rio Negro.	George Loddiges, Esq.
June	6.	A specimen of native iron from the province of Atacama in Peru; and a collection of the bones of the Mastodon, from Salta in Peru.	Woodbine Parish, Jun. Esq. F.G.S.
	12.	A collection of fossil plants from the Northumberland and Durham coal-field.	William Hutton, Esq. F.G.S.
	15.	A series of fossil shells from Monte Pelegrino near Palermo.	Marquis of Northampton, F.G.S.
	16.	Cast of the toe of the Iguanodon from Sandown Bay, Isle of Wight.	Rev. Prof. Buckland, D.D. F.G.S.
		Casts of three vertebræ found by Capt. Beechey on the shores of the Icy Cliff at Escholtz Bay, Beering's Straits.	....
		Specimens from a well sunk in the London and plastic clays, near Westwood.	Rev. J. H. Randolph, F.G.S.
		Specimens of an undescribed mineral, tungstate of lime and artificial oxide of tin.	Davies Gilbert, Esq. F.G.S.
Aug.	29.	Two specimens of sulphate of strontian on lias, from Cotham near Bristol.	J. S. Miller, Esq.
1830.			
Jan.	15.	Specimens of sulphuret of silver from the mining district of Guanaxuato.	J. Dickson, Esq.
		A crystal of selenite from Shotover.	Rev. Prof. Buckland, D.D. F.G.S.
		A specimen of lava containing crystals of muriate of soda from Vesuvius.	Mrs. Somerville.
Feb.	5.	*Hamites Gigas* and other fossils from Sandgate.	H. H. Goodhall, Esq. F.G.S.
		A collection of fossils from the upper greensand.	Roderick I. Murchison, Esq., Sec. G.S.
		Specimens from the crag of Suffolk.	R. C. Taylor, Esq. F.G.S.
		Neck of a whale found in making St. Katherine's Dock.	J. W. Lubbock, Esq. F.R.S.
Mar.	3.	Portions of four basaltic columns from the Giant's Causeway.	H. H. Price, Esq. F.G.S.
		A collection of specimens from Australia.	Archdeacon Scott, F.G.S.
		Fossils from the greensand, lias and carboniferous limestone of England.	Henry H. Goodhall, Esq. F.G.S.
	25.	A collection of geological specimens made by Captain Belcher, R.N. during the expedition to Beering's Straits, under the command of Capt. Beechey.	Capt. Belcher, R.N. F.G.S.
		A collection of specimens from Grätz.	Rev. Prof. Sedgwick, P.G.S. and Roderick I. Murchison, Esq. Sec. G.S.
		Specimens of native platina and native iridium with native alloy of iridium and osmium.	Thomas Johnson, Esq. F.G.S.
	26.	Specimens from the coal-basin of South Wales, and of fish from Epinac.	Josias Lambert, Esq. F.G.S.

1830.	SPECIMENS.	DONORS.
Mar. 31.	Specimens of *Rostellaria macroptera.*	Rev. John Ward, F.G.S.
	Bones of the Iguanodon from Brook in the Isle of Wight.	James Vine, Esq. F.G.S.
May 1.	A collection of bones of the Mastodon, and of rocks and simple minerals found in the United States.	The American Philosophical Society, held at Philadelphia.
4.	Fossils from the transition limestone of Devonshire.	H. T. De la Beche, Esq. F.G.S.
	A collection of fossils from the lias and oolitic coal measures of Yorkshire.	N. Dennys, Esq. F.G.S.
8.	Geological specimens from the South of Spain.	Col. Silvertop, F.G.S.
21.	A Series of specimens from the Siebengebirge, the Laacher-See and the Kaiserstuhl.	Frederick Page, Esq. F.G.S.
June 16.	Specimens of *Cyathea Serra* and *Arsophila armata* from Jamaica.	H. T. De la Beche, Esq. F.G.S.
	A specimen of *Spongia Patera.*	Major-General Hardwicke.
	Model of the largest specimen of native gold which has been found in Russia; and fossils from the lower greensand of England.	Sir Alexander Crichton, F.G.S.
Sept. 7.	Specimens of the fossil tree found at Wideopen.	William Hutton, Esq. F.G.S.
	Two deer's horns from the neighbourhood of the London Docks.	H. R. Palmer, Esq.
17.	Specimens from the gravel, and from a brickyard near Colchester.	John Brown, Esq.
	Specimens from Maestricht and Aix-la-Chapelle, and crystals of yenite.	William Henry Fitton, M.D. F.G.S.
Oct. 1.	A collection of rocks from the Siebengebirge.	M. Henri de Dechen, For. Mem. G.S.
12.	A collection of fossils from the neighbourhood of Farley near Bath.	Rev. B. Richardson, Hon. Mem. G. S.
	Specimens from Nova Scotia and New Brunswick.	Dr. Ridgway.
Nov 3.	Fossils from the lias, inferior oolite, Fuller's-earth and great oolite, in the neighbourhood of Bath.	Samuel P. Pratt, Esq. F.G.S.
4.	A collection of specimens from the Bay of Conception.	A. Caldcleugh, Esq. F.G.S.
5.	Specimens from the Island of Ascension.	Lieut. Fayrer, R.N.
10.	Fossils from the Isle of Wight.	John Willimott, Esq. F.G.S.
	Remains of the Palæotherium, Anoplotherium, a new species of deer, and of a turtle, from Binstead near Ryde.	Samuel P. Pratt, Esq. F.G.S.
	Specimens from the Island of Ascension.	C. Lyell, Esq. For. Sec. G.S.
	Casts of a femur of a tiger and part of the lower jaw of a bear found at Gailenruth.	Sir Philip Egerton, Bart. F.G.S.
Dec. 1.	Specimens from Chili.	Capt. P. P. King, R.N. F.G.S.
8.	Fossils from the crag.	Samuel Woodward, Esq.
	Remains of the elephant, rhinoceros, horse, ox, &c., from Kingsland, Middlesex.	W. Hobson, Esq. F.G.S.
9.	Fossils from Malton, Yorkshire.	E. Spencer, Esq. F.G.S.
28.	Vegetable remains from the South Staffordshire coal-field.	Rev. James Yates, F.G.S.
31.	Rock specimens from the neighbourhood of Guanaxuato.	E. Hussey, Esq. F.G.S.
	A Dapedium and other fossils from Lyme Regis.	Roderick I. Murchison, Esq. Sec. G.S.

1831.	SPECIMENS.	DONORS.
Jan. 29.	Specimens of coal from Bovey Tracey, and minerals from Haytŏr Mine.	T. H. Holdsworth, Esq. F.G.S.
	A plate of brown mica.	A. Caldcleugh, Esq. F.G.S.
Feb. 15.	Specimens from the Isthmus of Darien.	John A. Lloyd, Esq. F.R.S.
	Specimens of silicate of copper; of sulphate of barytes containing native silver, of limestone and fossils from Coquimbo in Chili.	A. Caldcleugh, Esq. F.G.S.
	Specimens from the district of Hunter's River, New South Wales, collected by Peter Cunningham, Esq.	John Barrow, Esq. F.R.S.
24.	Casts of Hamites.	Miss Benett.
Mar. 1.	A collection of recent shells and corals from Australia.	Archdeacon Scott, F.G.S.
16.	An Ammonite from the calcareous grit of Seend in Wiltshire.	J. O. Anstie, Esq. F.G.S.
	A Septarium from the gravel at Baldock in Hertfordshire.	H. C. White, Esq. F.G.S
30.	Fossils from the greensand near Warminster.	Rev. B. Richardson, F.G.S.
	A slab of Dudley limestone.	Earl of Dudley.
	Fossil fish from the slate of Engi, in the Canton of Glarus.	Viscount Cole, M.P. F.G.S.
	Specimens from Swan River and Garden Island.	Archdeacon Scott, F.G.S.
	Specimens from the Caucasus.	Colonel Monteith.
April 11.	A collection of bones from the caves and fissures of Wellington Valley, New South Wales.	Major Mitchell, F.G.S.
	Specimens of four genera of recent corals from Sincapore.	R. I. Murchison, Esq. P.G.S.
20.	Geological specimens from Pasco.	H. J. Brooke, Esq. F.G.S.
27.	A collection of fossils from the chalk, greensand, and Weymouth beds.	Miss Benett.
	Fossil corals from Pappenheim and Nattheim.	His Grace the Duke of Buckingham, F.G.S.
	Two specimens of coral from North America.	William Vaughan, Esq.
May 11.	Fossils from the lower greensand in the neighbourhood of Calne, Wilts.	Henry H. Goodhall, Esq. F.G.S.
	Fossils from the coral rag of Yorkshire.	W. D. Saull, Esq. F.G.S.
	A collection of chalk flints, containing organic remains.	Rev. H. Engleheart, F.G.S.
25.	Casts of Coprolites from the chalk, and cast of the jaw of the Megalosaurus.	Rev. Prof. Buckland, D.D. F.G.S.
June 8.	Specimens from the South of Ireland.	T. Weaver, Esq. F.G.S.
	Specimens collected in the mines in the parishes of St. Just, Paul and Gulvall, Cornwall.	W. J. Henwood, Esq. F.G.S.
	Cast of *Fucoides Alleghaniensis.*	G. W. Featherstonhaugh, Esq. F.G.S.
	Fossils from Sheppey.	Rev. H. Engleheart, F.G.S.
	A collection of organic remains from Van Diemen's Land, and of geological specimens from Ems.	Leonard Horner, Esq. F.G.S.
Aug. 1.	The collection of specimens made by Capt. P. P. King, R.N. during his voyage to the southern part of Cape Horn, and Terra del Fuego.	Capt. P. P. King, R.N. F.G.S.
	Coprolites from Lyme Regis.	Rev. Prof. Buckland, D.D. F.G.S.
12.	Specimens of iron ore from the Cerro del Meriado.	Directors of the United Mexican Mining Association.

1831.	SPECIMENS.	DONORS.
Aug. 12.	A block of the Gibraltar bone breccia.	Rev. Prof. Buckland, F.G.S.
	An Orthoceratite from the limestone at Newton on the Moor, near Felton.	Rev. James Cook.
	Four casts of impressions in red sandstone.	H. Witham, Esq. F.G.S.
Sept. 3.	Specimens from the submarine volcano thrown up off the coast of Sicily.	Capt. H. Jones, Royal Engineers.
25.	A collection of geological specimens from Malta and Sicily.	Turnbull Christie, M.D. F.G.S.
28.	Head of an hippopotamus.	Dr. Tebbs.
	Collection of specimens made by Capt. Belcher during his survey on the coast of Africa.	Capt. Belcher, R.N. F.G.S.
	Rock specimens from Lancashire and minerals from Cornwall.	Rev. James Yates, F.G.S.
30.	*Calymena macrophthalma* from Gerolstein, *Calceola sandelina* with the operculum from Blankenheim, and *Cyrtoceratites gracilis* from Weissebach near Dillenburg.	M. F. W. Hoeninghaus.
	Additional specimens from Port St. Julian and the Straits of Magalhaens.	Capt. P. P. King, R.N. F.G.S.
Nov. 21.	A specimen of Mantellia from Portland.	Miss Benett.
28.	Six specimens of Mantellia.	Rev. Prof. Buckland, D.D. F.G.S.
	Specimens from the volcanic island in the Mediterranean.	J. Barrow, Esq. F.R.S.
	A collection of fossils from Lackington Hill near Cheltenham.	S. P. Pratt, Esq. F.G.S.
	Additional specimens illustrative of the mines of Cornwall.	W. J. Henwood, Esq. F.G.S.
Dec. 13.	Specimens found in the clay-iron-stone of the New Hadley Iron-works near Wilmington, Shropshire.	T. H. Holdsworth, Esq. F.G.S.
	Fossils from Weymouth and Brighton.	H. H. Goodhall, Esq. F.G.S.
31.	Fossils from Normandy.	A. Majendie, Esq. F.G.S.
	Cast of the head of the Teleosaurus of Caen.	M. Deslongchamps.
	Fossils from the rock of Gibraltar.	Lieut.-Col. Harding, F.G.S.
1832.		
Jan. 7.	A fossil fish from the magnesian limestone.	J. W. Collings, Esq.
	Specimens from the Crimea.	Baron S. Chaudoir.
12.	Fossils from Dundry Hill.	H. H. Goodhall, Esq. F.G.S.
	Fossil corals from Flintshire.	John Taylor, Jun. Esq. F.G.S.
25.	Specimens of coal from the United States of America, from South Wales, and Staffordshire.	Arthur Aikin, Esq. F.G.S.
	Specimens from Stonesfield, and from the lias and oolites of the neighbourhood of Cheltenham.	R. I. Murchison, Esq. P.G.S.
Feb. 11.	Corals from the mountain limestone of Ireland.	Viscount Cole, M.P. F.G.S.
18.	A specimen of the new volcanic island off Sicily.	Baron Field, Esq.
25.	Leucite from Vesuvius.	John Kenyon, Esq. F.G.S.
	Minerals from Devonshire and Cornwall.	T. H. Holdsworth, Esq. F.G.S.
	Tusk of a Mammoth found in the gravel near Nine Elms, Surrey.	C. Larkin Francis, Esq. F.G.S.
	Chalk flints from Hemel Hempstead.	H. C. White, Esq. F.G.S.
	Cast of the head of a crocodile found in the London clay at Sheppey.	E. Spencer, Esq. F.G.S.

1832.	SPECIMENS.	DONORS.
Feb. 25.	An agate from the trap of Edinburgh.	A. Majendie, Esq. F.G.S.
	Chalk flints from the neighbourhood of Salisbury.	Rev. C. Watkins.
Mar. 9.	A specimen of Leucitic lava from Civita Castellana.	A. Majendie, Esq. F.G.S.
	Fossil wood from the Isle of Sheppey.	Viscount Cole, F.G.S.
16.	Casts of two toe-bones found near Cuckfield.	R. Trotter, Esq. F.G.S.
	Cast of the Duke of Buckingham's Plesiosaurus.	F. Chantrey, Esq. F.G.S.
	Cast of the *Plesiosaurus macrocephalus*, and of a tooth of the Deinotherium.	Viscount Cole, M.P. F.G.S.
	A slab of Dudley limestone.	Dr. Bostock, F.G.S.
	A specimen of Murchisonite.	R. I. Murchison, Esq. P.G.S.
26.	Fossils from the neighbourhood of Bath.	A. Majendie, Esq. F.G.S.
28.	Minerals and fossils from North America.	Dr. Macauley.
April 4.	Three casts of Asterias from the chalk.	Samuel Woodward, Esq.
10.	Indian palms and Cycadeæ.	The Hon. the Directors of the East India Company.
	Specimens from the neighbourhood of Lisbon and Oporto.	D. Sharpe, Esq. F.G.S.
	A specimen of a recent freshwater sponge and fossils from the chalk.	Rev. H. Engleheart, F.G.S.
	Specimens from Charnwood Forest.	T. H. Holdsworth, Esq. F.G.S.
	Fossils from the Weald clay and Hastings sand.	Gideon Mantell, Esq. F.G.S.
18.	Recent shells from the coast of Devonshire.	Mrs. Lane.
May 1.	Fossils from Buckinghamshire and Oxfordshire.	J. R. Wright, Esq. F.G.S.
3.	Specimens from the neighbourhood of Cheltenham.	R. I. Murchison, Esq. P.G.S.
4.	Specimens of sulphate of strontia and hæmatite from the neighbourhood of Bristol.	Frederick Page, Esq. F.G.S.
14.	A specimen of crystallized magnesian carbonate of lime.	Viscount Cole, M.P. F.G.S.
21.	Specimens from the fossiliferous grauwacke on the borders of Wales and England.	Roderick Impey Murchison, Esq. P.G.S.
	An additional specimen of Acatama iron.	W. Parish, Jun. Esq. F.G.S.
June 6.	Flints from the chalk of the neighbourhood of Farleigh near Salisbury.	Rev. C. Watkins.
	Specimens of semiopal from Dartmoor.	J. H. Deacon, Esq. F.G.S.
	Cast of a fish found in the coal measures near Leeds.	The Leeds Philosophical Society.
	Fossils from the lias of Rugby.	George T Fox, Esq. F.G.S.
8.	A collection of fossils found in the London clay at Highgate Archway.	N. T. Wetherell, Esq. F.G.S.
Aug. 6.	Casts of *Scaphites Cuvieri* from the marl of Delaware, and of a tooth of the Mosasaurus from the marl of New Jersey.	Dr. Morton.
	Tusk of an elephant found at Erith in Kent.	Messrs. Munn, Elston and Clark.
	A portion of the fossil tree found at Craigleith quarry.	H. Maclauchlan, Esq. F.G.S.
15.	Fossils from the transition formations on the banks of the Rhine.	John Willimott, Esq. F.G.S.
	Specimens of semiopal and granite veins from Devonshire and Cornwall.	Henry Deacon, Esq. F.G.S.

1833.	SPECIMENS.	DONORS.
Nov. 27.	Specimens from Ceylon.	Dr. Sibbald.
	Specimens from the neighbourhood of Swan River.	Capt. Mangles, R.N.
Dec. 18.	Portion of a metacarpal bone of an ox, from the peat of Woolhampton, between Reading and Newbury.	Robert Hunter, Esq. F.G.S.
21.	Quartz crystals from the coal measures, Monmouthshire.	Mrs. Taddy and Miss Morris.
	Specimens from the district of Peten, South America.	Lieut.-Col. Galindo.
31.	Specimens of Ophiura from the London clay at Child's Hill near Hampstead.	N. T. Wetherell, Esq. F.G.S.
	Specimens of forest marble from the neighbourhood of Castlecomb.	Poulett Scrope, Esq. F.G.S.
1833.		
Jan. 19.	Silver and other ores from the Province of La Plata and from Potosi; also specimens of opalized wood and pebbles from the Uruguay.	Woodbine Parish, Jun. Esq. F.G.S.
	Specimens collected by Capt. Coulthard in Bundelcund.	Royal Asiatic Society of Calcutta.
	A chalcedonic flint from Ridgeway between Dorchester and Weymouth, and recent corals and Serpulæ.	Miss Warne.
Feb. 1.	Specimens from the gold mines of North Carolina.	J. Taylor, Esq. Treas. G.S.
	Specimens of Ludlow rock.	Mr. Jones.
	Specimens of Ludlow rock.	G. Proctor, Esq.
	Fossils from the transition limestone of Shropshire and Herefordshire.	Rev. J. T. Lewis, A.M.
	Specimens of fossil fishes from Mansfield.	R. G. Killaly, Esq. F.G.S.
	Cast of a fossil plant from the coal measures.	Lewis Gower, Esq. F.G.S.
	Specimen of fossil wood from the lower greensand, Apsley Wood near Woburn.	E. Crocker, Esq.
27.	Fossil shells of existing species from the Red Sea.	James Burton, Esq. F.G.S.
	Specimens from the South of Spain.	G.B.Greenough, Esq. P.G.S.
	Coal plants from Cape Breton, Gulf of St. Laurence.	Thomas Bigge, Esq. F.G.S.
	Cast of the lower jaw of the Tetracaulodon.	Dr. Harlan.
	Fossils from Weymouth and France.	Miss Warne.
Mar. 11.	A collection of specimens from the neighbourhood of Bonn.	Leonard Horner, Esq. F.G.S.
	Five specimens of *Cerithium giganteum* from France, and recent shells from the English coast.	Miss Warne.
	Additional specimens illustrative of Mr. Murchison's memoirs on the grauwacke system of the border counties of England and Wales.	Roderick I. Murchison, Esq. F.G.S.
April 30.	Fossils from the neighbourhood of Weymouth.	Rev. Prof. Buckland, D.D. F.G.S. and Henry T. De la Beche, Esq. F.G.S.
	Part of a basaltic column from the Giant's Causeway.	Sir William Blizard.
	Series of specimens illustrative of the geology of Würtemburg, accompanied by a geological map.	Count Fred. Mandelsloh.
	Specimens of Bechite and corals from Devonshire.	Marquis of Northampton, F.G.S.
	Specimens of *Baculites vertebralis*, from Normandy.	Miss Warne.

1833.	SPECIMENS.	DONORS.
May 8.	Specimens from the Isle of Man; of Glarus slate; of ripple-marks in the new red sandstone of Cheshire; and Geodes from the magnesian limestone of Yorkshire.	Sir Philip Egerton, Bart. F.G.S.
	Specimens of kupferschiefer with impressions of fish; and fossils from the Montagne de Fīs.	Viscount Cole, M.P. F.G.S., and Sir Philip Egerton, Bart. F.G.S.
13.	Fish's head from the London clay.	G.S. Nicholson, Esq. F.G.S.
	Cast of the paddle of the Plesiosaurus found at Bedford.	Dr. Lee.
14.	A specimen of the millstone from the Paris Basin.	Prof. Christie, F.G.S.
	Fossils from the chalk of Wiltshire, and silicified wood from the Isle of Portland.	Miss Benett.
June 12.	A specimen of manganese from Upton Pyne and silicified wood from Ava.	Mr. J. De Carle Sowerby.
	Geological specimens from the Brazils.	W. Sturz, Esq.
	Remains of the rhinoceros from the cave of Santo Ciro near Palermo.	Samuel Pratt, Esq. F.G.S.
	Fossils from the mountain limestone and lower coal-shale, county of Fermanagh.	Sir Philip Egerton, Bart. F.G.S.
	Chalcedonic flints from Hemel Hempstead.	Henry C. White, Esq. F.G.S.
	Specimens from the mouth of the Tigris.	W. P. Richards, Esq. F.G.S.

IV. *Miscellaneous.*

1830.	MISCELLANEOUS.	DONORS.
June 16.	Two models to illustrate the coal district of Pontypool.	R. C. Taylor, Esq. F.G.S.
Dec. 15.	Models to illustrate slips in veins.	W. Sturtz, Esq.
1833.		
Feb. 6.	The skeleton of a Dugong, and specimens of *Draco volans* and other Saurians.	Roderick I. Murchison, Esq. P.G.S.
April 30.	A mahogany cabinet, containing in the lower compartment fourteen drawers in which have been arranged by Capt. Basil Hall, R.N., the results of Sir James Hall's experiments on the fusibility of lime, basalt and other rocks, found at the time of his death.	Capt. Basil Hall, R.N. F.G.S.
	Bronze medallion of the late Baron Cuvier.	Roderick I. Murchison, Esq. F.G.S.
	Cast of the bust of Baron Cuvier.	M. David.

PLATES AND MAPS

IN ILLUSTRATION

OF

VOLUME III.

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OF

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EXPLANATION OF THE PLATES.

PLATES I. & II.

Illustrate Mr. Phillips's paper on a Group of Slate Rocks between the rivers Lune and Wharfe.

PLATE I.

The sections contained in this Plate are fully explained in the paper, and in the description accompanying each.

PLATE II.

Geological Map of part of Craven, included between the rivers Lune and Wharfe: p. 5.

PLATE III.

Illustrates Professor Sedgwick and Mr. Murchison's paper on Arran: p. 24.

PLATES IV. V. VI. VII. VIII. IX. X. XI. XII.

Illustrate Professor Sedgwick's paper on the Magnesian Limestone, &c.

PLATE IV.

Nos. 1. 2. 3. & 4. Geological Maps showing the range of the formation through certain parts of Yorkshire: pp. 45. 53. 54. 93. &c.

Figs. 1. 2. 3. Sections showing great dislocations: pp. 113. 114. &c.

PLATE V.

Fig. 1. Section from the Kirkby coal-pits to the escarpment of the magnesian limestone: pp. 56. 57. 80. 81.

Fig. 2. Coast section from Tynemouth to Cullercoats in Northumberland: p. 62.

Fig. 3. Section through the Eppleton, Hetton, and Ellemore coal-pits in the county of Durham: pp. 60. 61. 72. 73. 112.

Fig. 4. A. B. Concretionary structure of the Magnesian Limestone: p. 97.

Plate VI.

Fig. 1. Fault traversing the cliff at Tynemouth: p. 62.

Figs. 2. 3. 4. 5. & 6. Sections showing the occasional want of conformity between the lower red sandstone and the magnesian limestone: p. 74.

Figs. 2. 3. Bramham Moor: pp. 73. 74. 111.

Figs. 4. 5. Quarries west of North Deighton: p. 74.

Fig. 6. Position of the magnesian limestone on the beds of the lower red sandstone in the left bank of the Nid below Knaresborough: p. 74.

Plate VII.

Fig. 1. Section at Clack's Heugh on the south bank of the Wear: pp. 71. 73.

Fig. 2. Quarry at West Bolden: p. 78.

Fig. 3. Concretions of crystalline limestone in the magnesian limestone quarry near Ripon: p. 89.

Fig. 4. Cellular magnesian limestone resting on marl-slate near North-point, east of Durham: p. 79.

Fig. 5. Masses of magnesian limestone on the coast of Durham, south of Castle Eden-dean: p. 91.

Fig. 6. Junction of the upper beds of magnesian limestone with the marls of the new red sandstone near Knottingley: pp. 103. 105. 110.

Plate VIII.

Fig. 1. Palæothrissum magnum: pp. 77. 117.

Fig. 2. Scales of ditto enlarged.

Fig. 3. Fragment of a fossil fish; species not ascertained: p. 117.

Fig. 4. Scales of ditto enlarged.

Plate IX.

Fig. 1. Palæothrissum elegans, S. N.: p. 117.

Fig. 2. Palæothrissum macrocephalum: p. 117.

Fig. 3. Operculum of a large fish: p. 118.

Plate X.

Fig. 1. Fossil fish; not determined: p. 118.

Figs. 2. 3. represent a part of the scales enlarged: p. 118.

EXPLANATION OF THE PLATES.

Plate XI.

Fossil fish : p. 118.

Plate XII.

Fig. 1. Fossil fish ; genus not determined : p. 118.
Fig. 2. Inner part of the scales magnified.
Fig. 3. Fossil fish of the same genus with the preceding, but apparently of a different species.
Fig. 4. represents part of the scales magnified.

N.B. All the preceding fossils, commencing with Plate VIII., were found in the marl-slate of Midderidge and East Thickley *.

Fig. 5. Unknown coralline body.
Fig. 6. Retepora virgulacea : p. 120.
Fig. 7. Internal cast of an unknown Coralline.
Fig. 8. Retepora flustracea : p. 120.

PLATES XIII. XIV. XV. XVI. XVII.

Illustrate the memoir by Professor Sedgwick and Mr. Murchison on the Structure and Relations of the Deposits between the Primary Rocks and the Oolitic Series in the North of Scotland.

Plate XIII.

Sketch of a Geological Map of the North of Scotland. The object being simply to carry the eye to the range of the secondary deposits, no subdivisions have been attempted. Thus in the red colour are included all the primary formations mentioned in this memoir : the pale brown represents the new red sandstone and conglomerate, bituminous schist, coal measures, old red sandstone and conglomerate ; and the dark brown the lias, the oolitic series, and its subordinate coal beds, as described in the present volume : p. 125.

Plate XIV.

Fig. 1. Section from the north coast of Caithness : p. 132.

* The two fossil fish figured in this Plate were found during the passage of the paper through the press, and only one of the specimens is alluded to above (p. 118). No generic and specific names are given to these imperfect specimens : but it may be observed that they do not belong to the genus Chætodon, or to the genus Stromateus. It may be proper to state, that a fossil fish of the genus Palæothrissum occurs abundantly in the coal formation of Saarbruck ; an additional fact to show the near connexion between the fossils of the magnesian limestone and those of the inferior formations. (See p. 99.)

Figs. 2. 5. Sections from the Ord of Caithness and the Maiden Paps to the upper red sandstone of Dunnet Head : pp. 135. 141.

Fig. 3. Section from Ben Wyvis to the North Sutor of Cromarty : pp. 145. 148. 149.

Fig. 4. Section from the hills of Spey through the extreme point of Tarbet Ness to the granitic hills of Sutherland : p. 150, &c.

Fig. 5. Section through the Maiden Paps and Scarabins : pp. 138. 139.

Plate XV.

Figs. 1. 2. 3. Dipterus macropygopterus. Of these fig. 1. is the most perfect specimen, showing a pointed anal fin prolonged nearly as far as the inferior lobe of the caudal fin : p. 143.

Fig. 2. This specimen is represented with the belly upwards, and the double fin of the back downwards. (See the bend of the lateral line.)

Fig. 3. In this the caudal fin is less clearly seen than in No. 1., although the generic and specific characters are not wanting.

Fig. 4. The genus Dipterus restored in all its parts. (A sketch by the hand of Baron Cuvier.) : p. 142.

Plate XVI.

Figs. 1. & 3. Dipterus Valenciennesii : p. 143.

Fig. 2. Dipterus macrolepidotus (young) : p. 143.

Figs. 4. & 5. Fragments of Dipterus macrolepidotus : p. 143.

Fig. 6. Fragment of Trionyx : p. 144.

Fig. 7. Operculum of Dipterus.

Plate XVII.

Figs. 1. 2. 3. Dipterus brachypygopterus : p. 143.

PLATES XVIII. XIX. XX.

Illustrate Mr. De la Beche's paper on Tor and Babbacombe Bays.

Plate XVIII.

Contains a Geological Map of the coasts of Tor and Babbacombe Bays, and Sections. pp. 162. 163. 166. 169.

Plate XIX.

Examples of contorted carboniferous limestone near Torquay, showing that the curvature of the strata has been effected in all directions : p. 165.

EXPLANATION OF THE PLATES.

Plate XX.

An undescribed fossil from the carboniferous limestone in the vicinity of St. Mary Church, probably allied to the Tunicata: p. 164, note.

PLATES XXI. XXII. XXIII. XXIV.

Illustrate Mr. De la Beche's paper on Nice.

Plate XXI.

Geological Map of the environs of Nice, and of the coast thence to Vintimiglia. The dolomite and compact, light-coloured limestone are represented of one colour, as they are so intermingled that they could not be separated without rendering the Map confused. These rocks, together with the gypsum, are considered as an equivalent of some part of the oolite formation of England; but recent observations have shown that they may also be some modification of the great green sand series. As this point has not yet been cleared up, the original reference to the oolite formation has been retained: p. 175.

Plate XXII.

A general view of the coast of the Mediterranean as seen from Mont Moron near Nice: p. 171.

Plate XXIII.

Various sections, showing the relative positions of the compact limestone, dolomite with gypsum, the green sand, and the tertiary rocks.

Fig. 1. Section from the sea near Nice to Mont Revel.

Fig. 2. Section from the Var near Ste. Marguerite to St. Sauveur: p. 176.

Fig. 3. Section from the Fanal or light-house at the point of St. Hospice peninsula to Drap on the Paglion Torrent.

Fig. 4. Coast section from Roccabruna to the river Nervia, on the road from Vintimiglia to Genoa: p. 178.

Plate XXIV.

Fig. 1. Natural section of the contact of the sub-Apennine clay-marl and rolled-pebble-conglomerate in the valley of la Maddelaine (the conglomerate resting apparently unconformable upon the clay-marl). There are two or three exhibitions of the same nature in the neighbourhood. The more general character, at least on the points of contact of these rocks, is an interstratification and alternation of the one with the other: p. 176.

Fig. 2. Section of a cleft containing osseous breccia at the Castle Hill of Nice: p. 173.

PLATES XXV. XXVI.

Illustrate Captain Franklin's paper on the Geology of a Portion of Bundelcund, Boghelcund, and the districts of Saugor and Jubulpore.

Plate XXV.

Geological Map of the Country: p. 191.

Plate XXVI.

Section from Mirzapore to Jubulpore.

PLATE XXVII.

Illustrates Professor Buckland's paper on the Pterodactyle.

Fig. 1. Pterodactylus macronyx: p. 220—222.

Fig. 2. Extremities restored: p. 220.

Fig. 3. Jaw from the lias at Lyme Regis, supposed to be of a Pterodactyle: p. 220.

PLATES XXVIII. XXIX. XXX. XXXI.

Illustrate Professor Buckland's paper on Coprolites.

Plate XXVIII.

Figs. 1. to 9. inclusive. Specimens of Sauro-coprus exhibiting the external spiral structure of these bodies: the number of folds varies in different specimens—compare them with the recent injected intestines, Plate XXXI. figs. 19. 20. 21. 22.

Figs. 10. 11. Longitudinal sections of Sauro-copri, exhibiting the cone-like structure of their interior similar to that of fig. 8. Plate XXXI., but the latter is in an inverted position.

Fig. 12. Transverse section of a Sauro-coprus, showing the spiral folding of the lamina of digested bone of which it is composed; and also showing the transverse sections of fish-scales included in it.

Figs. 1. 2. 4. 9. show the transverse fracture at the upper end of the folded laminæ of digested bone.

Figs. 6. & 7. show minute superficial impressions derived from the vessels of the intestines in which they were formed.

Figs. 8. & 9. have large rugose impressions derived also from pressure of the intestines. Small fish-scales are seen on the surface of figs. 6. & 9.

Fig. 4. is black, and is the specimen which Dr. Prout's analysis shows to be coloured probably by Sepia.

PLATE XXIX.

Fig. 1. Large Coprolite, showing the transverse section at the upper end of its folded lamina, and containing fish-scales.

Fig. 2. Portion of a large Coprolite in the collection of Captain Waring, containing an undigested vertebra of Ichthyosaurus and fragments of other large bones.

Fig. 3. Opposite side of fig. 2. exhibiting the same vertebra, and two smaller ones.

Fig. 4. Part of the largest Coprolite yet discovered at Lyme, exhibiting vertebræ of Ichthyosaurus at its fractured surface.

Fig. 5. Portion broken from fig. 4. showing the same vertebræ, and the coracoid bone of an Ichthyosaurus imbedded in it: this bone has been transferred in the drawing to A, from its real place at B, on the other side of the specimen.

PLATE XXX.

Figs. 1. to 12. inclusive, are Coprolites from the lias at Lyme Regis.

Fig. 1. Sauro-coprus, containing rings, resembling the horny rings in the cups of the suckers of Sepiæ; it also shows the edge of the folded lamina.

Fig. 2. Sauro-coprus full of fish-scales, and at the point A containing a congeries of small rings resembling those at the extremity of the arm of a small Sepia.

Fig. 3. Magnified appearance of the rings at A. fig. 2.

Fig. 4. Coprolite full of fish-scales, and exhibiting no traces of folded structure.

Fig. 5. Amorphous Coprolite, thin and flattened; it appears to have been evacuated in a semi-fluid state before it was moulded to the usual shape in the intestines.

Figs. 6. to 12. inclusive. Small Coprolites from the lias at Lyme Regis, resembling many of those in the lias on the Severn; they are without spiral structure.

Figs. 7. 10. 11. & 12. have small fish-scales in them.

Figs. 13. to 29. inclusive. Coprolites from the bone bed in the lowest lias at Westbury-on-Severn, Aust Passage, and Blue Anchor near Watchet; they are mostly black, smooth, and glossy; and many of them have small round points (like those on urinary calculi) irregularly projecting from their surface, but they contain no uric acid; it is unknown from what animals they are derived; few of the forms here represented occur among the Coprolites at Lyme Regis.

Figs. 17. & 18. exhibit on their surface a convoluted structure.

Fig. 19. contains small scales and fragments of small bones: scales and bones are rare in the Coprolites from the Severn district.

Figs. 26. 27. have the shape of tamarind stones, and a kind of case or epidermis, as if formed by secretion, round their margin.

Fig. 28. in shape resembles a kidney bean.

Fig. 29. seems to be a fragment of a broken sphere, and in shape resembles fig. 30.

Fig. 30. is a concretion of phosphate of lime from a human gall-bladder.

Figs. 31. to 41. inclusive, are small Coprolites of various shapes from the bone bed near the bottom of the carboniferous limestone at Clifton near Bristol.

PLATE XXXI.

Figs. 1. to 7. inclusive. Specimens of Iulo-eido-coprus from the chalk and chalk-marl of Sussex; the wavy lines and corrugations on their surface are apparently derived from the intestines in which they were formed. See the surface of the recent intestines, figs. 20. & 21.

Figs. 9. 10. 11. Iulo-eido-copri, from Maestricht, in the collection of Col. Houlton of Farley Castle.

Figs. 2. & 11. at their larger extremity show the edge of the thin winding plate, the coils of which around itself make up the body of the Coprolite.

Fig. 6. exhibits scales of fishes imbedded in the substance, and parallel to the surface of the lamina of digested bone. See a similar parallelism in the scales and lamina of fig. 12. Plate XXVIII.

Fig. 8. Longitudinal section of fig. 7. showing the conical arrangement of the interior, like that at Plate XXVIII. figs. 10. 11. but inverted.

Fig. 11a. Coprolite figured as an unknown fruit in Burtins' *Oryctogr. de Bruxelles*, Pl. V. G.

Fig. 12. Amia-coprus from the chalk near Lewes, found by Mr. Mantell within the skeleton of an Amia: p. 234.

Fig. 13. Coprolite from the chalk at Lewes; not yet ascertained from what animal.

Fig. 14. Coprolite purchased by Dr. Buckland in a collection of fossils from the Isle of Sheppey.

Fig. 15. Coprolite from the freshwater coal shale at Fuveau near Aix, in the collection of Mr. Murchison.

Fig. 16. Coprolite from the freshwater marl containing insects above the gypsum at Aix, in the collection of Mr. Murchison.

Fig. 17. Coprolite from the green sand of Wiltshire.

Fig. 18. Coprolite, from the sandstone of Tilgate Forest, in the collection of Mr. Mantell. See fish-scale on its surface.

Figs. 19. 20. 21. Intestines of Dog-Fish injected with Roman cement, showing spiral coils; and in figs. 20. 21. exhibiting vascular structure, as on the surface of figs. 1. 4. 5. 9. 11.

Fig. 22. Intestine of a Skate injected with Roman cement; the external coil marking the spiral fold of its interior.

EXPLANATION OF THE PLATES.

PLATE XXXII.

Six sections to illustrate Mr. Lonsdale's paper on the Neighbourhood of Bath.

PLATES XXXIII. & XXXIV.

Illustrate Mr. Murchison's paper on the Fossil Fox found at Œningen.

Plate XXXIII.

The Fossil Fox.

Plate XXXIV.

Outline of the Fossil Fox. (See Mr. Mantell's anatomical description, p. 291.)

PLATES XXXV. XXXVI. XXXVII. XXXVIII. XXXIX. & XL.

Illustrate the paper of Professor Sedgwick and Mr. Murchison on the Eastern Alps.

Plate XXXV.

Map of the Eastern Alps.

The accompanying geological Map has been constructed chiefly from the observations of Mr. Murchison, during his visits to the Central and Eastern Alps in the years 1828, 1829 and 1830. The leading points elucidated in the memoir having been also examined by Professor Sedgwick in 1829. The portion of the southern flanks of the Alps which includes the districts of Verona, Vicenza, Monte Bolca, and the Euganean hills, is coloured from observation made during an excursion with Mr. Lyell in 1828. The adjoining district of Bassano was afterwards examined by Mr. Murchison alone (see Phil. Mag. and Annals of Philosophy, N. S. 1829), who in the same year travelled through the valleys of the Adige and Fassa, and portions of the Southern and Northern Tyrol.

A very large portion of the Map has necessarily been coloured from the authority of other observers; and in the first rank of merit among these must be mentioned an unpublished geological Map of the Archduchy of Austria by Dr. Boué, presented by him to the Geological Society of London*.

This map was found to harmonize, in most respects, with the observations of the authors in the same district; and the points on which they differ from Dr. Boué, have been detailed in the memoir. Considerable insight into the general struc-

* M. Boué intends to publish this map, which has recently been returned to him for that purpose, by the Council of the Geological Society.

ture of the chain was obtained by consulting an original map of great merit, executed many years since by Mr. Greenough: much assistance has also been received from M. P. Partsch of Vienna, and great obligations are due to Mons. de Buch, the reputed author of the general map of Martin Schropp & Co. The geological features of the southern part of Styria, including the Bacher and Matzel Gebirge, are chiefly taken from an original map executed by several Austrian geologists, under the direction of His Imperial Highness the Archduke John, and presented by him to the Geological Society of London. For the map of all those parts of Styria which lie within, or surround the basin of Gratz, the authors are, however, personally responsible.

A tertiary deposit is marked at Guttaring, far within the area of the primary rocks, on the authority of M. Keferstein, whose general maps have also been consulted. M. Necker de Saussure has pointed out the occurrence of a tertiary deposit at Kropp on the Save in the Alps of Carniola, where it reposes on secondary limestone (*Ann. des Sciences Naturelles*, vol. viii.). The same author has also shown the existence of a ridge of primary rocks, succeeded, between Schio and Recoaro, by others of various secondary ages. This remarkable outbreak takes place on the confines of the cretaceous series being accompanied by new porphyritic rocks which overlie the scaglia, and are probably of the same age as the Euganean trachytes. A phenomenon similar in many respects, though on a smaller scale, is seen in the northern flank of the Alps (Sonthofen, Bavaria), which is described in detail in this Memoir, p. 333, 334. Section, Pl. XXXVI. fig. 4.

The great expanse of green-sand and "scaglia" in the neighbourhood of Feltre, is inserted from the works of Professor Catullo *.

In the highest group, No. 1. of the map, are comprehended all the accumulations from the most recent alluvions down to the coralline, tertiary limestone of the Leitha hills near Vienna, and of Wildon &c. near Gratz. Under this colour, therefore, is represented the greatest superficial range of tertiary deposits around the Alps, particularly all those at a considerable distance from the edges of the chain.

No. 2. represents the middle and older tertiary formations, and is supposed to commence with deposits of the age of those of "Bourdeaux," and to end in the period of the "calcaire grossier." This group is found in bands and patches close along the edges of the Alps (from Bregenz to Füssen, for example,) in the forms of molasse, sandstone and conglomerate, and again in various parts of the valley of the Danube, usually in the state of marl with shells, as near Traunstein on the Alpine side, or near Ortenburgh and Pielach on the flanks of the Bohemian chain. The coal-field of Häring is assigned to the lower part of this group.

On the southern flank of the Alps the shelly deposits of the Vicentin, described by M. Brongniart, and those of Bassano, by Mr. Murchison, are amongst the most unequivocal exhibitions of these formations.

No. 3. The copperas green colour marks a peculiar shelly deposit unknown in

* The colours are only intended to indicate great groups of strata, the subdivisions of which, whether in the secondary or tertiary system, will be found in the Plate of Sections.

England, and nearly so in France and Germany, but extensively developed within, as well as on the skirts of, the Alpine chain; as at Gosau in the one case, and at Kressenberg in the other. The term "Gosau Deposits" is adopted to prevent all ambiguity, and they are shown to be supra-cretaceous in figures 6, 7, 9, and 13 of the Plate of Sections. For various patches of this formation see the Map. M. Boué has traced it into the Carpathian chain. The iron ore of the Kressenberg is placed in this group.

No. 4. comprehends all the strata from the scaglia or red chalk of the Southern Tyrol down to the base of the green-sand series, in the lowest term of which the authors place the Vienna grit or sandstone. See particularly figs. 4. and 5. of Plate XXXVI. The iron ore of Sonthofen is in the upper or cretaceous part of this group.

No. 5. This group, comprehending the Alpine and Jura limestones with dolomite, &c. includes the whole of the oolitic series and lias, and most of the salt-breccias or rock salt, as well as the principal lead veins of the Alps.

No. 6. The ferruginous red colour represents a group supposed to be of the same age with the new red sandstone and magnesian limestone. Salt and gypsum occur in it, though not in such abundance as in the limestone No. 5.

No. 7. The term "old slaty rocks" is here applied in a very comprehensive sense, and embraces every formation from the primary crystalline rocks, up to those of true transition type, occasionally containing organic remains.

(Spathose iron ore is most abundant in this class of rocks, though it does sometimes occur in granitoid rocks, and also in primary limestone.)

No. 8. represents the granitic axis of the chain, the general direction of which bears from W.S.W. to E.N.E. A remarkable bifurcation takes place near its eastern extremity, the southern branch of which stretching out into the Pach and Kor Alps, and thence into the Bacher-Gebirge, encircles the tertiary basin of Lower Styria; whilst the northern branch or continuation of the principal chain separates the Styrian basin from that of Vienna. It reappears in the Leitha Gebirge, and again beyond the Danube in the Carpathians.

The intrusive or igneous rocks are designated under two colours only, it having been found impracticable in a map of this scale to make a further separation of the different rocks of volcanic origin.

a. All volcanic rocks which traverse the tertiary or secondary deposits.

b. Older porphyries (as in the Southern Tyrol) which were consolidated anterior to the formation of the new red sandstone.

Plate XXXVI.

Sections.

This Plate contains sixteen transverse sections illustrative of the structure of the secondary and tertiary formations of the Eastern Alps. Fig. 1. is an ideal section, and is prefixed to convey a general notion of the structure of the chain, and of the relations of the above-mentioned deposits to an axis of primary and transition rocks, and also to mark the great difference in the elevation of the youngest deposits on the north and south side of the chain *. The colours are modifications of those used in the Map, each subformation being distinguished by a tint of the colour of the great group of formations to which it belongs. (*Vide* Map.)

The horizontal distances in the detailed sections are proportioned to each other. The altitude of the mountains is much exaggerated with relation to the horizontal distances, and the culminating peaks of each section have reference only to the contiguous valley or river, without any regard to their actual height above the sea level.

R. I. M.

Plates XXXVII. XXXVIII. & XXXIX. represent unpublished species of organic remains in the Eastern Alps.

Gosau.

Plate XXXVII.

Fig. 1. Turbinolia aspera.
Fig. 2. Cyathophyllum rudis.
Fig. 3. ——— compositum.
Fig. 4. Astrea grandis.
Fig. 5. ——— media.
Fig. 6. Astrea formosissima.
Fig. 7. ——— ambigua.
Fig. 8. ——— tenera.
Fig. 9. ——— ramosa.

Gosau.

Plate XXXVIII.

Fig. 1. Nucula concinna.
Fig. 2. Pectunculus calvus.
Fig. 3. Crassatella impressa.
Fig. 4. Corbula angustata.
Fig. 5. Gryphæa expansa, p. 349.
Fig. 6. ——— elongata.
Fig. 7. Plicatula aspera, p. 365.
Fig. 8. Astarte macrodonta.
Fig. 9. Tornatella gigantea.
Fig. 10. Auricula decurtata.
Fig. 11. Natica lyrata.
Fig. 12. ——— angulata.
Fig. 13. Natica bulbiformis.
Fig. 14. Turbo arenosus.
Fig. 15. Trochus spiniger.
Fig. 16. Nerinea flexuosa.
Fig. 17. Solarium quadratum.
Fig. 18. Turritella biformis.
Fig. 19. ——— rigida.
Fig. 20. ——— læviuscula.
Fig. 21. Rostellaria costata.
Fig. 22. ——— plicata.
Fig. 23. ——— granulata.
Fig. 24. ——— læviuscula.

* See De Humboldt's new work (*Fragmens de Climatologie et Géologie*, vol. i. p. 89, note), in which it is stated, that the plateau of Bavaria is 1560 French feet above the sea, whilst the highest plains of Lombardy are only 480 French feet,—making a difference of 1080 French feet as the mean difference of their respective elevations.—December, 1831.

PLATE XXXIX.

Gosau.

Fig. 15. Cardium productum.
Fig. 16. Tornatella Lamarckii.
Fig. 17. Cerithium reticosum.
Fig. 18. ——— conoideum.
Fig. 19. ——— pustulosum.
Fig. 20. Pleurotoma fusiforme.
Fig. 21. ——— spinosum.
Fig. 22. Fascicolaria elongata.
Fig. 23. Fusus heptagonus.
Fig. 24. —— carinella.
Fig. 25. Fusus muricatus.
Fig. 26. —— abbreviatus.
Fig. 27. —— cingulatus.
Fig. 28. Nassa carinata.
Fig. 29. —— affinis.
Fig. 30. Mitra cancellata.
Fig. 31. Voluta acuta.
Fig. 32. Terebra coronata.
Fig. 33. Volvaria lævis.

Lower Styria.

Fig. 1. Lutraria convexa.
Fig. 2. Cardium transversum.
Fig. 3. ——— minutum.
Fig. 4. ——— planicostatum.
Fig. 5. Amphidesma minimum.
Fig. 6. Venus obtusa.
Fig. 7. Pullastra nana.
Fig. 8. Modiola cymbæformis.
Fig. 9. Trochus variabilis.
Fig. 9*a*. ——— (recent, p. 395.)
Fig. 10. Cerithium pulchellum.
Fig. 11. ——— lineolatum.
Fig. 12. ——— disjunctum.
Fig. 13. ——— turritella.
Fig. 14. Buccinum duplicatum.

PLATE XL.—(*Lithographic View of Gosau-thal.*)

In the foreground are the church and principal village of Gosau-thal. The wooded mountain on the right is the Horn, that on the left is the Ressenberg; the summit of the former being composed of reddish, gritty sandstone, the latter of greenish, micaceous whetstone; and both are based upon blue marls with a profusion of shells, which are best exposed in deep ravines right and left of the spectator.

The steep and arid peaks in front consist of Alpine limestone, chiefly considered as the equivalents of the oolitic series, and are called in the neighbourhood the Stein Gebirge, each peak being known by a local name, as the "Donner Kogel," "Henner Kogel," &c.

PLATE XLI.

Illustrates Dr. Buckland's memoir on Fossil Bones of the Iguanodon found in the Iron Sand of the Wealden Formation in the Isle of Wight and Isle of Purbeck: p. 425.

Plate XLII.

Map to illustrate Mr. R. C. Taylor's account of a part of the Mineral Basin of South Wales, in the vicinity of Pontypool. The portion of the Map coloured represents the mountain limestone; the portion uncoloured, the coal measures: p. 433.

PLATE XLIII. to XLVI.

Illustrate Mr. Clift's memoir on the Megatherium: p. 437.

Plate XLIII.

A copy of a portion of a Manuscript Map in the possession of Woodbine Parish, Jun., Esq., which comprehends that part of Spanish America in which those Remains of the Megatherium which have hitherto been sent to Europe were chiefly discovered.

No. 1. Denotes the situation on the River Lujan (or Luxan) whence the bones were derived which were sent to Spain in 1789 by the Marquis of Loreto, and from which were constructed the Skeleton of the Megatherium now preserved in the Royal Cabinet of Natural History at Madrid, described and figured by Don Juan Bautista Bru, and published by Don Joseph Garriga, under the title "*Descripcion del Esqueleto de un Quadrúpedo muy corpulento y raro,*" Madrid, 1796:—and by Messrs. Pander and D'Alton under the name of "*Das Riesen-Faulthier, Bradypus giganteus,*" Bonn, 1821.

No. 2. Rincon de Sosa, (situated in the southern part of the Map,) the property of Don Hilario Sosa, on the banks of the River Salado, the spot on which were discovered the Bones which form the subject of the present paper. Not any portion of Shell or Cuirass was found at this spot.

No. 3. The lake Las Averias, at which locality was found the most perfect example of the Cuirass, imbedded in a stratum of hard clay, at about four feet below the upper surface, together with some bones, which were exposed to view by the occasional beating of the waters against the sides of the Lake in stormy weather. The shell, when first discovered, (according to the assurances of the Peons, or country people, who accompanied the person sent by Mr. Parish to the spot,) was at least twelve feet in length, and from four to six feet in the widest or deepest part. The Bones on being taken out of the earth almost immediately mouldered away. A fragment of the pelvis was all that reached Buenos Ayres. The Skeleton was said to have appeared to be as large as that found at Señor Sosa's.

An external and internal view of a small but characteristic fragment of this Shell or Cuirass is given in Plate LXVI.

No. 4. Villanueva. The bones found at this spot, dug out of the bed of a small rivulet, were of small size, and in a very fragile state, and crumbled to pieces on exposure to the air. Part of a jaw with one very small though nearly perfect tooth in the socket, part of a scapula, and some of the feet-bones were all that were capable of being preserved. The shell lay about a foot below the principal mass of the bones, the concave side uppermost, and resembled the section of a large cask; but would not bear to be lifted out of its bed, broke into small pieces, and crumbled to dust almost immediately.

Plate XLIV.

An outline traced from Plate I. of Messrs. Pander and D'Alton's work above mentioned, with the intention of showing all the parts hitherto known, or supposed to be known, of this extraordinary animal, the Megatherium.

The simple outline represents the state of the skeleton, as now articulated, in the Royal Cabinet of Natural History at Madrid. Whether properly or improperly mounted, i. e. whether all the parts are of one or more individuals, whether they belong to the situation or position in which they are placed, whether all the parts are genuine or partly modelled, or whether parts are eked out by bones that do not belong to the part or situation in which they are now located, does not interfere with the object of the outline in this Diagram; no blame being intended to be attributed to the Articulator, who, probably, had little or no guide in such a difficult task. Upon this outline are engraved up, but in a *faint* degree, 1st, those parts which have been collected and preserved by Mr. Parish that also exist in the Madrid Skeleton; 2ndly, *in a greater degree of strength*, those parts which are preserved in the series of Bones described in this paper which are deficient in the Skeleton at Madrid; thus endeavouring to show at one view the general tenour of the Skeleton, together with all the important points hitherto determined.

Plate XLV.

Fig. 1. represents, of the natural size, the last phalanx of a toe belonging to one of the fore feet. This has been selected as one of the smallest bones, capable of being represented on a quarto plate, that could in any degree give a just notion of the magnitude of the creature to which it appertained; and by comparison with the same bone *in situ* in Plate XLIV. it cannot fail of answering that intention better than the most correct description, or minute detail of admeasurement.

Fig. 2. represents, also of the natural dimension, a molar tooth or grinder, of which class all the teeth of the animal consist. This tooth was selected as one of the largest and most entire among those discovered; but although imperfect as regards its entire length (of which it is about two inches minus at its lower extremity, a fact determined by other specimens, less perfect in other respects), it shows more of its real form and structure than a perfect example could have permitted from any one point of view. This figure shows the inclination of the four facets of which the grinding or cutting surface of the tooth is composed,—the curved and slightly convex form of the anterior part of its body,—its flat side slightly depressed in the centre, and its flat and somewhat concave posterior surface. The fractured lower part permits a view of its square hollow cavity, which contained the vascular pyramidal pulp, on and from which the tooth was continually growing and projected upwards, in proportion as its grinding surface was worn away by attrition.

Plate XLVI.

Two views of a small fragment of the shell or cuirass discovered at Las Averias, and described at No. 3. Plate XLIII., represented of the natural size. Although a considerable number of pieces of this armour have been preserved,—as many, perhaps, as would cover a space of five feet square,—it was difficult to select a portion sufficiently perfect on both surfaces to show its structure satisfactorily. A great part of this covering is incrusted on both surfaces by a very dense calcareous cement, the removal of which always produced more or less injury to the fragile surface. In this example, however, both surfaces are sufficiently perfect to show the relative size and number of tesseræ of which it is composed, and their forms, which are generally irregular hexagons. They are united to each other by indented sutures.

Fig. 1. The external surface.

Fig. 2. The internal surface.

PLATE XLVII.

Sections in North Wales, distinguishing stratification from cleavage; in illustration of Prof. Sedgwick's memoir on the Structure of large mineral masses, p. 461.

Fig. 1. Transverse section through a part of the great chain of North Wales, showing the anticlinal lines. The cleavage planes are omitted: see p. 470.

Fig. 2. Section through the western flank of the chain, as seen on the south side of the great road about seven miles east of Bangor. The beds and cleavage planes are both exhibited: see p. 475.

Fig. 3. Section near Harlech; (*a*) beds, (*b*) cleavage planes: p. 475.

Fig. 4 and 4 *a*. Contorted strata on the left bank of the Towey: pp. 470, 475.

Fig. 5. represents the position of the beds and cleavage planes in a section on the banks of the Wye, a few miles above Rhaiadr: p. 476.

Fig. 6. Arched beds in the slate quarry called Craig y Grebbin, on the road from Llangollen to Ruthin: p. 476.

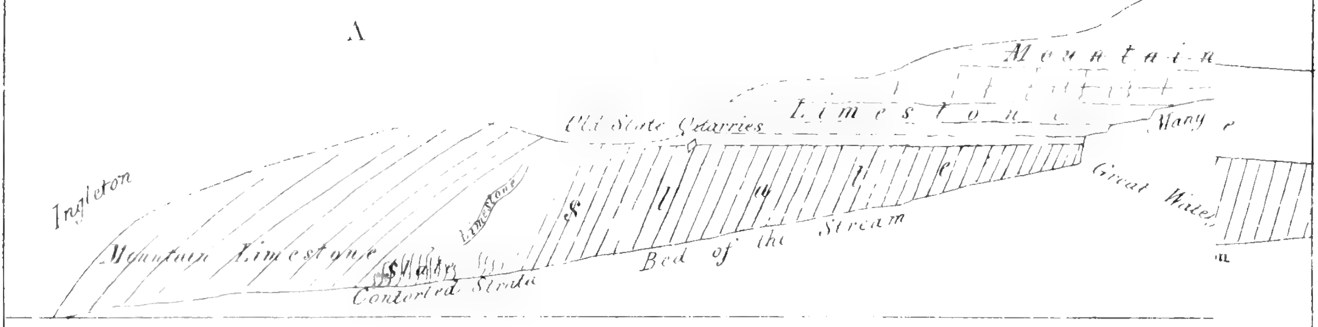
Fig. 7. Section of calcareous slate rock, with subordinate beds of impure limestone, on the west side of Foel Faur, about two miles from Llanrhaiadr: p. 476.

Fig. 8. Profile of a ridge a few miles south-east of Bala. The lines represent the cleavage planes; and the dots the stripes in the slate: p. 477.

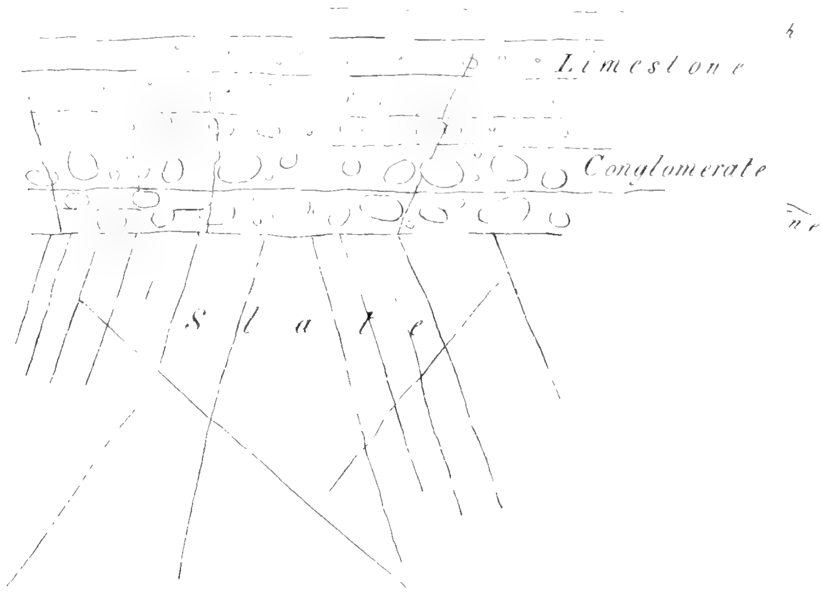
Kingsdale

The Section follows the Stream

(p. 9)



Appearances at the Waterfall in Kingsdale. *(p 10)*



Distant Outline of Ingleborough from the South West.

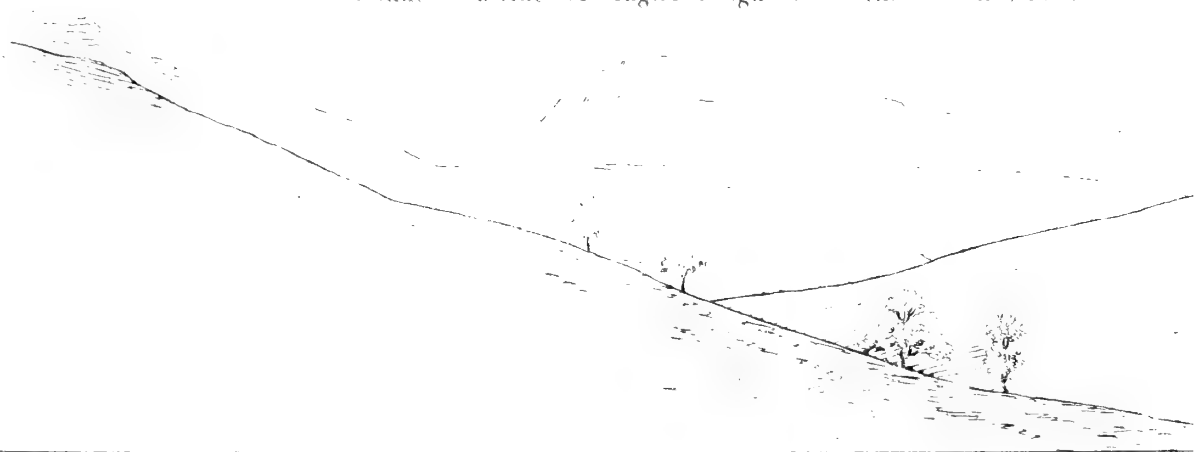


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PLATE XLVII.

Sections in North Wales, distinguishing stratification from cleavage; in illustration of Prof. Sedgwick's memoir on the Structure of large mineral masses, p. 461.

Fig. 1. Transverse section through a part of the great chain of North Wales, showing the anticlinal lines. The cleavage planes are omitted: see p. 470.

Fig. 2. Section through the western flank of the chain, as seen on the south side of the great road about seven miles east of Bangor. The beds and cleavage planes are both exhibited: see p. 475.

Fig. 3. Section near Harlech; (*a*) beds, (*b*) cleavage planes: p. 475.

Fig. 4 and 4 *a.* Contorted strata on the left bank of the Towey: pp. 470, 475.

Fig. 5. represents the position of the beds and cleavage planes in a section on the banks of the Wye, a few miles above Rhaiadr: p. 476.

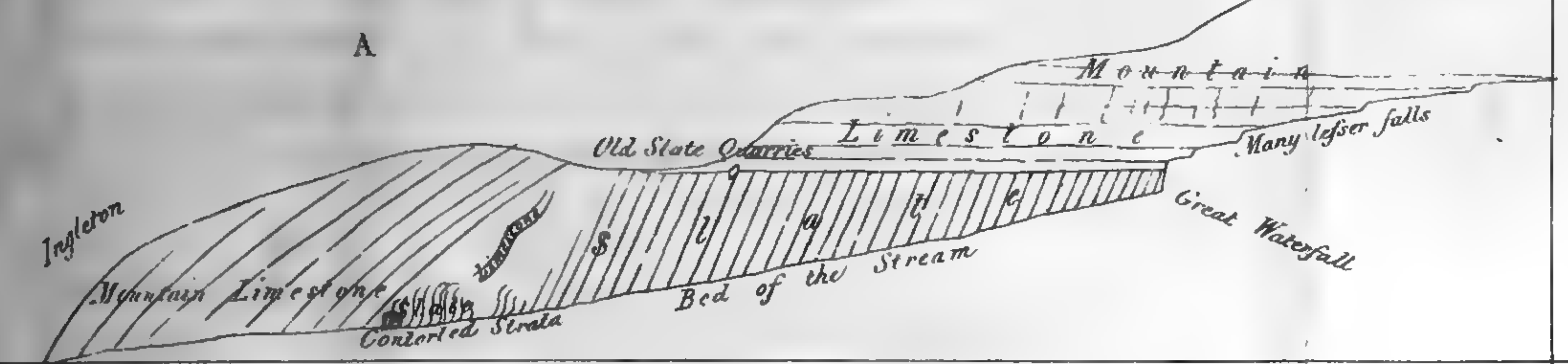
Fig. 6. Arched beds in the slate quarry called Craig y Grebbin, on the road from Llangollen to Ruthin: p. 476.

Fig. 7. Section of calcareous slate rock, with subordinate beds of impure limestone, on the west side of Foel Faur, about two miles from Llanrhaiadr: p. 476.

Fig. 8. Profile of a ridge a few miles south-east of Bala. The lines represent the cleavage planes; and the dots the stripes in the slate: p. 477.

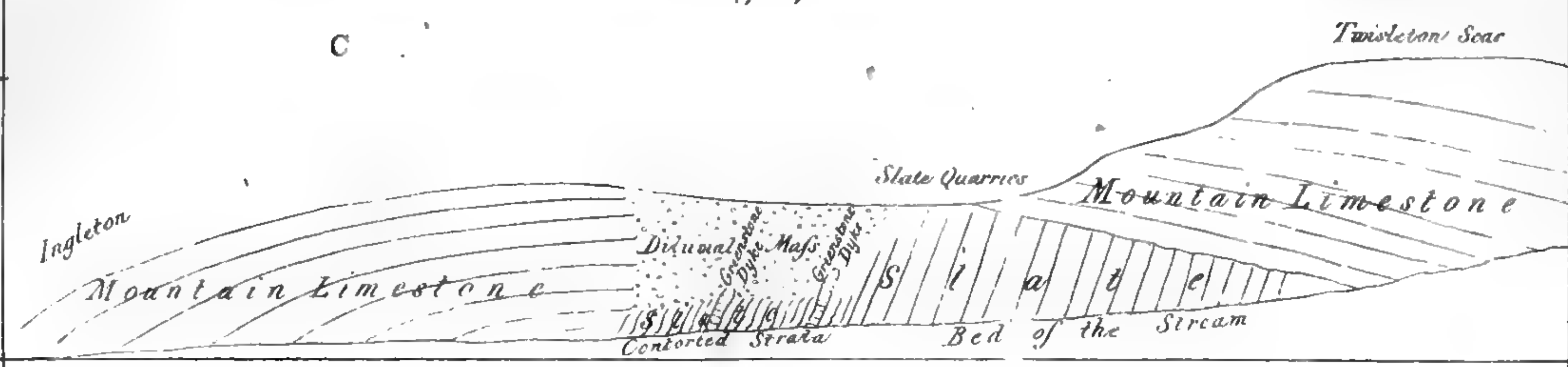
Kingsdale
The Section follows the Stream
(p.9)

A



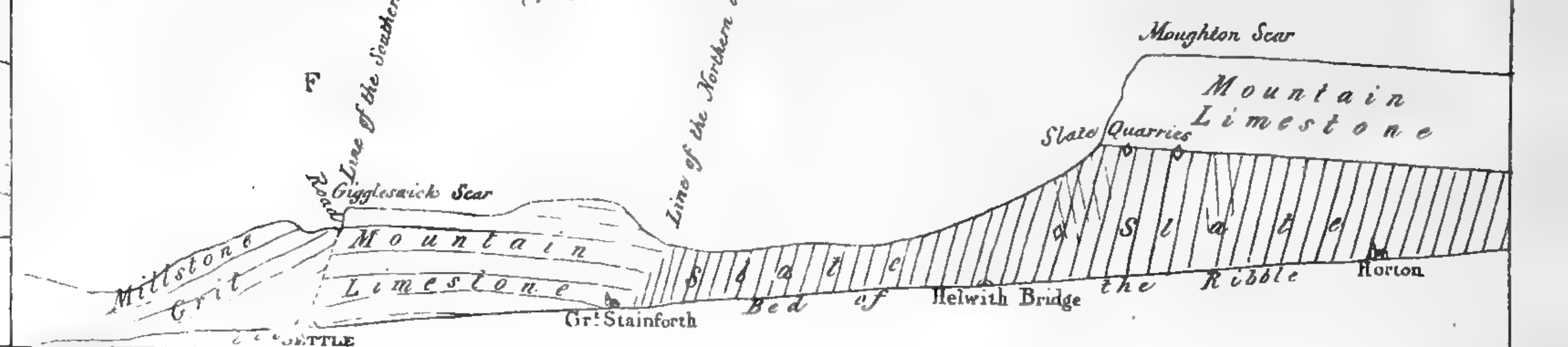
Chapel le Dale.
The Section follows the Stream
(p.11)

C



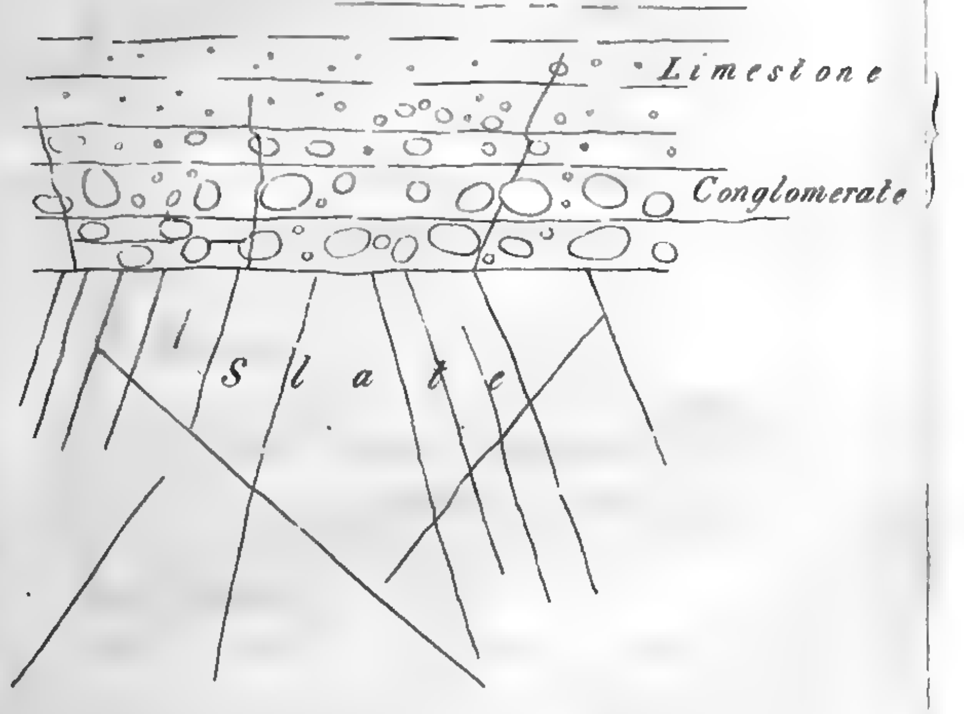
General Structure of Ribblesdale
Line of Section on the West Side
(p.13)

F



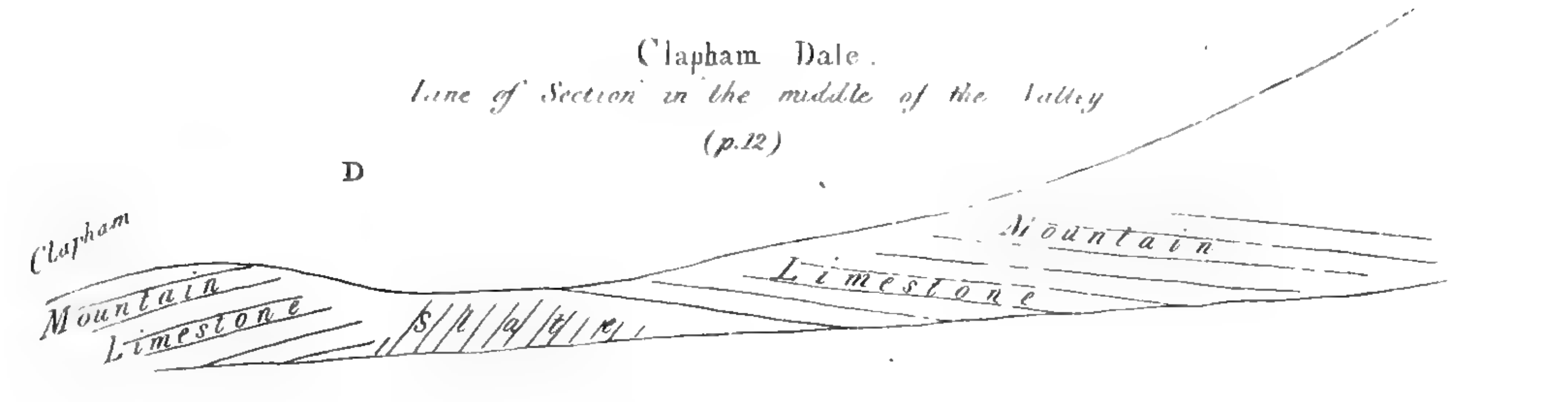
Appearances at the Waterfall in Kingsdale. (p.10)

B

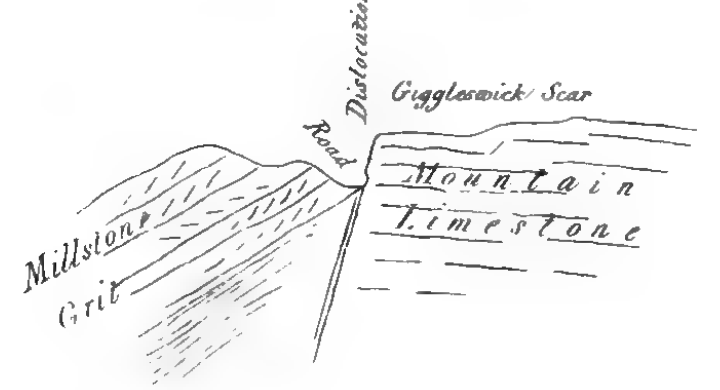


Clapham Dale.
Line of Section in the middle of the Valley
(p.12)

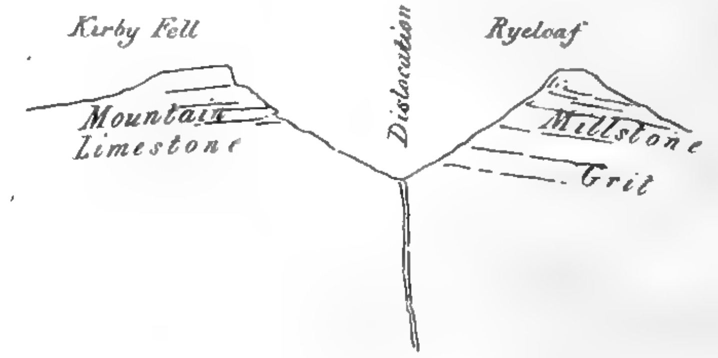
D



G (p.18)

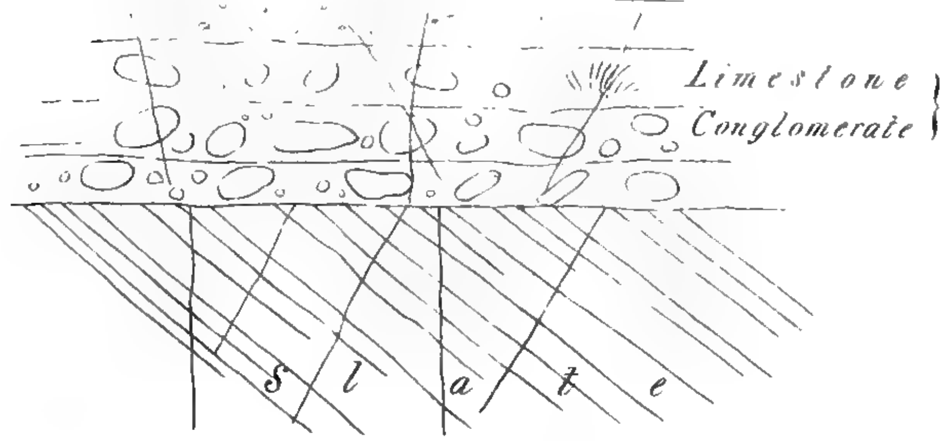


H (p.19)



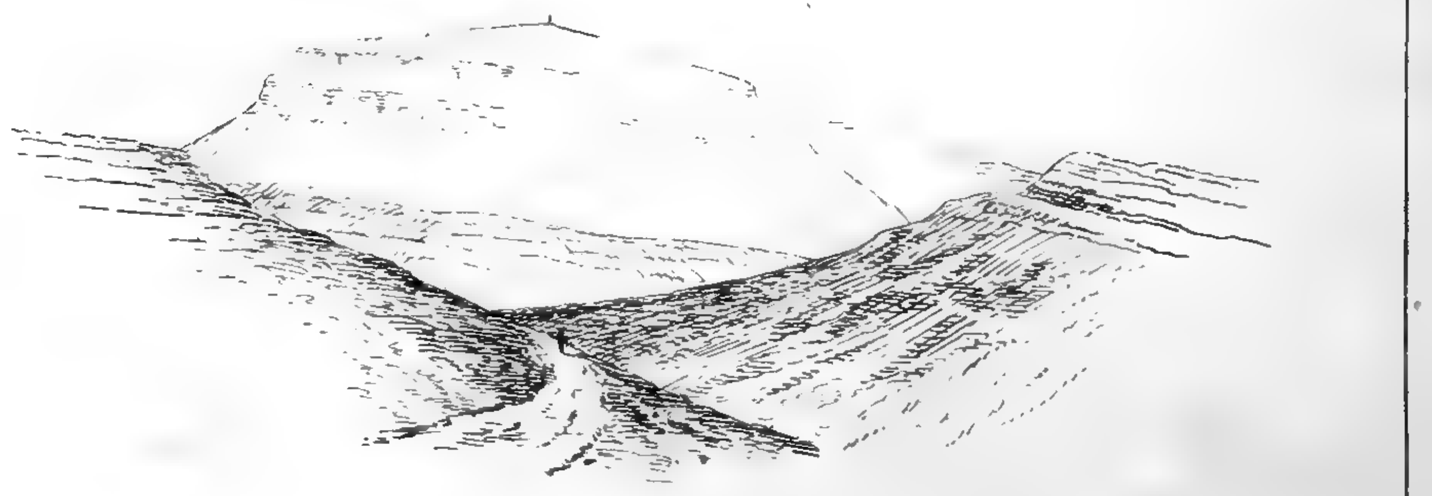
Appearances at the Edge of Moughton Scar. (p.13)

E

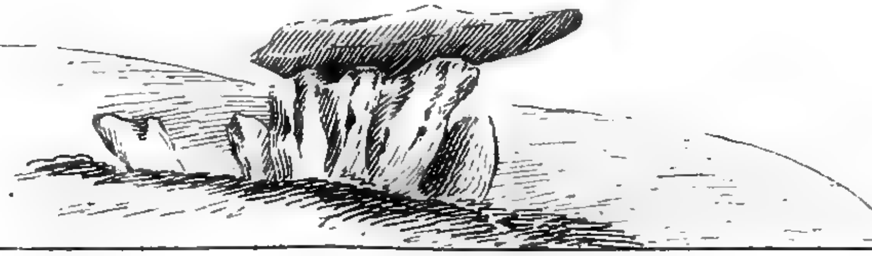


Distant Outline of Ingleborough from the South-West.

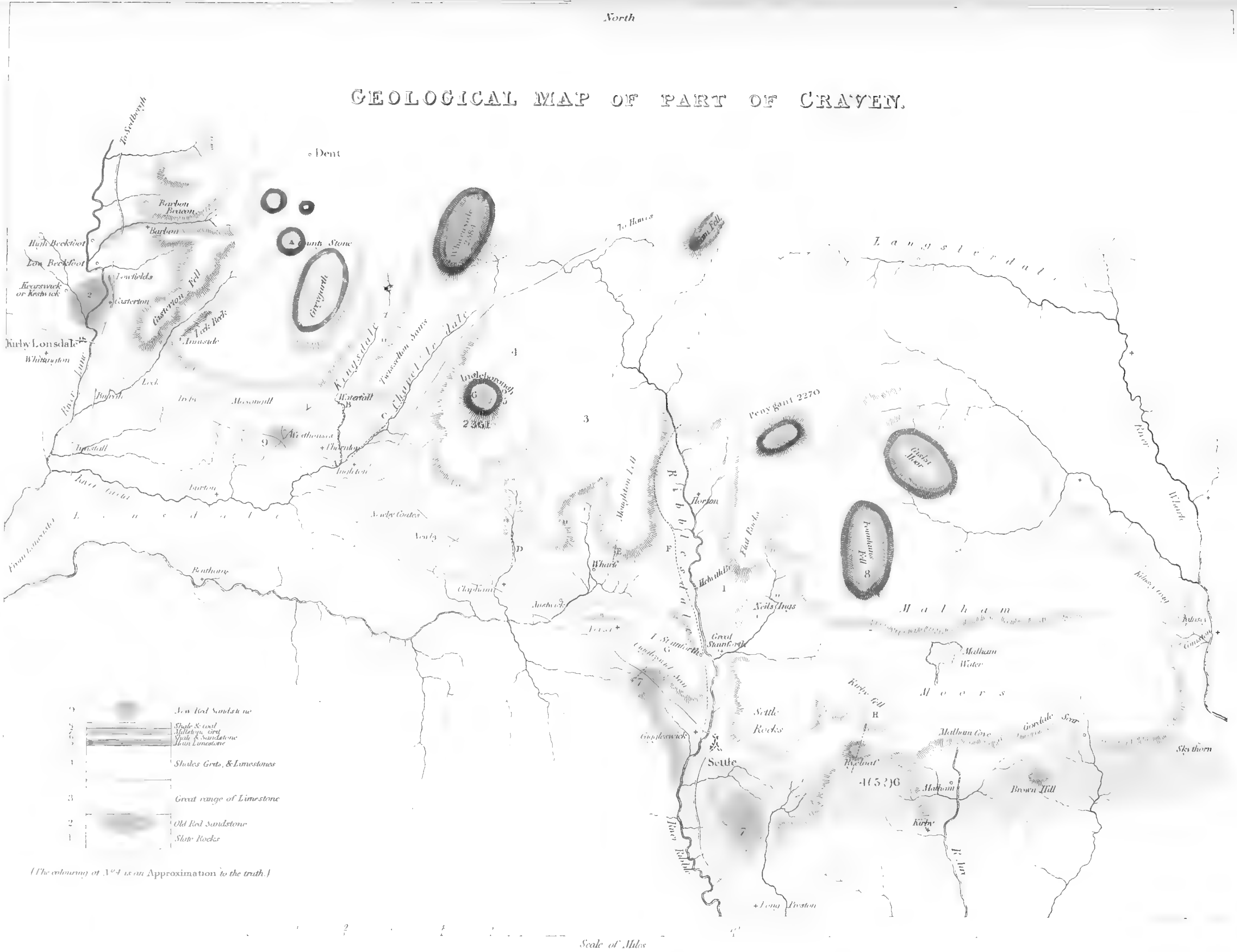
Penygent from the South



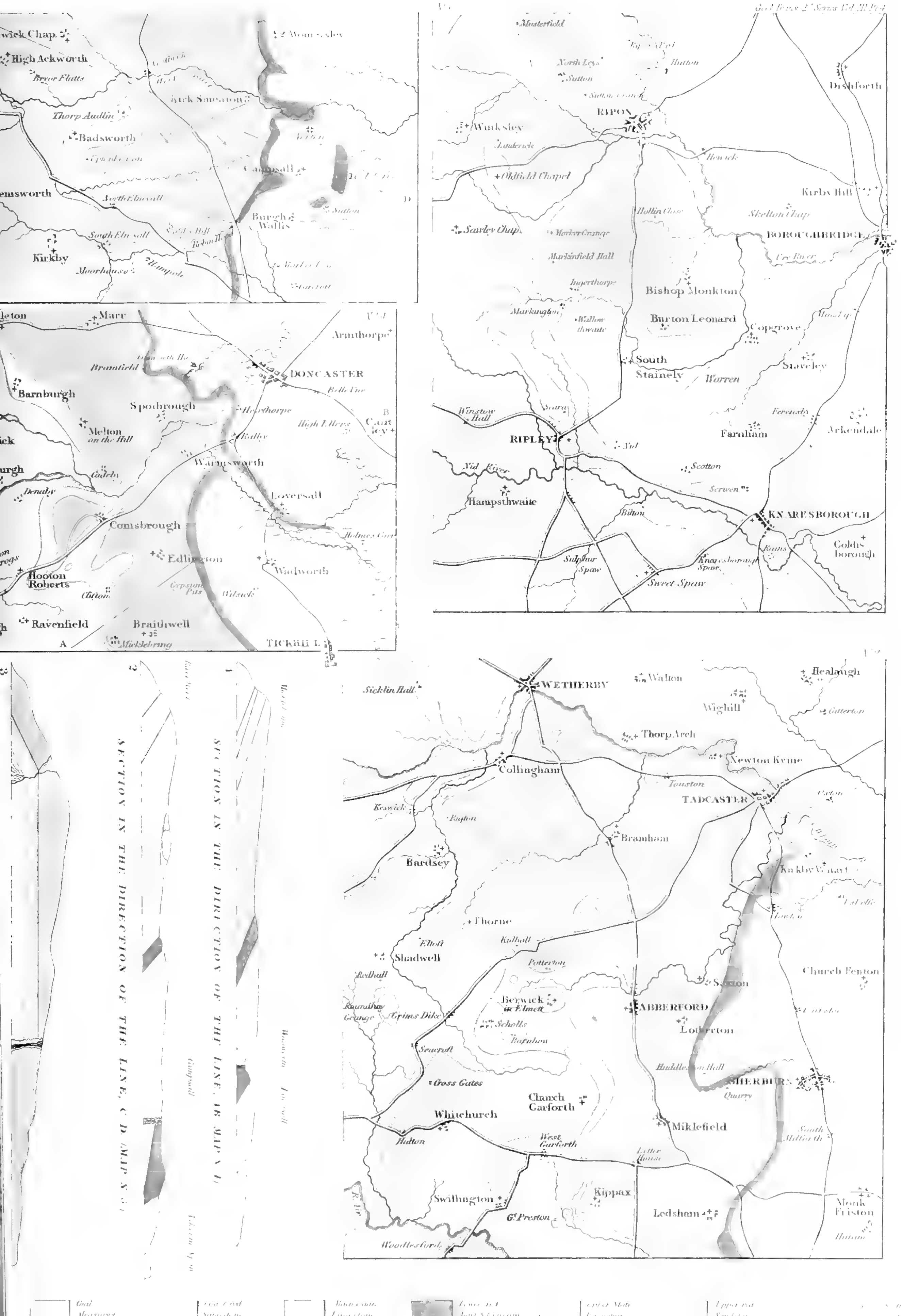
Slate Boulder resting on Limestone (Page 13)



GEOLOGICAL MAP OF PART OF CRAVEN.



SECTIONAL VIEW OF COAST OF THE ISLAND OF ARRAN FROM CLACHLAND POINT TO LOCH RANZA.


High Ackworth
Thorp Audlin
Badsworth
Hemsworth
Kirkby
Campsall
Burgh Wallis
Marr
Armthorpe
DONCASTER
Barnburgh
Spotbrough
Melton on the Hill
Warmsworth
Loversall
Conisbrough
Edlington
Wadworth
Hooton Roberts
Ravenfield
Braithwell
Micklebring
RIPON
Winksley
Oldfield Chapel
Dishforth
Kirby Hill
Skelton Chap.
BOROUGHBRIDGE
Sawley Chap.
Markinfield Hall
Bishop Monkton
Burton Leonard
Copgrove
South Stainely
Warren
Staveley
Winstow Hall
RIPLEY
Farnham
Arkendale
Nid River
Hampsthwaite
Scotton
KNARESBOROUGH
Goldsborough
Sulphur Spaw
Sweet Spaw
WETHERBY
Sicklin Hall
Walton
Healaugh
Wighill
Thorp Arch
Newton Kyme
Collingham
TADCASTER
Keswick
Bramham
Bardsey
Thorne
Shadwell
Redhall
Church Fenton
Berwick in Elmett
Grims Dike
ABBERFORD
Saxton
Lotherton
Seacroft
Gross Gates
SHERBURN
Church Garforth
Whitchurch
Miklefield
Halton
West Garforth
Swillington
Kippax
Ledsham
Monk Friston
Gt. Preston
Woodlesford
SECTION IN THE DIRECTION OF THE LINE, A B. MAP N. 1.
SECTION IN THE DIRECTION OF THE LINE, C D. MAP N. 3.

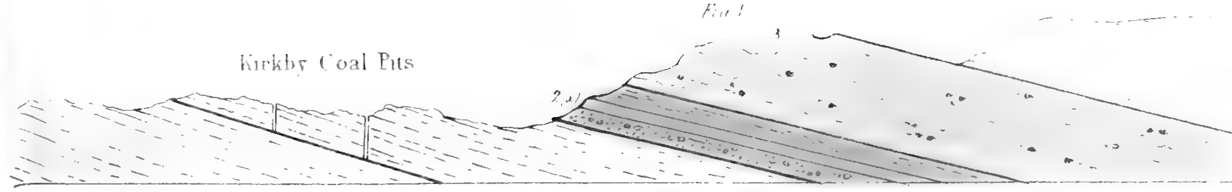


Fig. 1

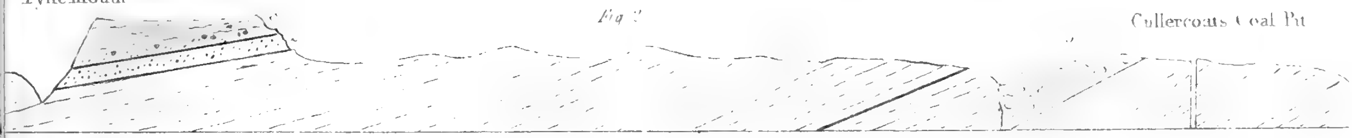


Fig. 2

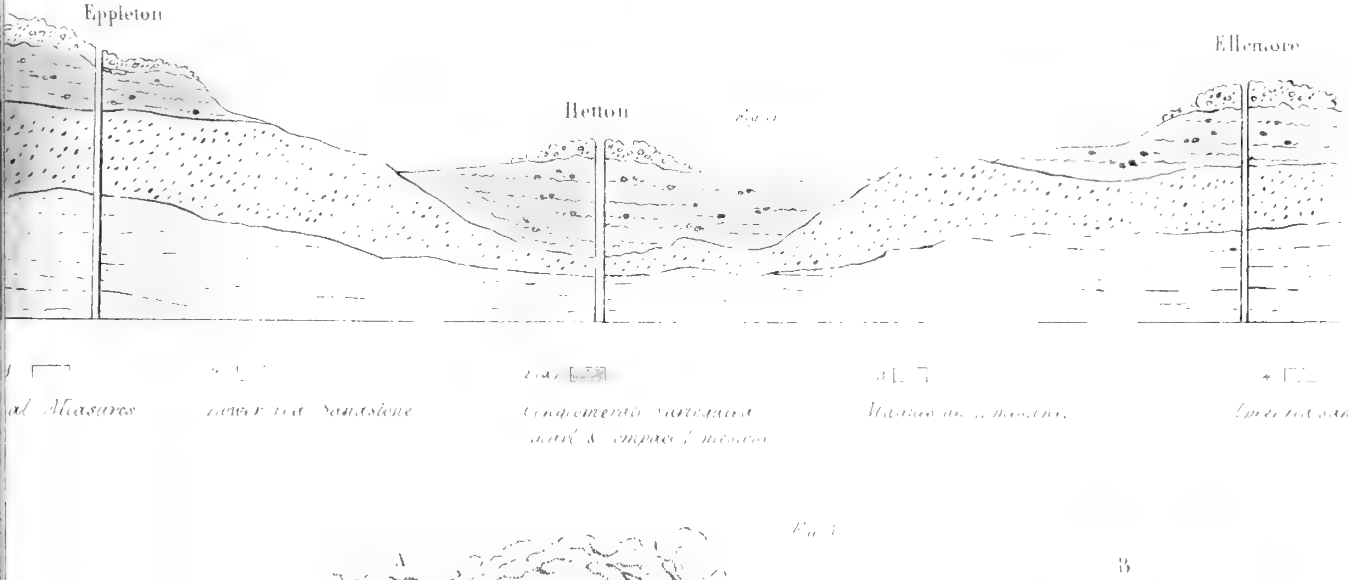


Fig. 3

al Measures | Sandstone | marl & compact |

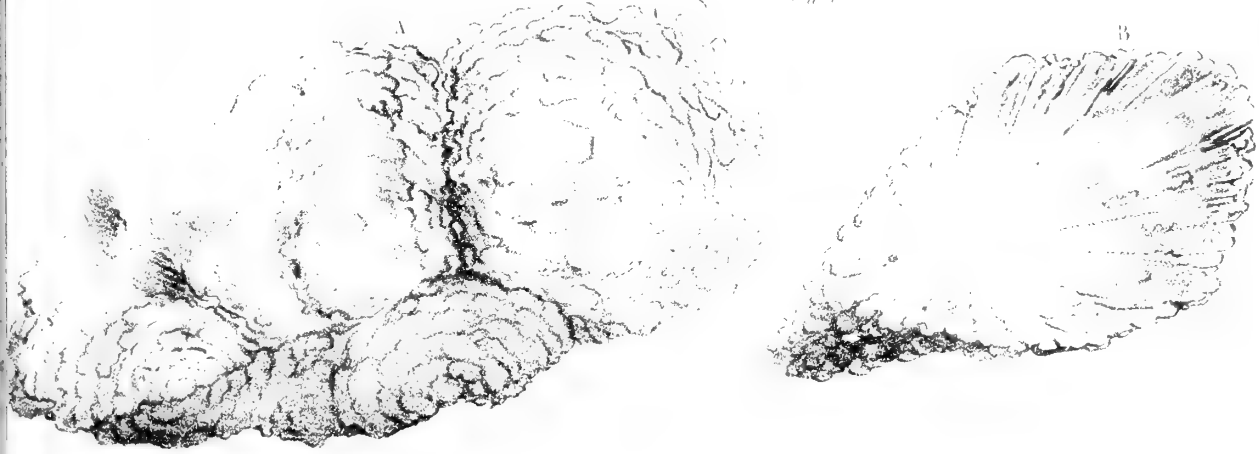
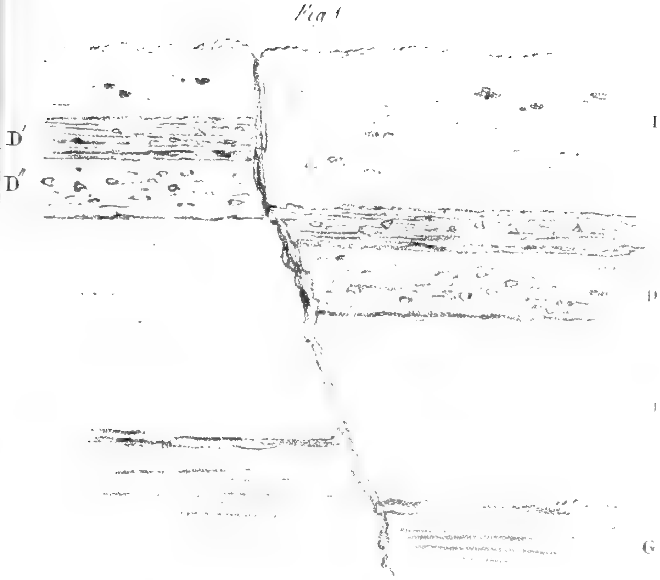
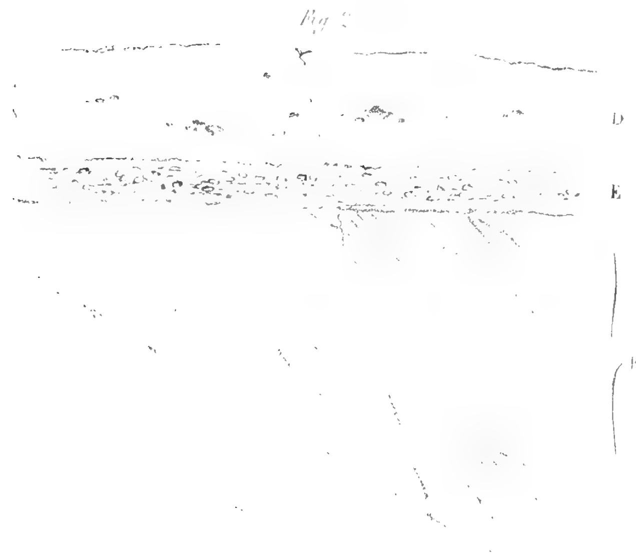
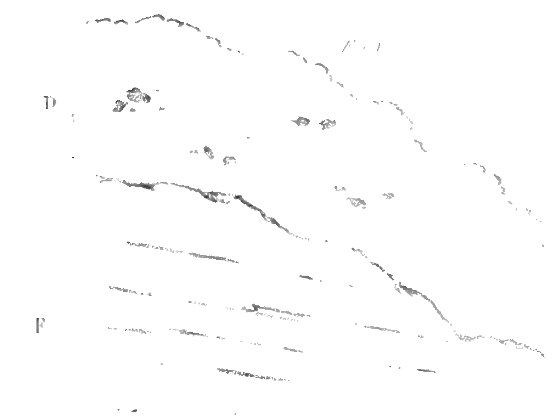


Fig. 4

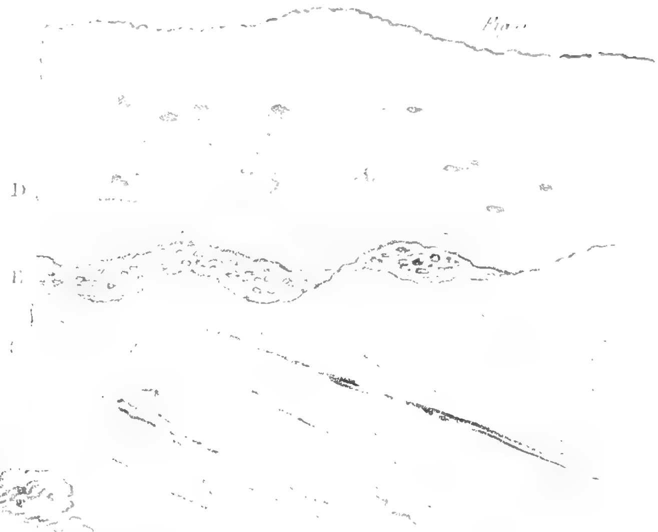
Branham Moor



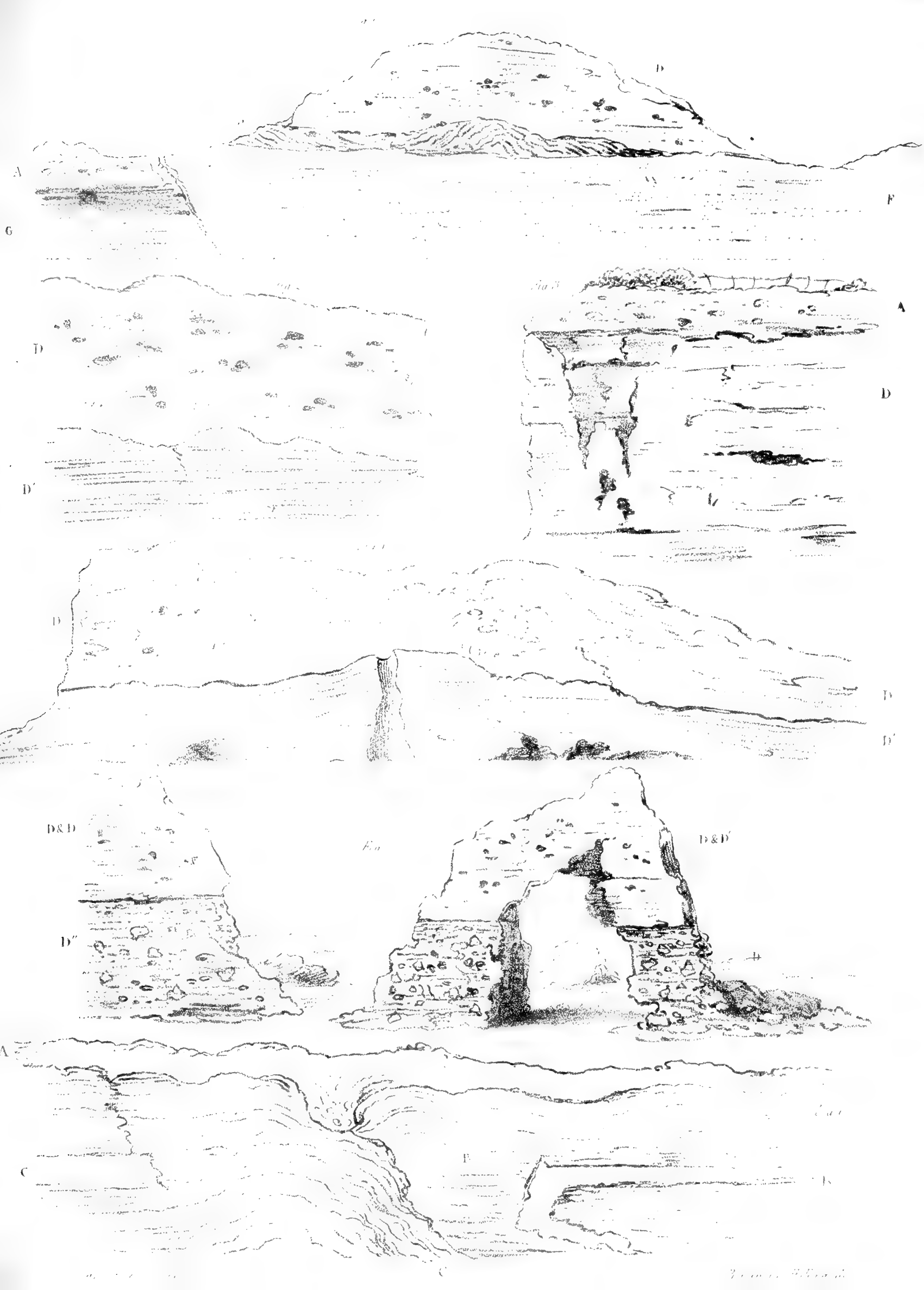




Branham Moor



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.



D
A
F
G
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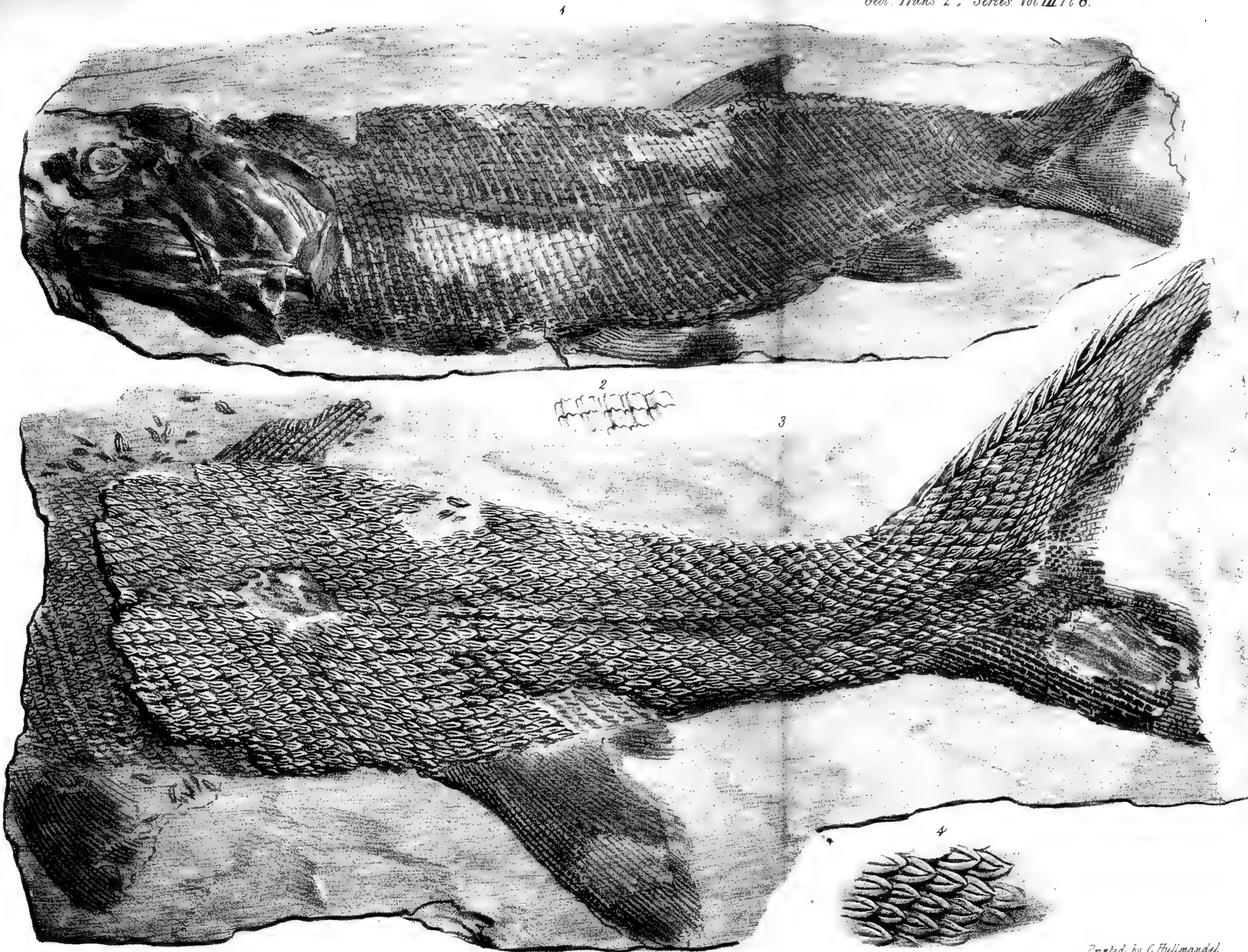
D
D
D'
D
D
D'
D&D
D&D'
D''
D
A
C
E
E



Lithog. from Nature by G. Scharf.

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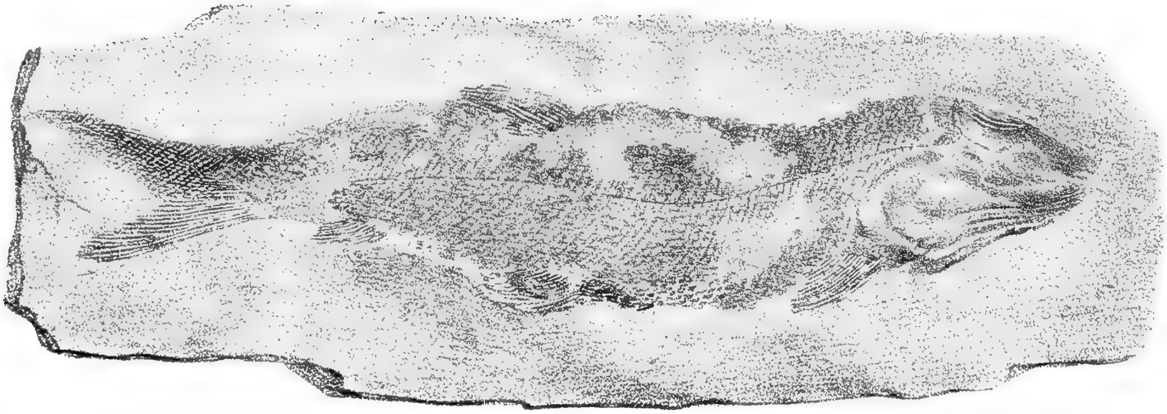

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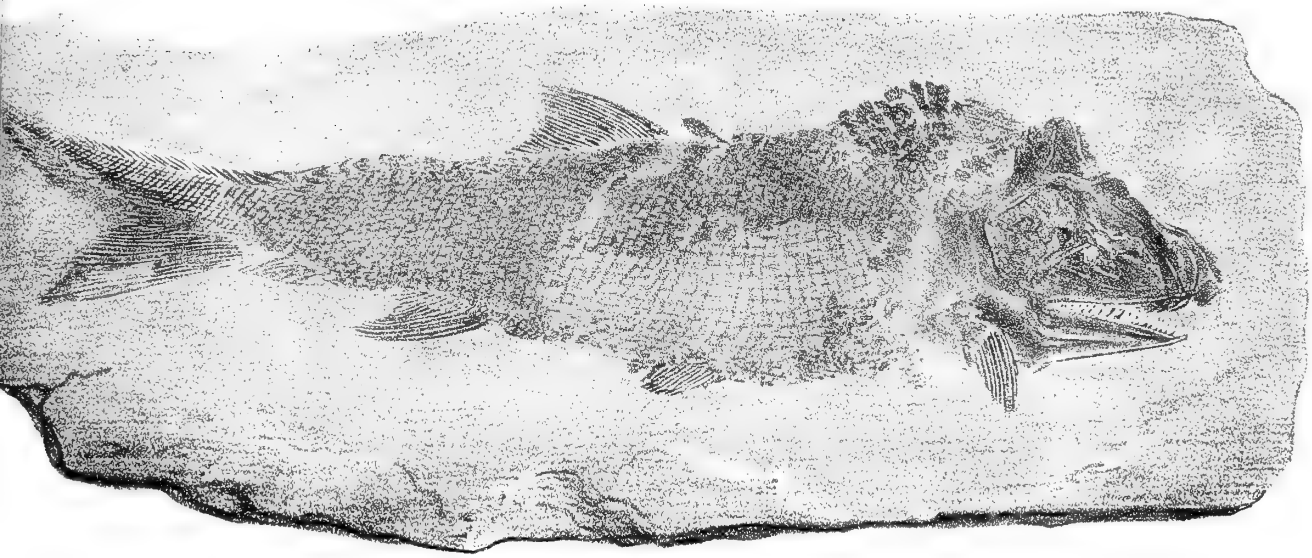

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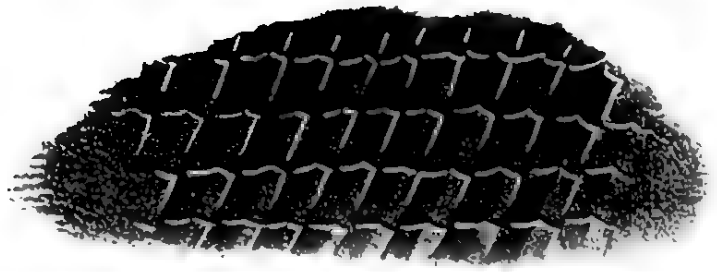

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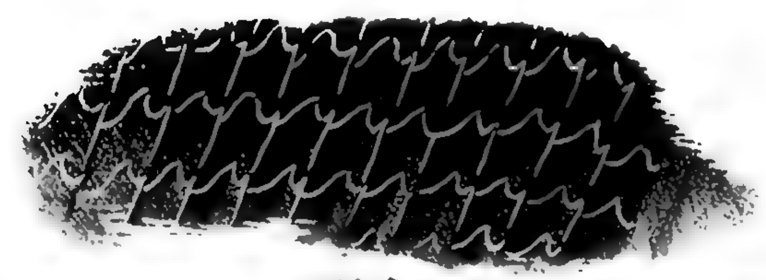

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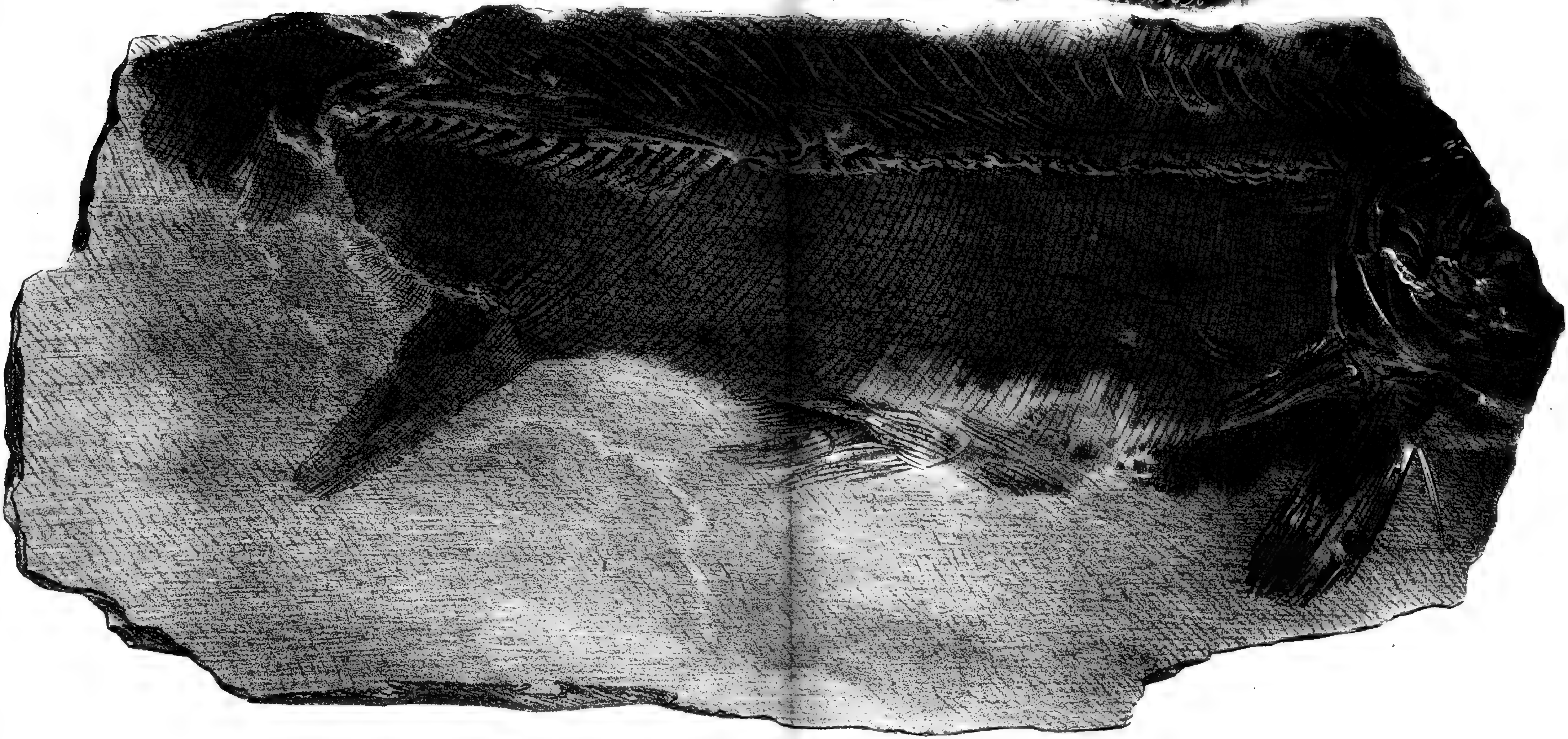

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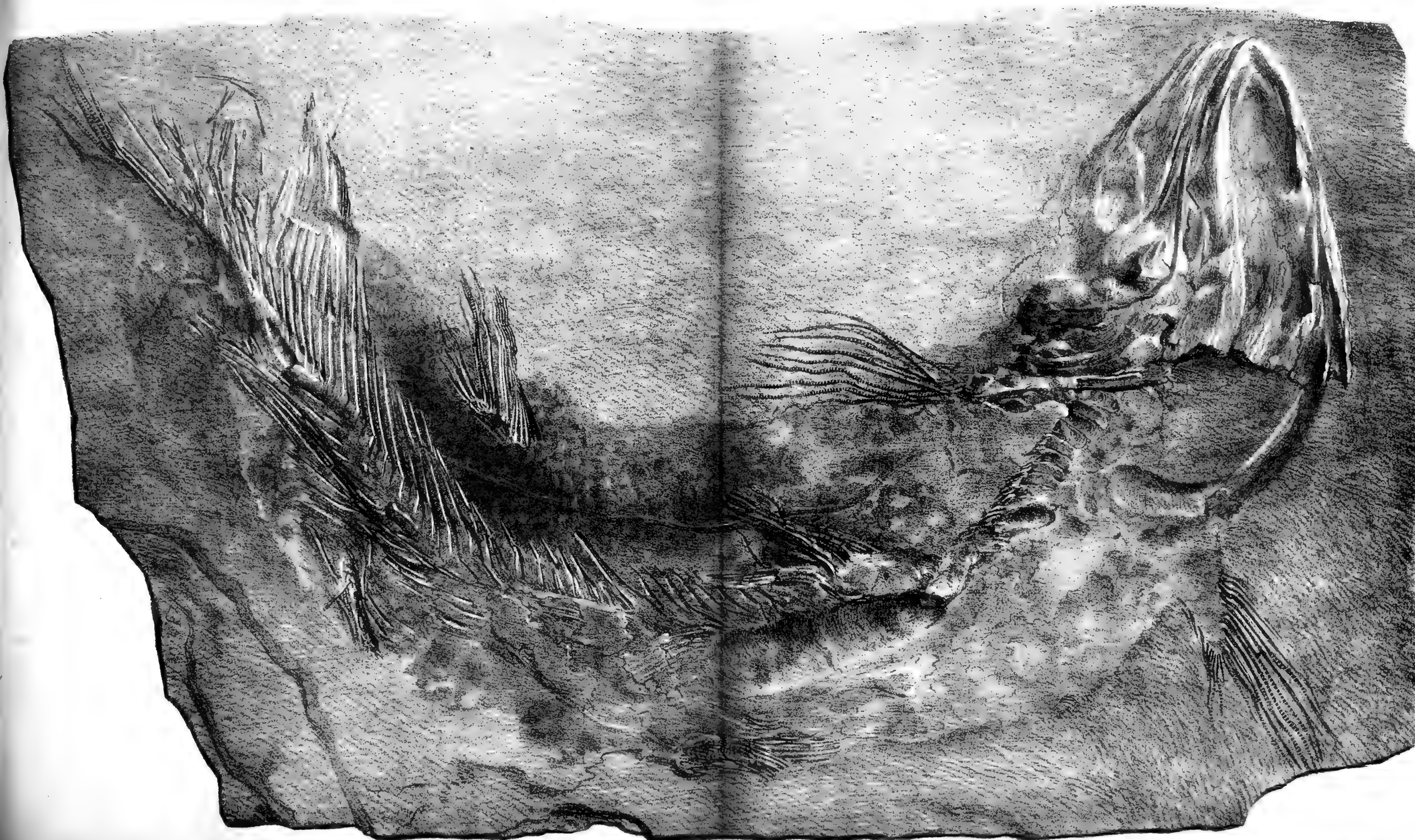

Lithographed from Nature by G. Scharf.

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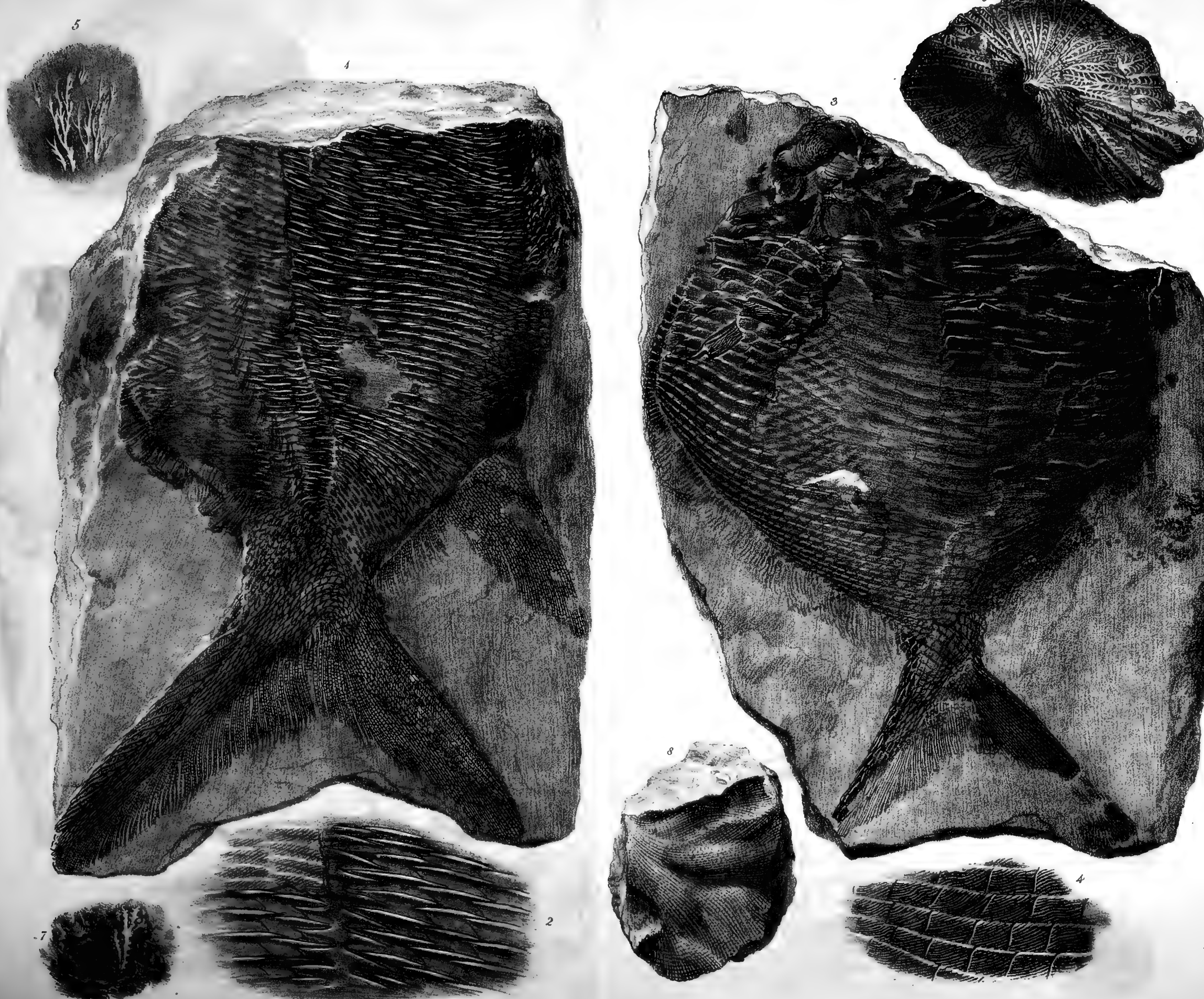

Lithog. from Nature by G. Scharf.

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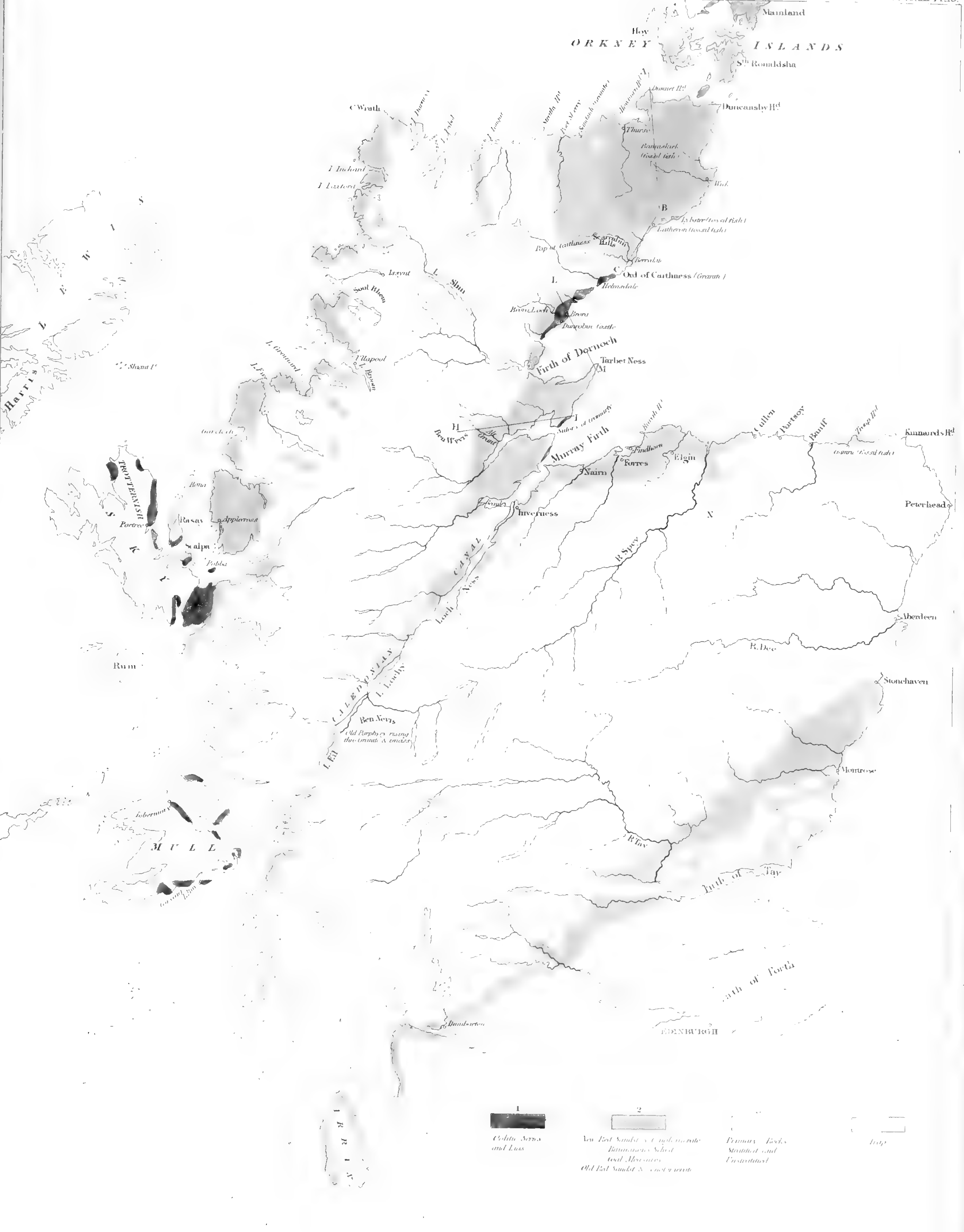
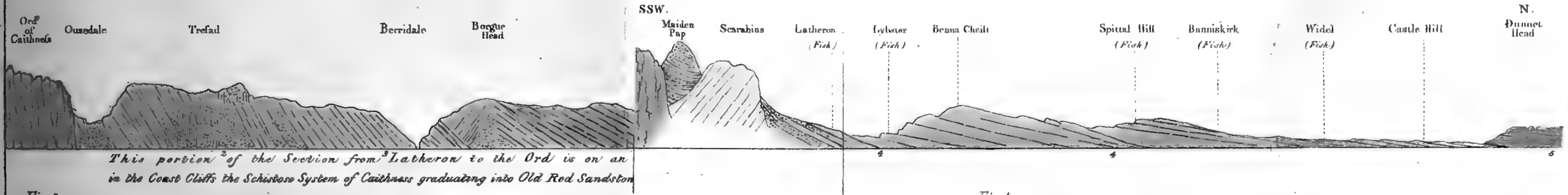

Mainland
Hoy
ORKNEY ISLANDS
Sth Ronaldsha
Duncansby Hd
C Wrath
Thurso
Wick
B
Scaraben Hills
Ord of Caithness (Granite)
Brora
Dunrobin Castle
Firth of Dornoch
Tarbet Ness
Murray Firth
Findhorn
Forres
Elgin
Nairn
Inverness
Cullen
Portsoy
Banff
Kinnaird's Hd
Peterhead
R. Spey
Aberdeen
R. Dee
Stonehaven
Montrose
R. Tay
Firth of Tay
Firth of Forth
EDINBURGH
Dumbarton
Ben Nevis
L. Eil
Loch Ness
CALEDONIAN CANAL
Soul Bhen
Ullapool
Applecross
Rasay
Scalpa
Portree
TROTTERNISH
SKYE
Rum
MULL
Tobermory
Harris
LEWIS
Issynt
L. Shin
Oolite Series and Lias
New Red Sandst & Conglomerate
Bituminous Schist
Fossil Fish
Old Red Sandst & Conglomerate
Primary Rocks
Stratified and Unstratified
Trap

Fig: 2.

SECTION across CAITHNESS from the OLD RED CONGLOMERATE of BERRIDALE and the MAIDEN PAPS to the NEWER RED SANDSTONE of DUNNET HEAD.
(on the Line A B C of the Map.)

Fig. 5. INLAND SECTION.



This portion of the Section from Latheron to the Ord is on an in the Coast Cliffs the Schistose System of Caithness graduating into Old Red Sandston

Fig: 1.

CONTACT of GRANITE with the SECONDARY DEPOSITS on the NORTH COAST of CAITHNESS near SANDSIDE

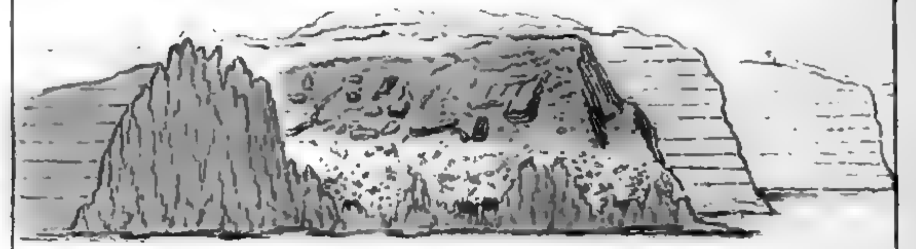


Fig: 3.

SECTION from BEN WYVIS across EASTER ROSS to the NORTH SUTOR of CROMARTY
(on the Line HI of the Map)

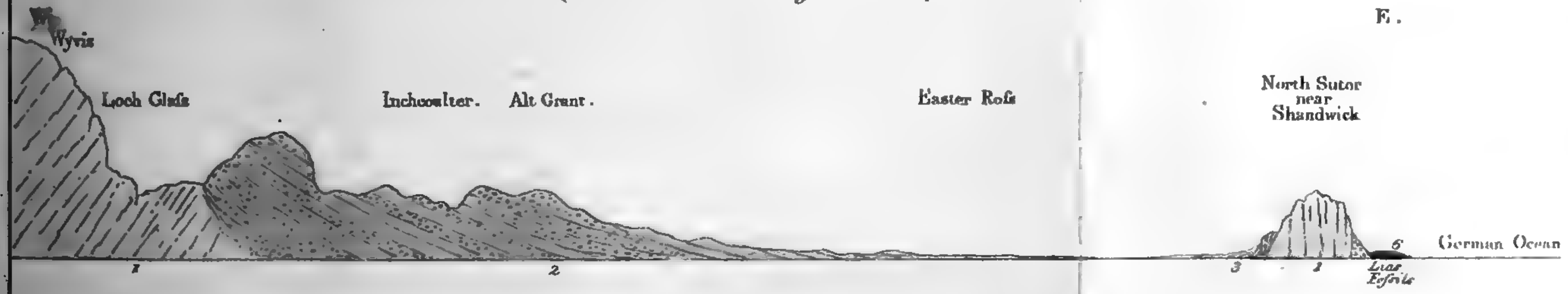
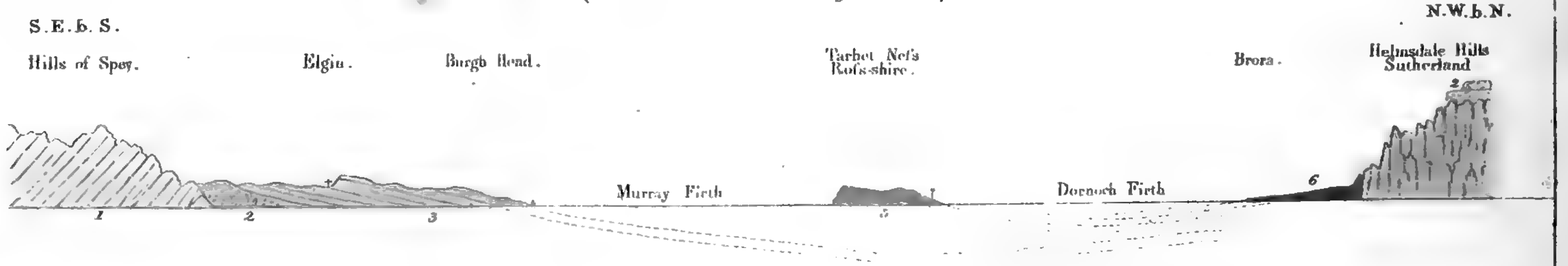
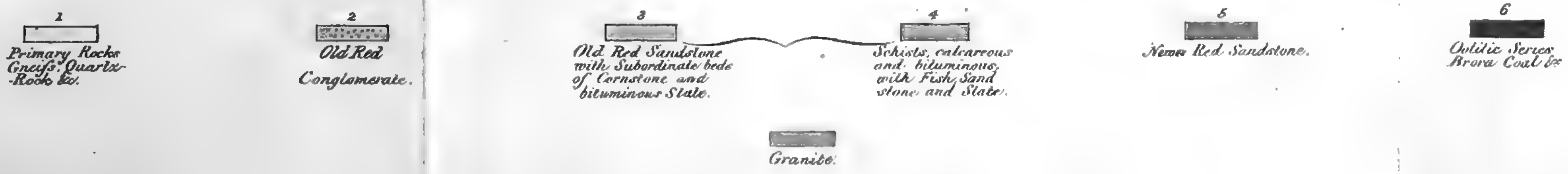
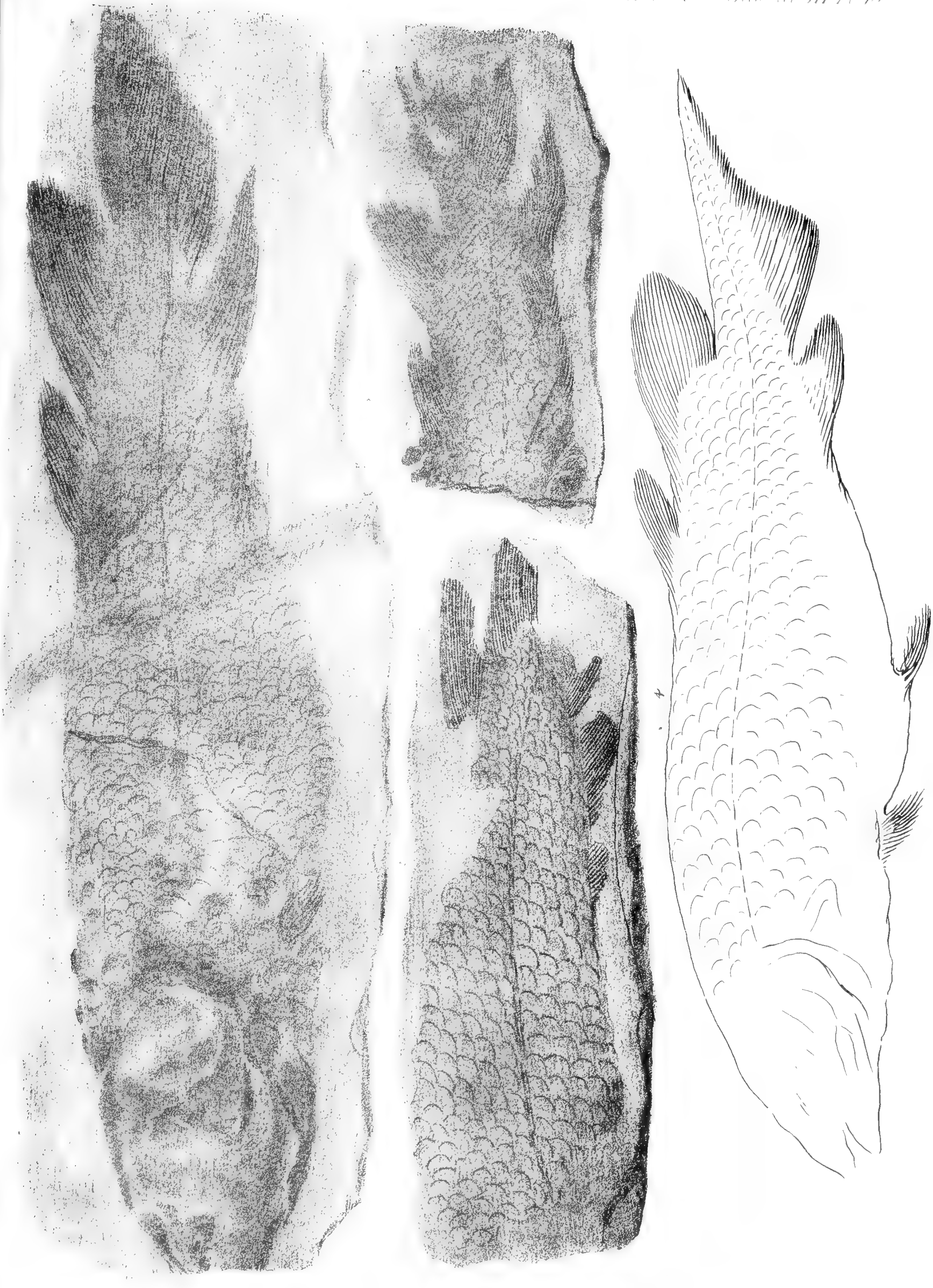


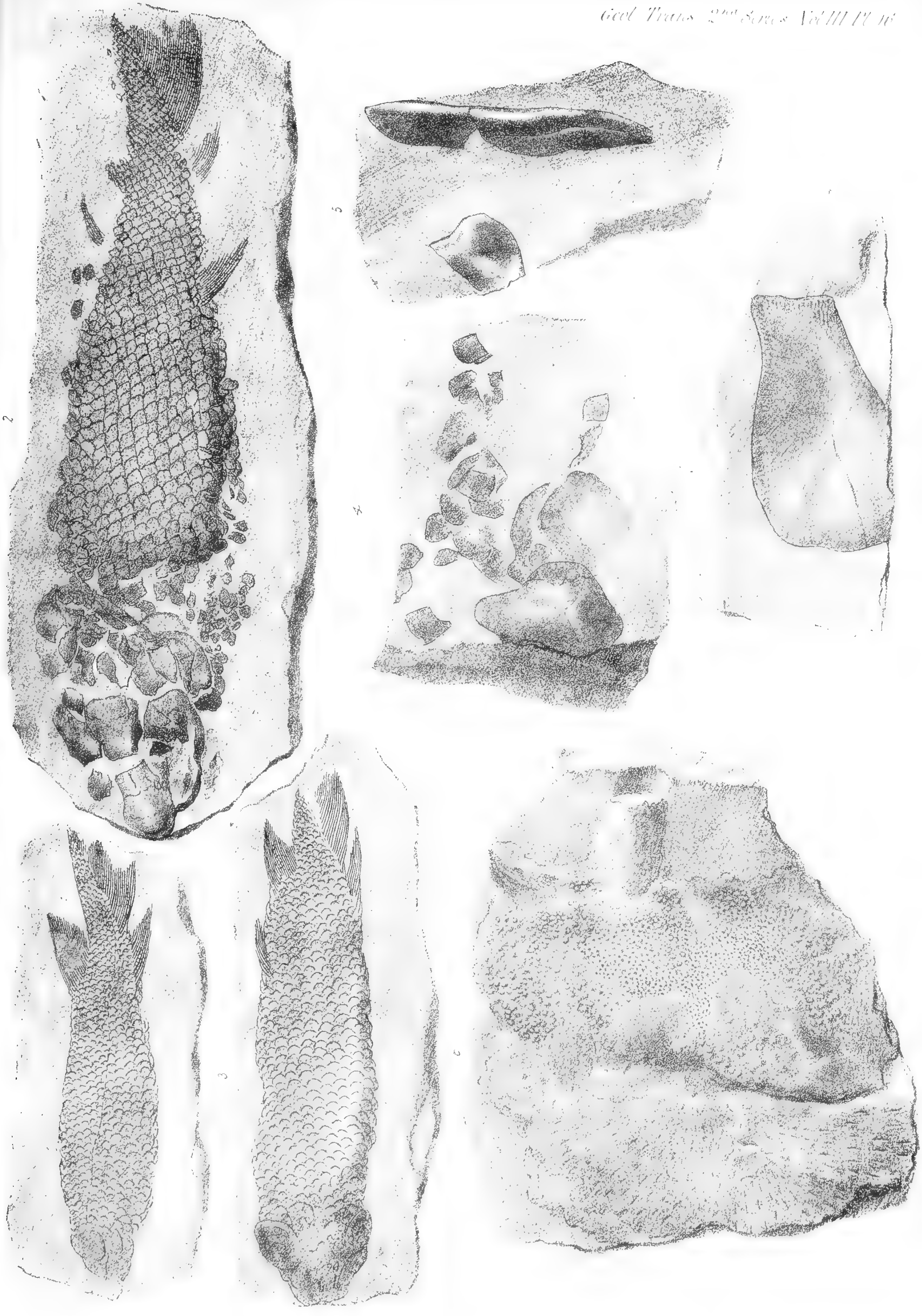
Fig. 4.

SECTION from the GRANITIC RIDGE N.W. of BRORA across the DORNOCK FIRTH to TARBET NESS, ROSS
And thence across the MURRAY FIRTH to ELGIN and the HILLS OF SPEY.
(on the Line L M N of the Map)








2
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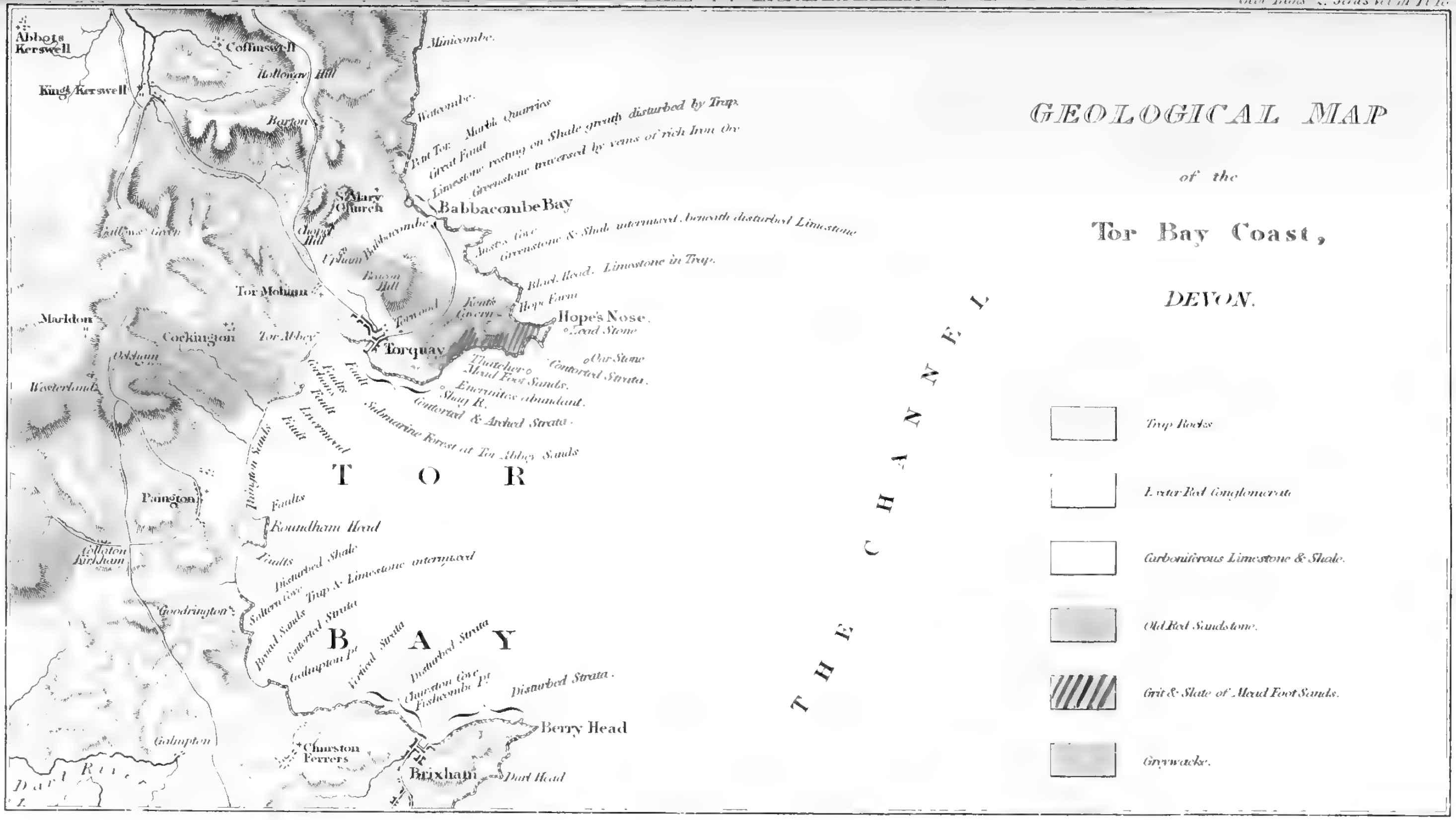


Fig 1 Coast Section from Hope's Nose, to Petit Tor.

Fig. 2. Section from Westerland to Black Head.

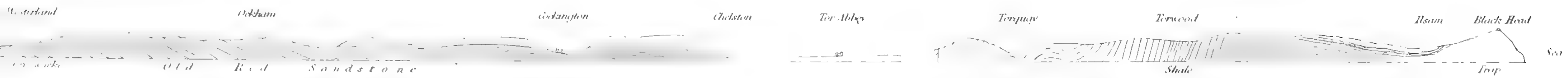


Fig 3

Quarry near Kings Kerswell.

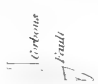
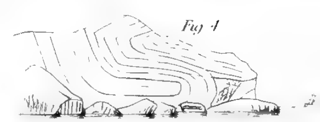


Fig.

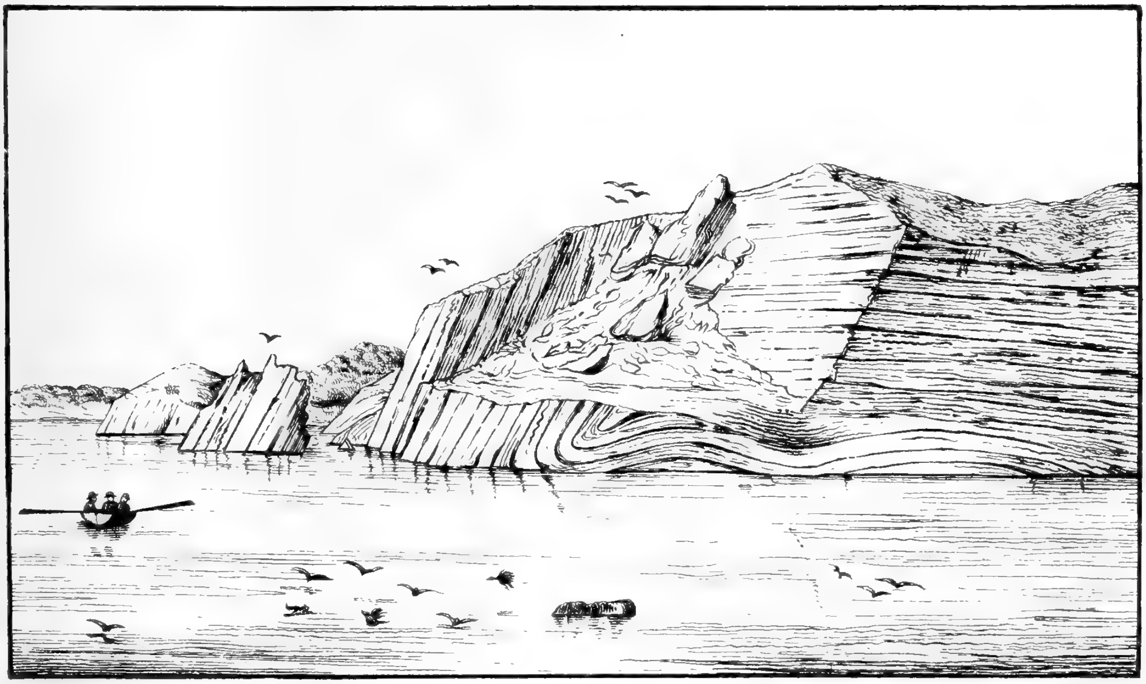
Fig 4



Near Hope's Nose, Tor Bay.

H. T. de la Beche del.

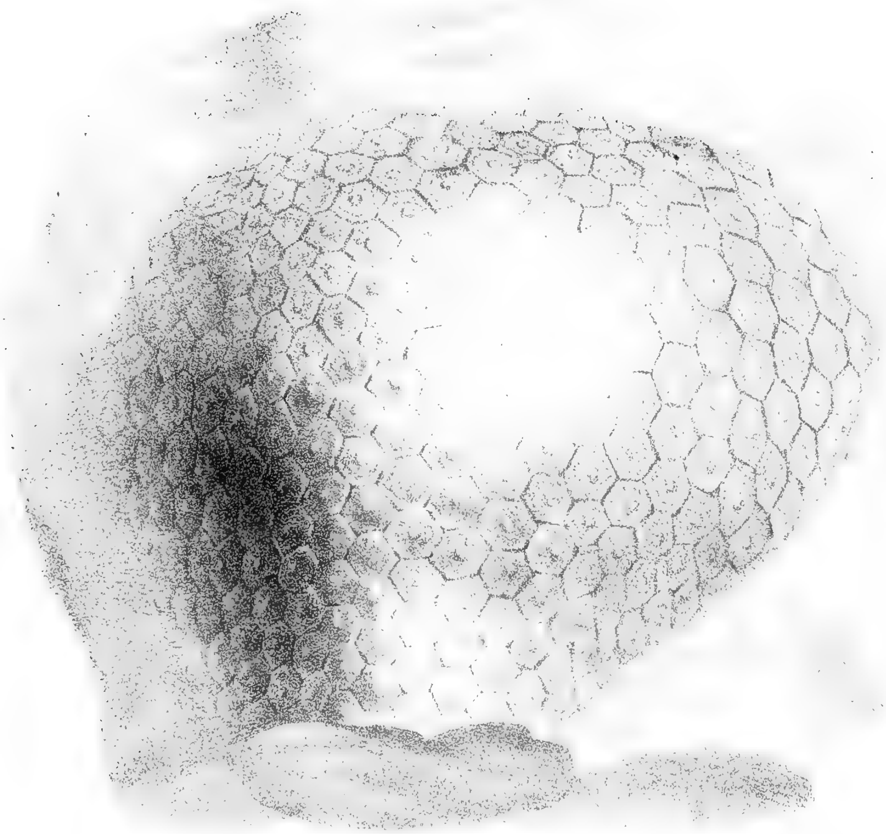
Fig. 1.



Contorted, Carboniferous Limestone, near Torquay.

Fig. 2

Arched Strata of Carboniferous Limestone, Peaked Tor Cove, Torquay.



H. T. de la Beche del:

H. T. de la Beche del.

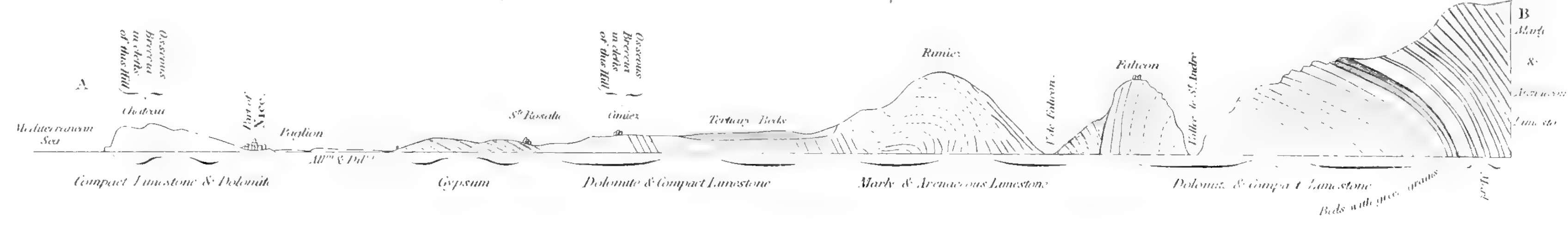
VIEW FROM MOUNT MORON NEAR NICE.

a. Mountains towards St. Tropez *(Granite Greenstone &c.)*
bbbb L'Estrelle Mountains, b being Cap Roux *(principally Red Porphyry.)*
c. Cap d'Antibes.
d. Antibes. *(Light Colored Limestone & Green Sand. Osseous breccia.)*
e. Mouth of the Var.
f. } g. } g'. } Mountains in Provence. *(g Light Colored Limestone.)*
h. Cerion?
k. Croix de Marbre
l. Port de Limpia
m. Chateau de Nice *(Dolomite & Light Colored Limestone. _ Osseous breccia.)*
& & &. *Hills composed of Tertiary Rocks.*

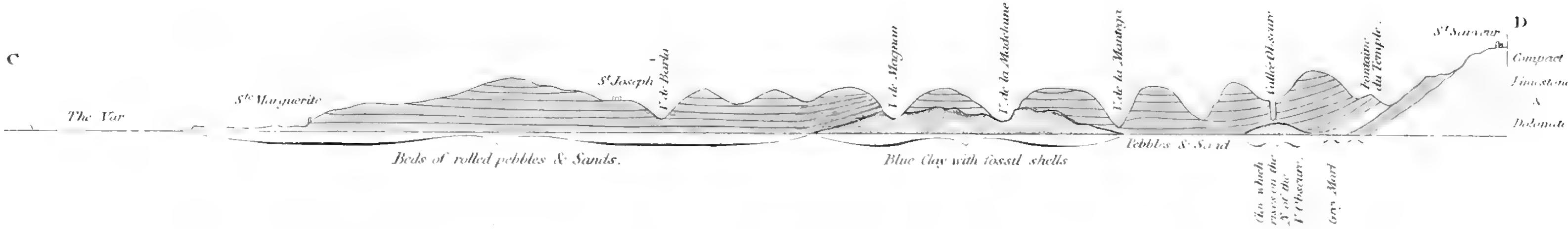
n. Nice. *the town almost concealed by the Chateau Hill.*
o. Convent of the Cimies. (ancient Cemenelium) *(Dolomite & Light Colored Limestone. Osseous breccia.)*
p. Paglion Torrent
q. Mont Cao _ Monte Calvo _ Mont Chauve
r. Rimiés. *(Green Sand.)*
w. Castalets. *(Dolomite & Light Colored Limestone.)*
qq. Part of the Cimies Hill *(Gypsum)*
s. Crest of the Maritime Alps
t. Ferrion.
u. Mont Revel. *(Green Sand.)*
v. Bordina *(Green Sand.)*
x. Vinaigre. *(Dolomite & Light Colored Limestone.)*
y. Mont Alban *(Dolomite & Light Colored Limestone.)*
z. Villafranca or Villefranche. (ancient Olivula.)

1. Pecanaia *(Dolomite & Light Colored Limestone.)*
2 2. Road to Genoa
3. Agel
4. Village of Eza *(Dolomite & Light Colored Limestone.)*
5. Baussi Rausa *(Perpendicular strata of Light Colored Limestone.)*
6. Turbigha (ancient Tropheea Augusti.) *(Light Colored Lime & Green Sand.)*
7. Cap d'Aglio. *behind which is* Monaco (ancient Portus Herculis Monoeci.)
8. Vintimiglia *(Tertiary Rocks.)*
9. Bordighera *(Green Sand & T. R.)*
10. Saint Hospice *(Green Sand.)*
11. Fanal or Light house *(Dol. & Light Colored Limestone.)*
12. Bay of Villefranche
13.13.13.13. Part of the Peninsula of St. Hospice *(Green Sand.)*

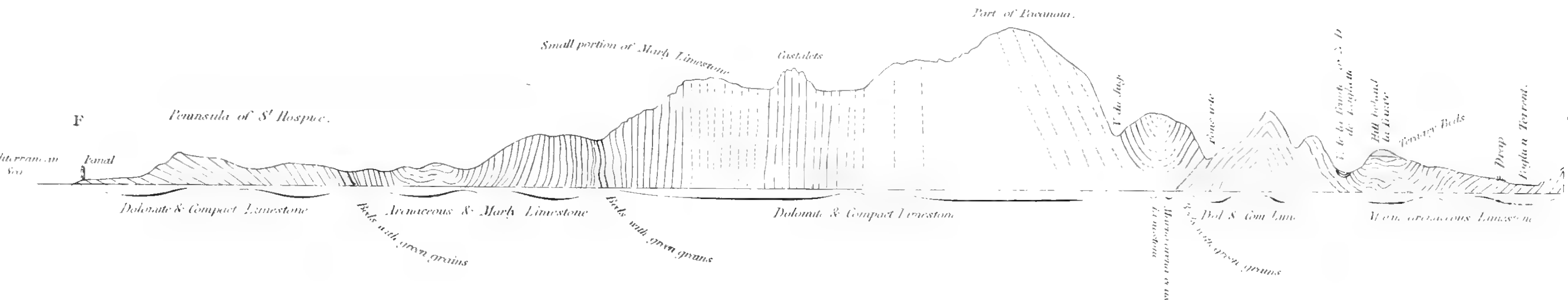
(Fig. 1.) SECTION AB. OF MAP.



(Fig. 2.) SECTION CD. OF MAP.



(Fig. 3.) SECTION FG. OF MAP.



(Fig. 4.) SECTION HI. OF MAP.

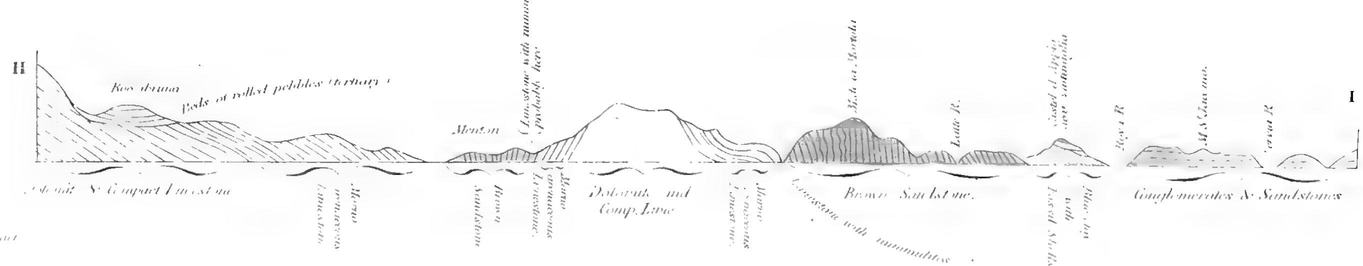
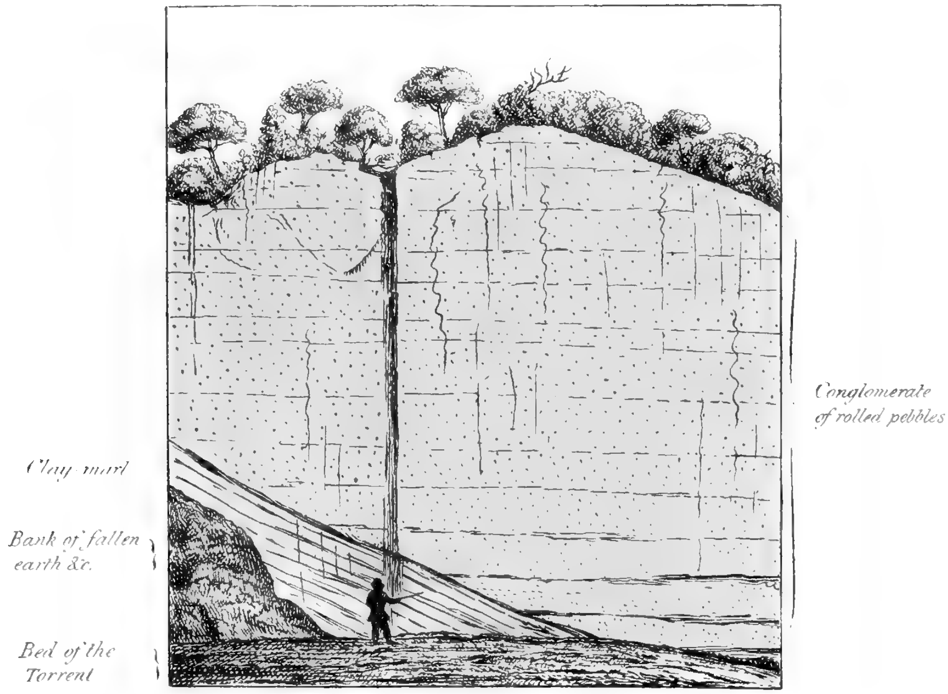
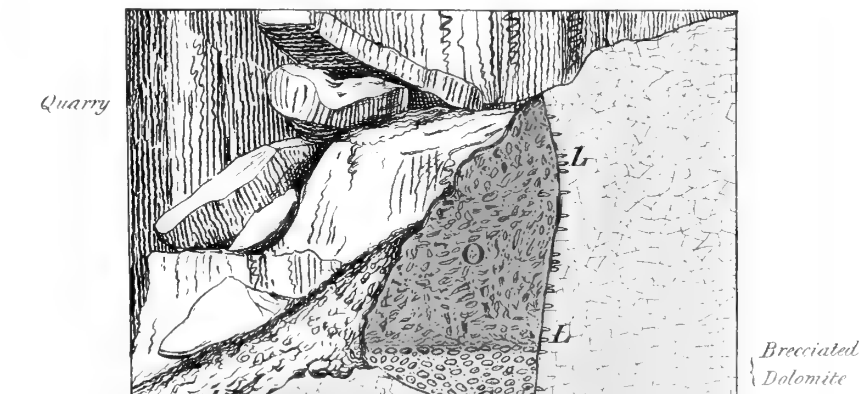


Fig. 1



In the Valley of la Maddelaine.

Fig. 2

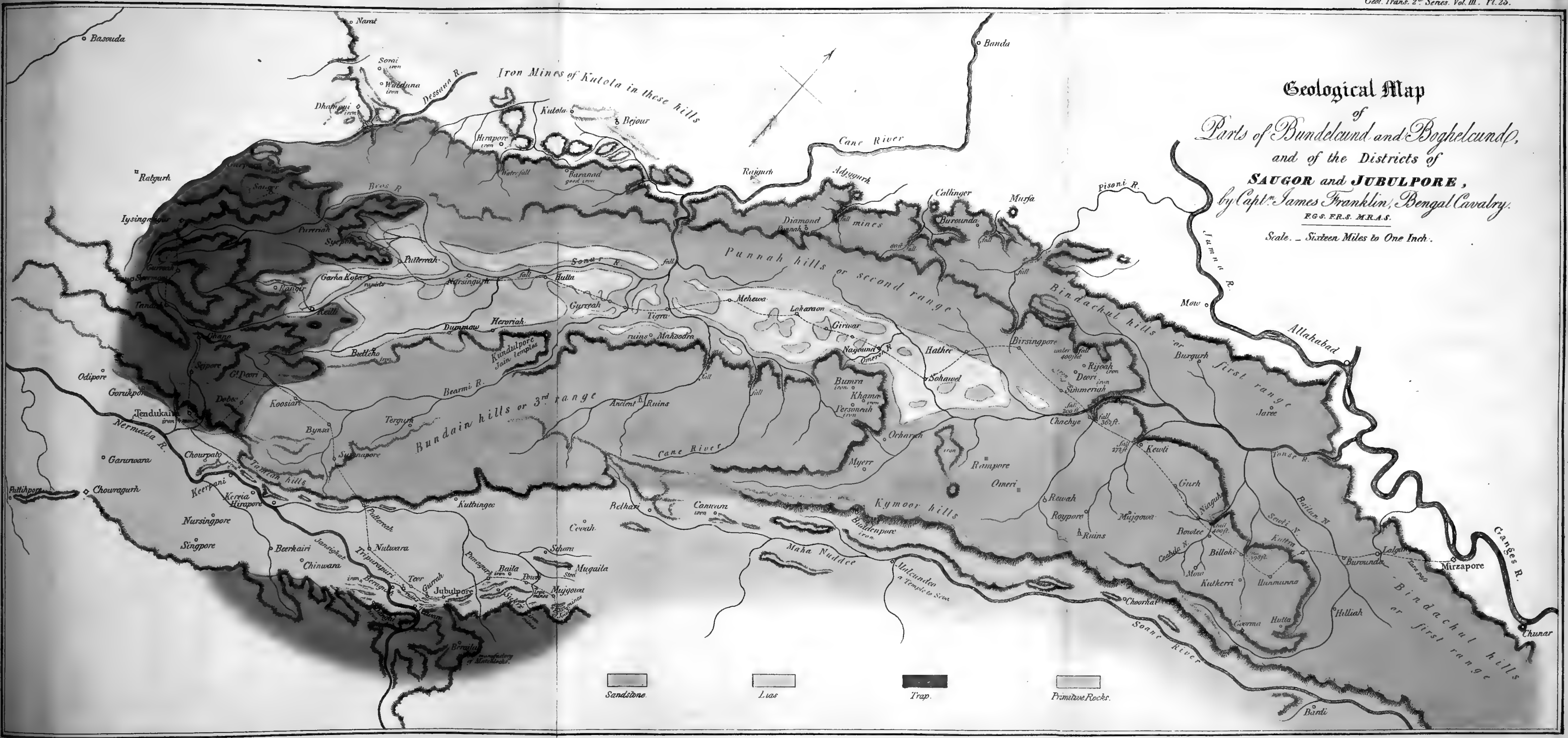


Section of Osseous Breccia, Cliff of the Chateau de Nice.

O. *Hard osseous breccia.* C. *Conglomerate of rolled pebbles with a compact cement or base.*

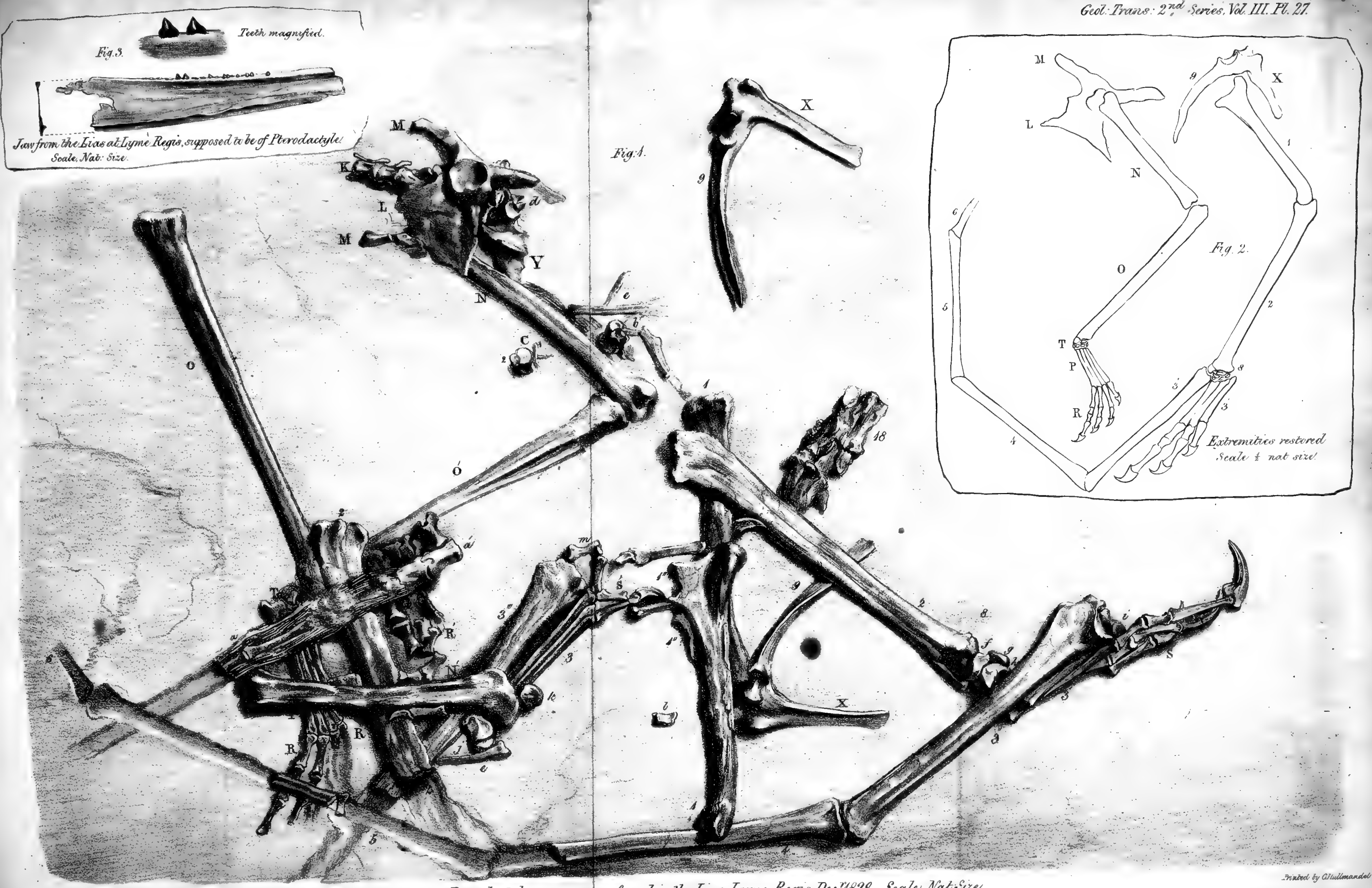
L. L. L. *Holes pierced by Lithodomæ in brecciated dolomite of the N. side of the cleft.*

H.T. De la Beche, del.


Geological Map
of
Parts of Bundelcund and Boghelcund,
and of the Districts of
SAUGOR and JUBULPORE,
by Captn. James Franklin, Bengal Cavalry.
F.G.S. F.R.S. M.R.A.S.
Scale. _ Sixteen Miles to One Inch.
Sandstone.
Lias
Trap.
Primitive Rocks.
Basouda
Narut
Banda
Iron Mines of Kutola in these hills
Dessana R.
Kutola
Bejour
Hirapore
Cane River
Rajgurh
Adjygurh
Callinger
Murfa
Pisoni R.
Ratgurh
Baranad
Waterfall
Bros R.
Iysingnagur
Diamond
Punnah
mines
Burounda
Punnah hills or second range
Putteriah
Sonar R.
Hutta
Narsinguth
Garha Kota
Mehewa
Lokaraon
Girwar
Tigra
Gurreah
Dummow
Heroriah
Makoodra
ruins
Nagound
Omeron R.
Hathee
Sohawel
Birsingpore
Rijoah
Deori
Simmeriah
Bindachul hills or first range
Mow
Allahabad
Burgurh
Jaree
Jumna R.
Kundulpore
Jain temples
Bearmi R.
Odipore
Gorukpor
Tendukaira
Nermada R.
Koosiari
Bundain hills or 3rd range
Ancient Ruins
Bumra
Khama
Personeah
Ocharah
Chachye
Kewti
Tonse R.
Bynsa
Tergurh
Cane River
Rampore
Omeri
Myerr
Chourpato
Garurwara
Futtihpore
Chowragurh
Keerpani
Kereia
Hirapore
Nursingpore
Singpore
Kuthingee
Betharí
Canwara
Kymoor hills
Rewah
Roypore
Ruins
Mujgowa
Gurh
Nyaguhr
Bowtee
Billohi
Kuttra
Seuti N.
Railan N.
Ganges R.
Mirzapore
Lalganj
Burounda
Bindachul hills or first range
Cowah
Beerkairi
Chinwara
Jansighat
Tripurupuri
Nutwara
Tigurah
Jubulpore
Baila
Sohara
Mugaila
Mujgowa
Maha Nuddee
Bulderpore
Malcundea
a Temple to Siva
Choorhat
Soane River
Mow
Kutkerri
Hunmunna
Hilliah
Goorma
Hutta
Chunar
Berraila
Bardi

A GEOLOGICAL SECTION, with Barometrical Elevations from the bed of the RIVER GANGES at MIRZAPORE to Nursingurh, Iysingnugur, Tendukaira, and thence across the BUNDAIN HILLS to JUBULPORE.

Scale: Two Thousand Feet to One Inch of Height; and Sixteen Miles to One Inch of Distance



Jaw from the Lias at Lyme Regis, supposed to be of Pterodactyle. Scale, Nat: Size.

W Clift del. G. Scharf lithog.

Pterodactylus macronyx, found in the Lias, Lyme Regis, Dec.r 1828. Scale Nat: Size.

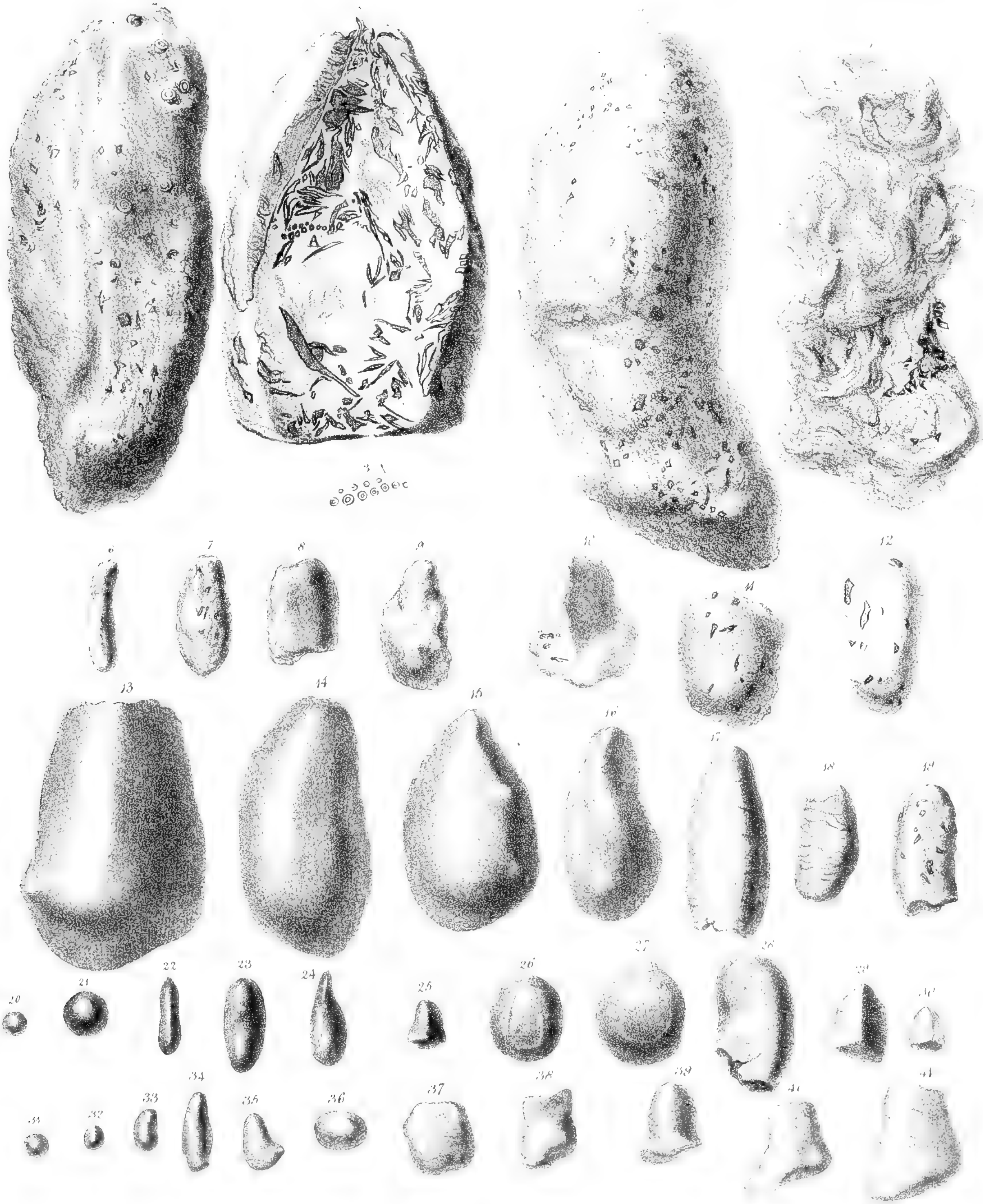
Printed by C. Hullmandel

Lithographed from Nature by G. Scharf

Coprolites and Sections of Coprolites from the Lias at Lyme Regis. Scale, Natural Size.

Coprolites from the Lias at Lyme Regis containing Scales of Fishes and large undigested Bones.

[illegible] Natural Size.

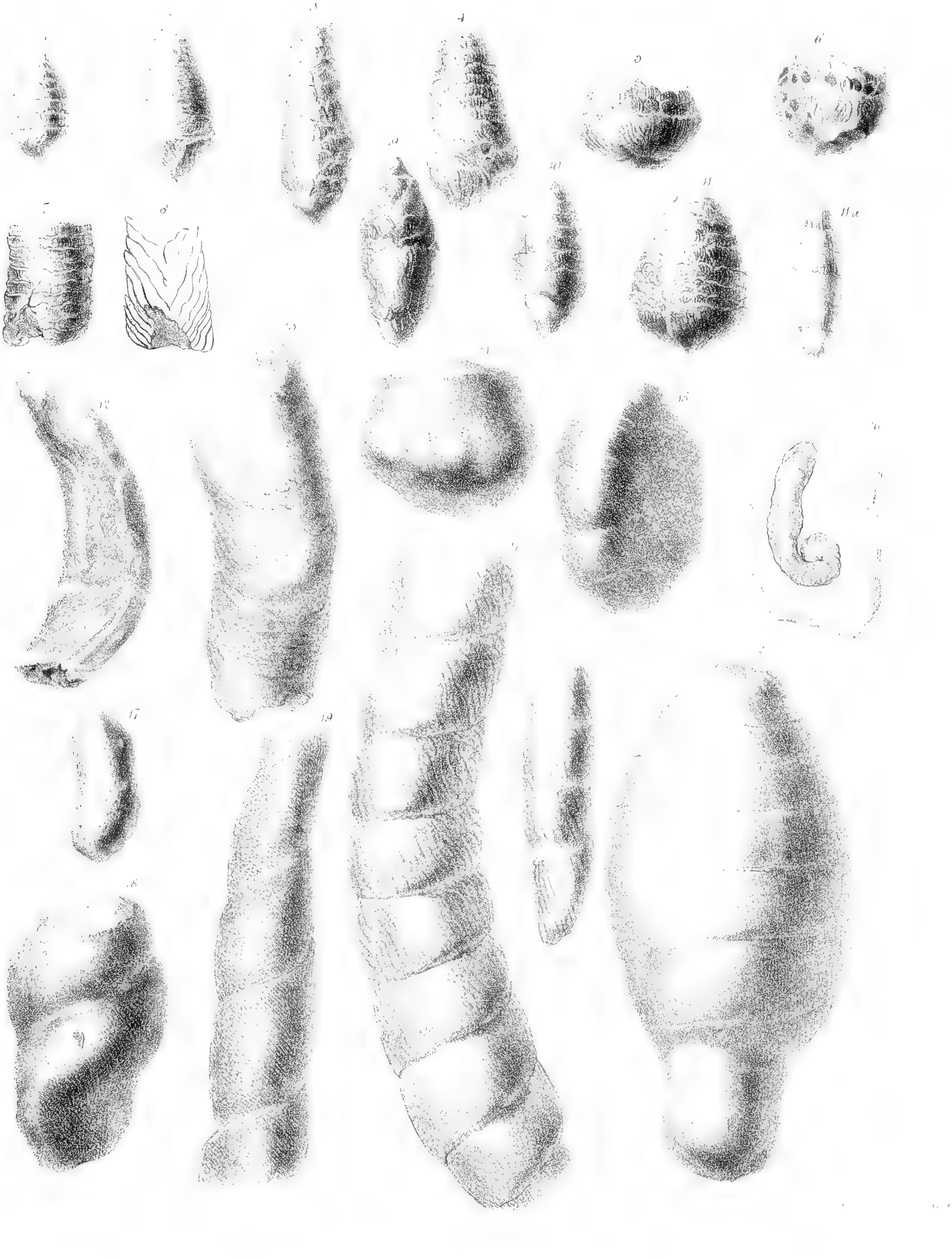


G. Scharf del et lithog

Printed by C. Hullmandel

Coprolites from Lias, at Lyme Regis & Westbury on Severn & from Carboniferous Limestone.

Scale Natural Size



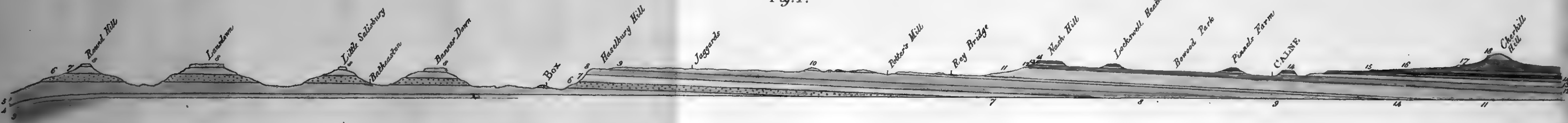
Scharf del. et lith.

[Co]prolites, from Chalk. Tertiary Strata Green Sand & Tilgate Sandstone with recent Intestines of Dog fishes & Skate injected.

Scale Natural Size.

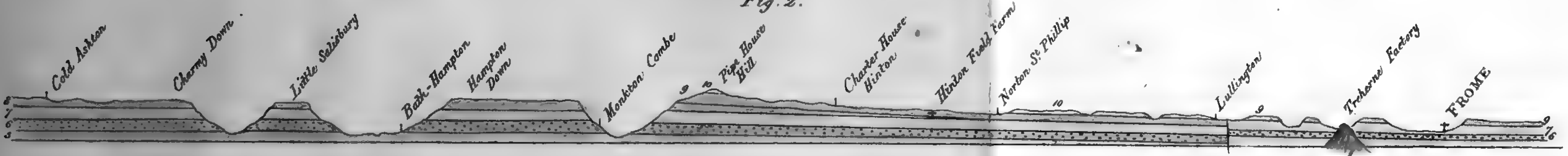
Section from Round Hill near BATH to Cherhill Hill near CALNE.

Fig. 1.



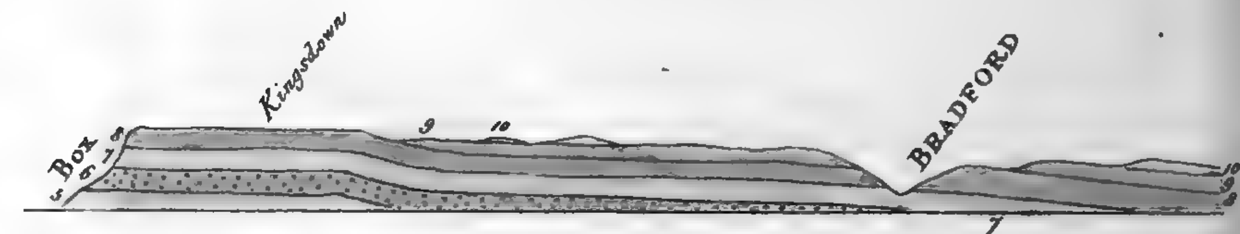
Section from Cold Ashton near MARSHFIELD to FROME.

Fig. 2.



Section from Box to BRADFORD.

Fig. 3.

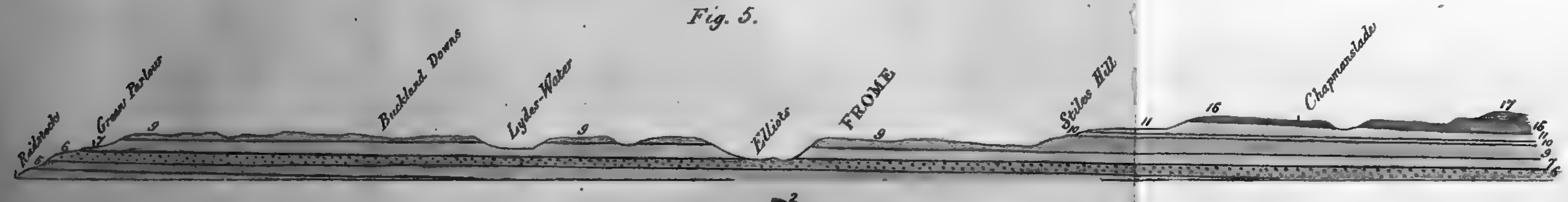


Section from Cock Road near FROME to Etchilhampton Hill near DEVIZES.

Fig. 4.

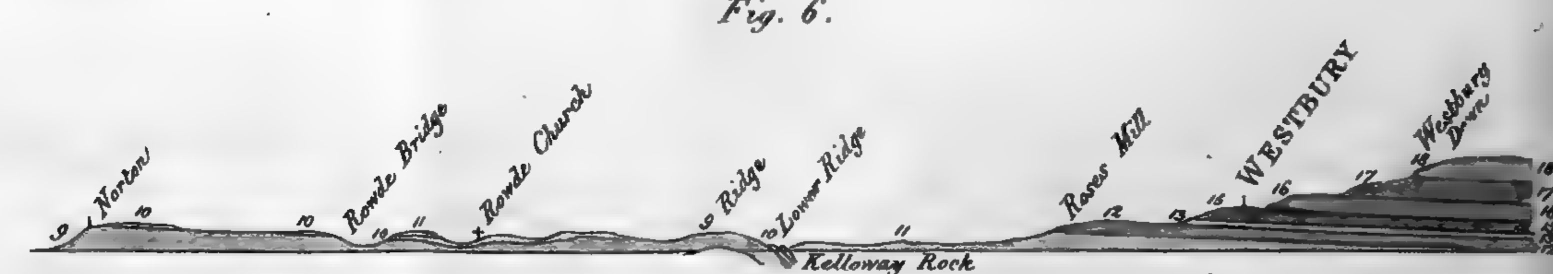
Section from Radstock to Chapmanslade.

Fig. 5.



Section from Norton to WESTBURY.

Fig. 6.



G. Scharf del. et lithog.

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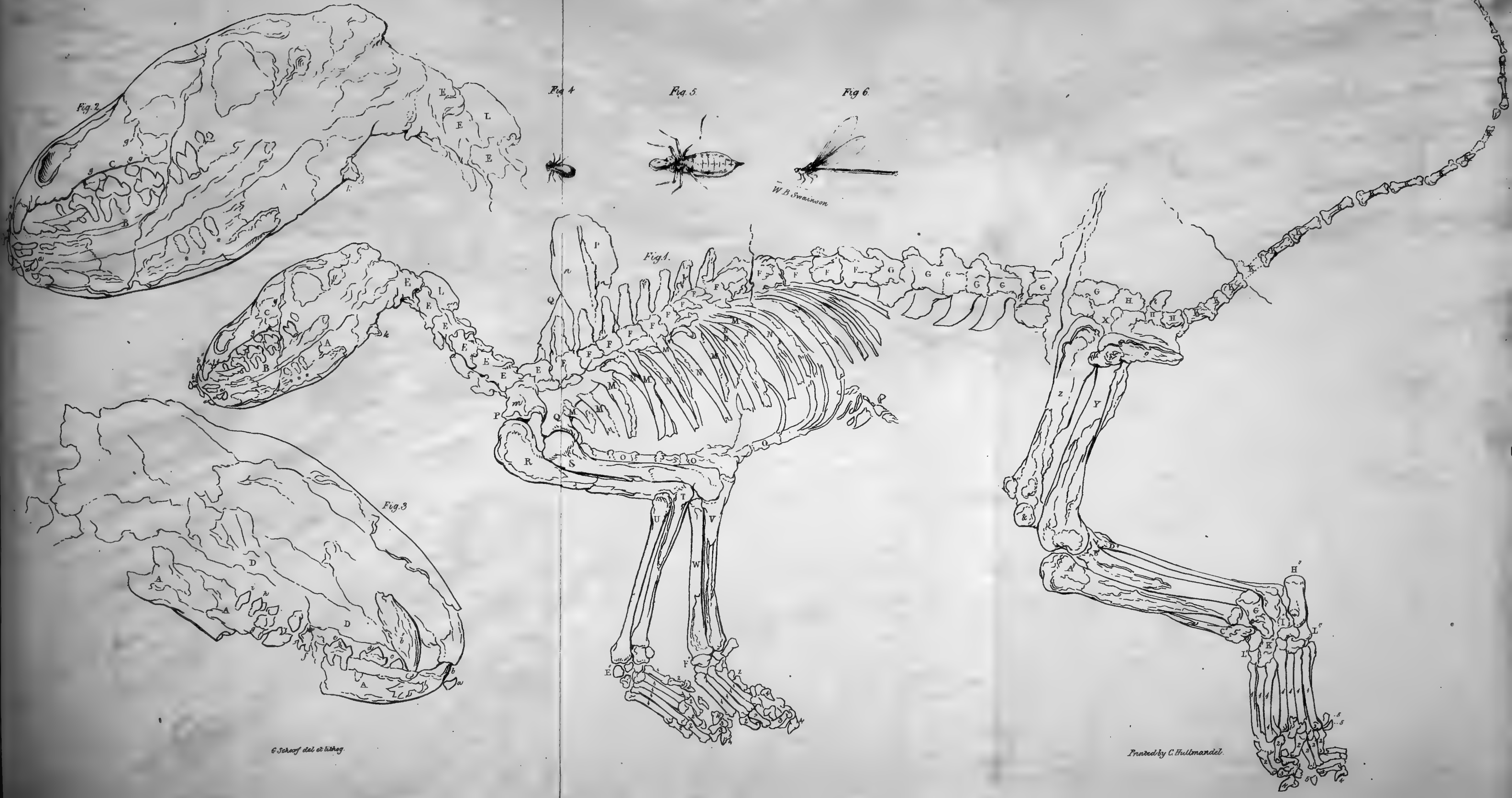
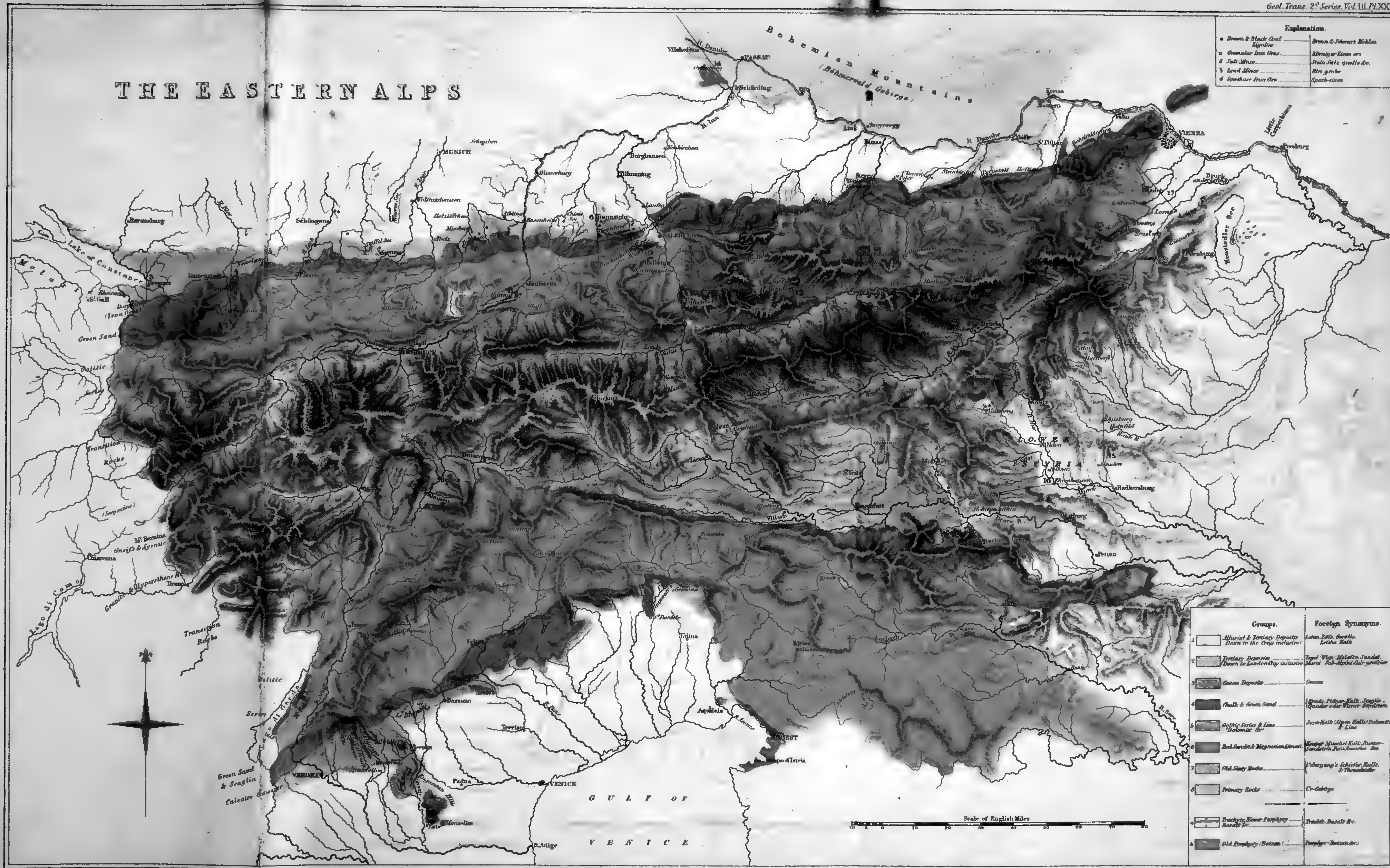


G. Scharf del et lithog.

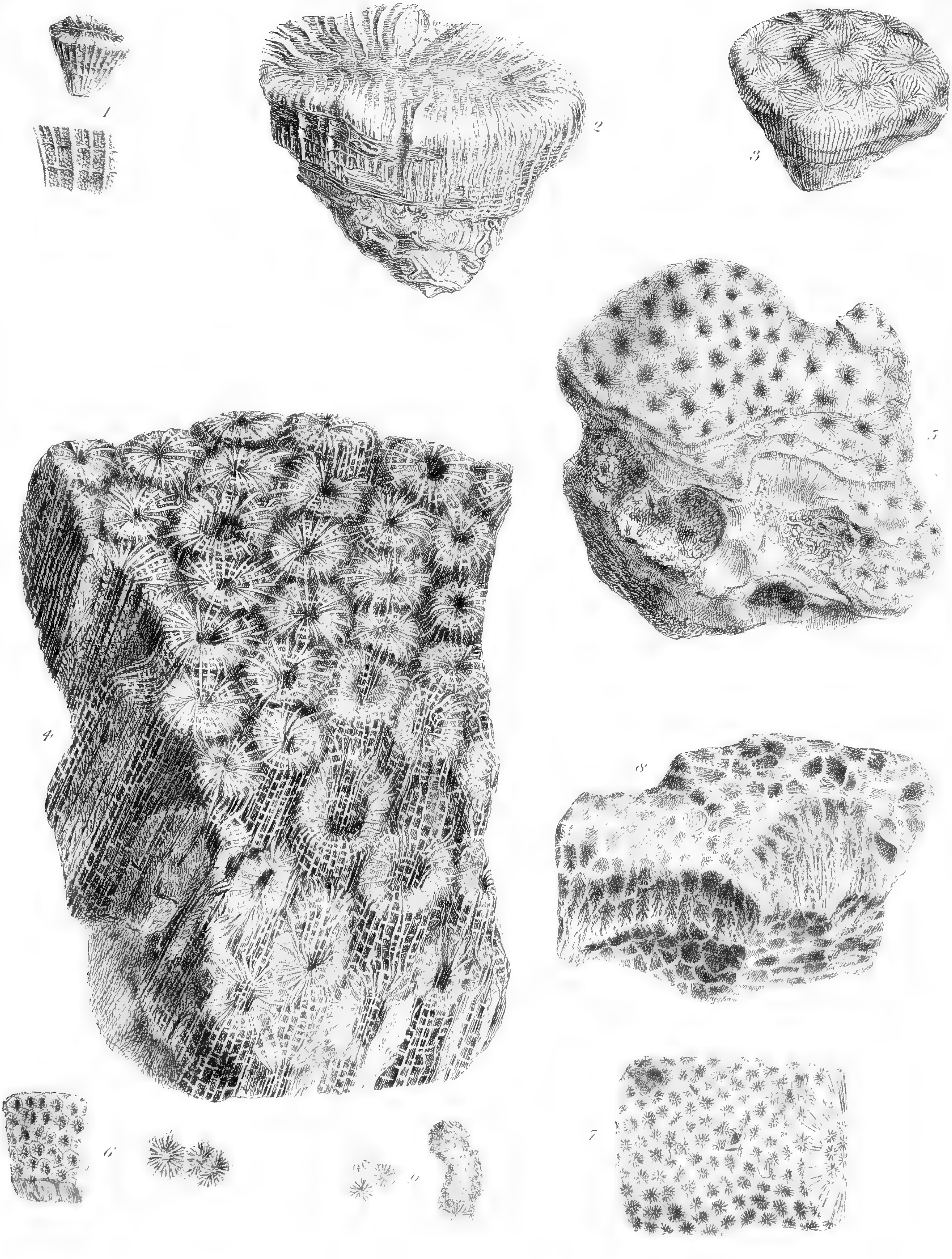
Printed by C. Hullmandel.



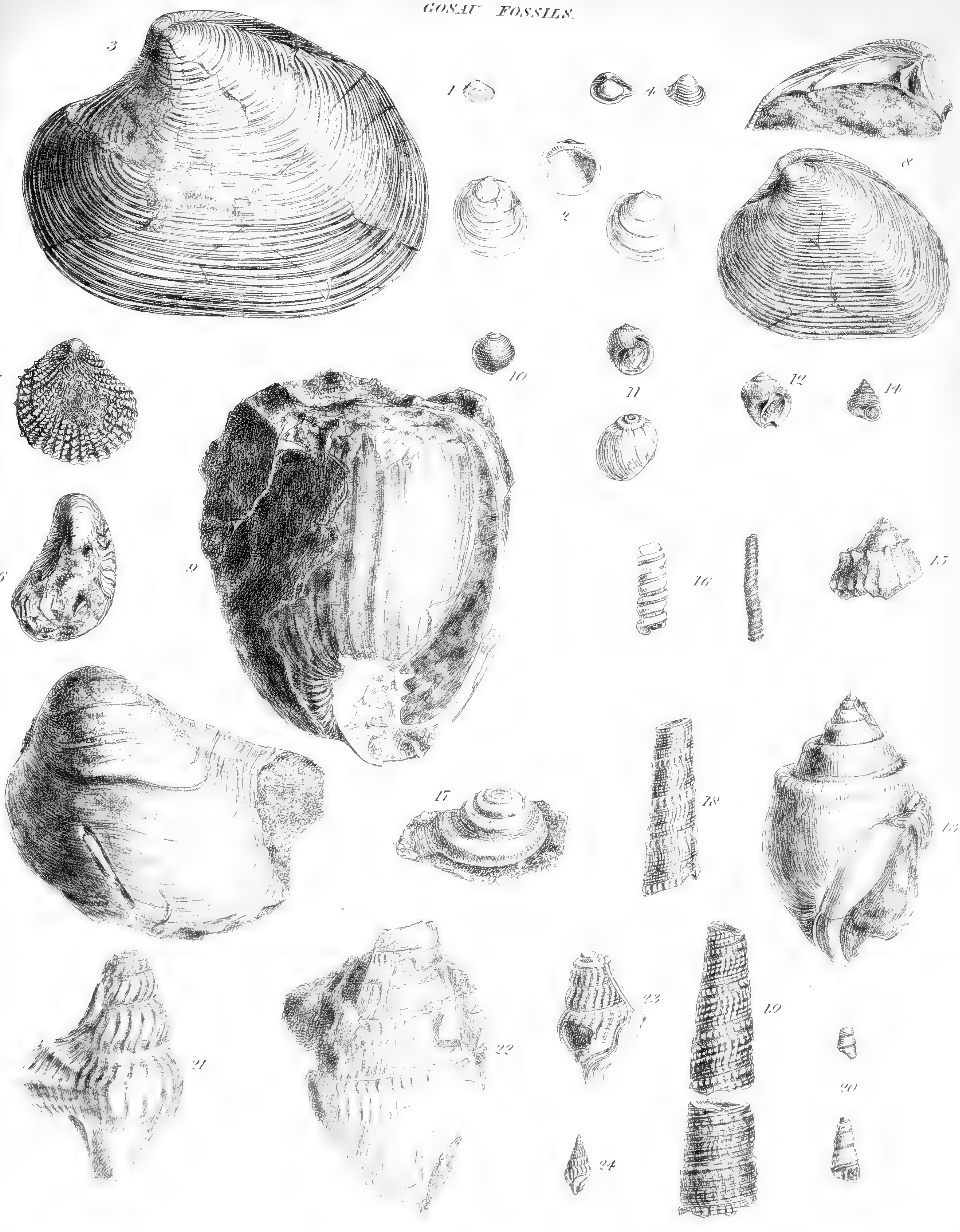
Engraved by J. Gardner


Fig. 1
GENERAL VIEW OF THE STRUCTURE OF THE EASTERN ALPS.
South
North
Fig. 2
SALZBURG ALPS.
S.S.E.
N.N.W.
Tauern Gebirge
Fig. 3.
EAST END OF THE LAKE OF CONSTANCE.
North
South
Sands & Conglomerates.
Molasse
Green Sand Series.
Fig. 4.
VALLEY OF SONTHOFEN, ALLGAU (Bavaria)
South
North
N. FLANK OF BAVARIAN ALPS.
Fig. 5.
South
North
Fig. 6.
BANKS OF THE RIVER TRAUN (Bavaria)
South
North
Fig. 7.
KRESSENBERG IRON MINES, (Bavaria)
South
North
Fig. 8.
HÄRING COAL FIELD (Tyrol)
E.S.E.
W.S.W.
TERMINATION OF THE ALPS W.S.W. OF SALZBURG
Fig. 9.
S.S.E.
N.N.W.
Oolitic Series
Gosau Beds
Fig. 10.
VALLEY OF GOSAU.
East
West
Fig. 11
VALLEY OF GOSAU.
North
South
Fig. 12.
N.N.W.
S.S.E.
S.S.W. OF VIENNA.
Fig. 13.
North
South
Fig. 14.
RELATIONS OF THE BOHEMIAN CHAIN TO THE DEPOSITS IN THE VALLEY OF THE DANUBE.
S.E.
N.W.
Granite
Fig. 15.
LOWER STYRIA (Along the frontier of Hungary)
North
South
Fig. 16.
FROM THE STYRIAN ALPS TO THE FRONTIER OF HUNGARY.
East
West
Level of the River Mur.
Calcareous Sandstone
Oolitic Limestone &c.
Conglomerates & Marls.
White Marl & Marlstone.
Fig. 17
BASIN OF VIENNA.
West
East
Leitha Kalk

GOSAU FOSSILS.

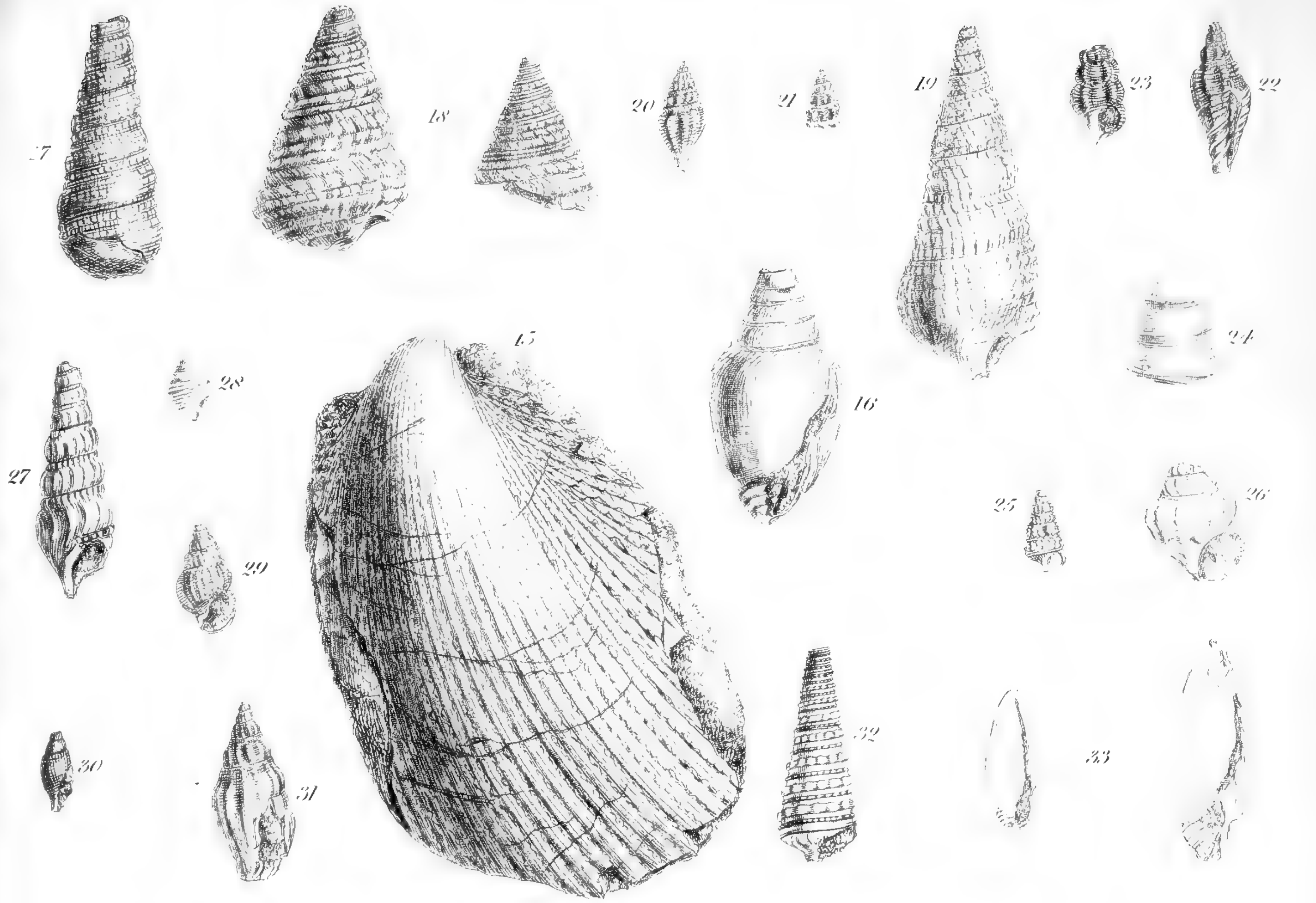


GOSAU FOSSILS.

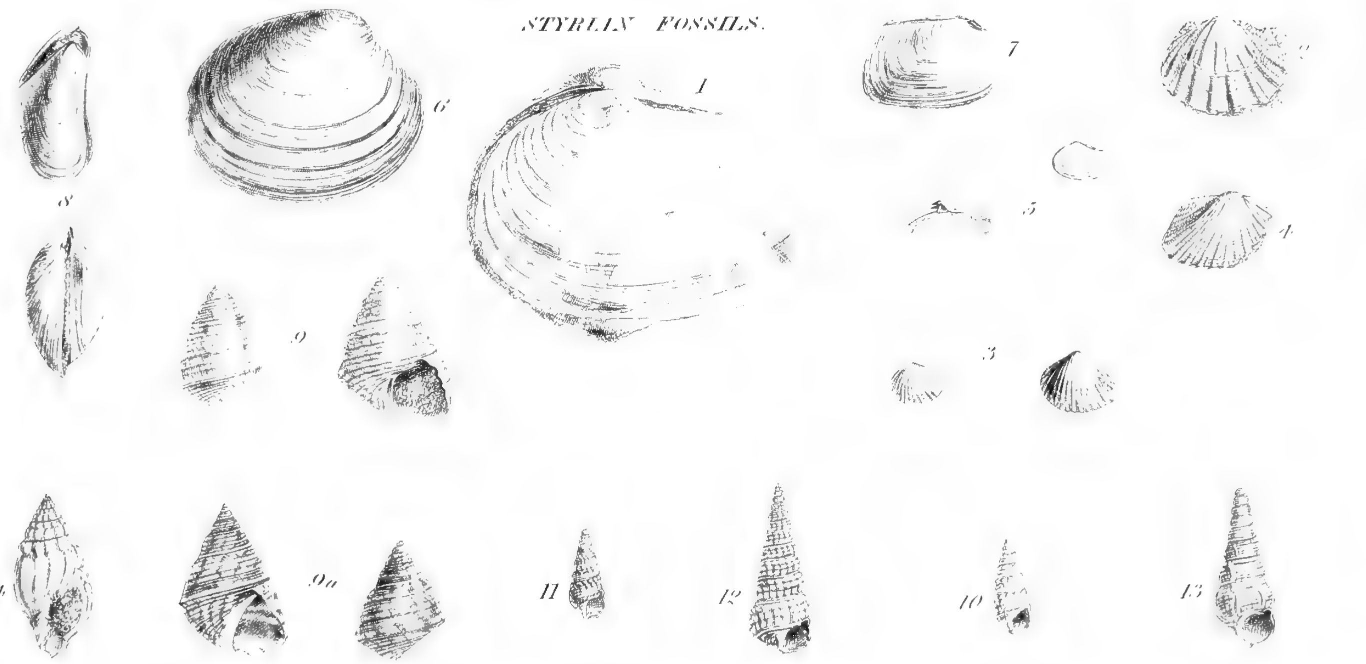


J.D.C. Sowerby, fecit

GOSAU FOSSILS.



STYRIAN FOSSILS.



J. D. C. Sowerby fecit

Drawn from Nature and on Stone by Charlotte Murchison.

Printed by C. Hull[illegible]

VALLEY OF GOSAU.

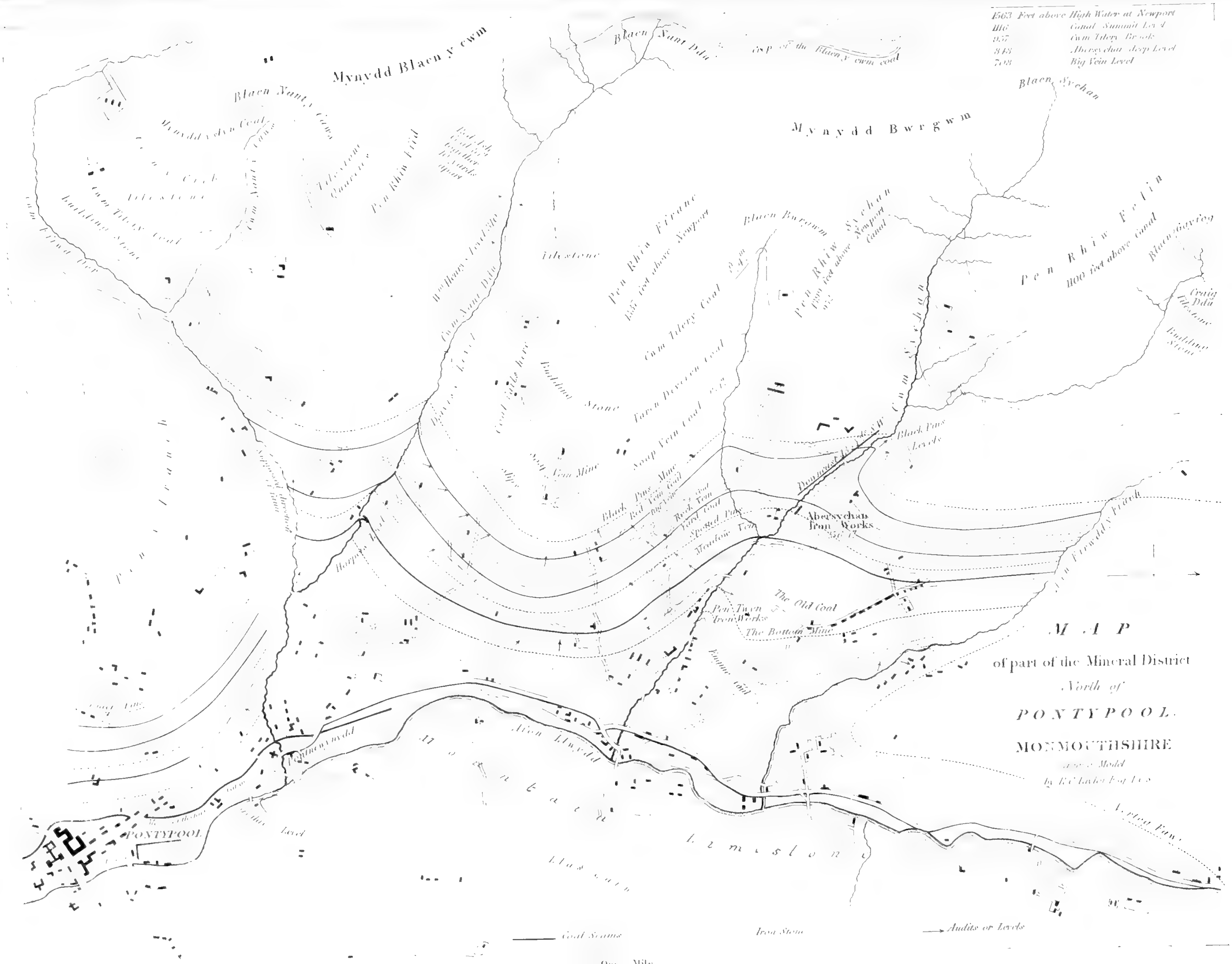
Salzburg Alps.

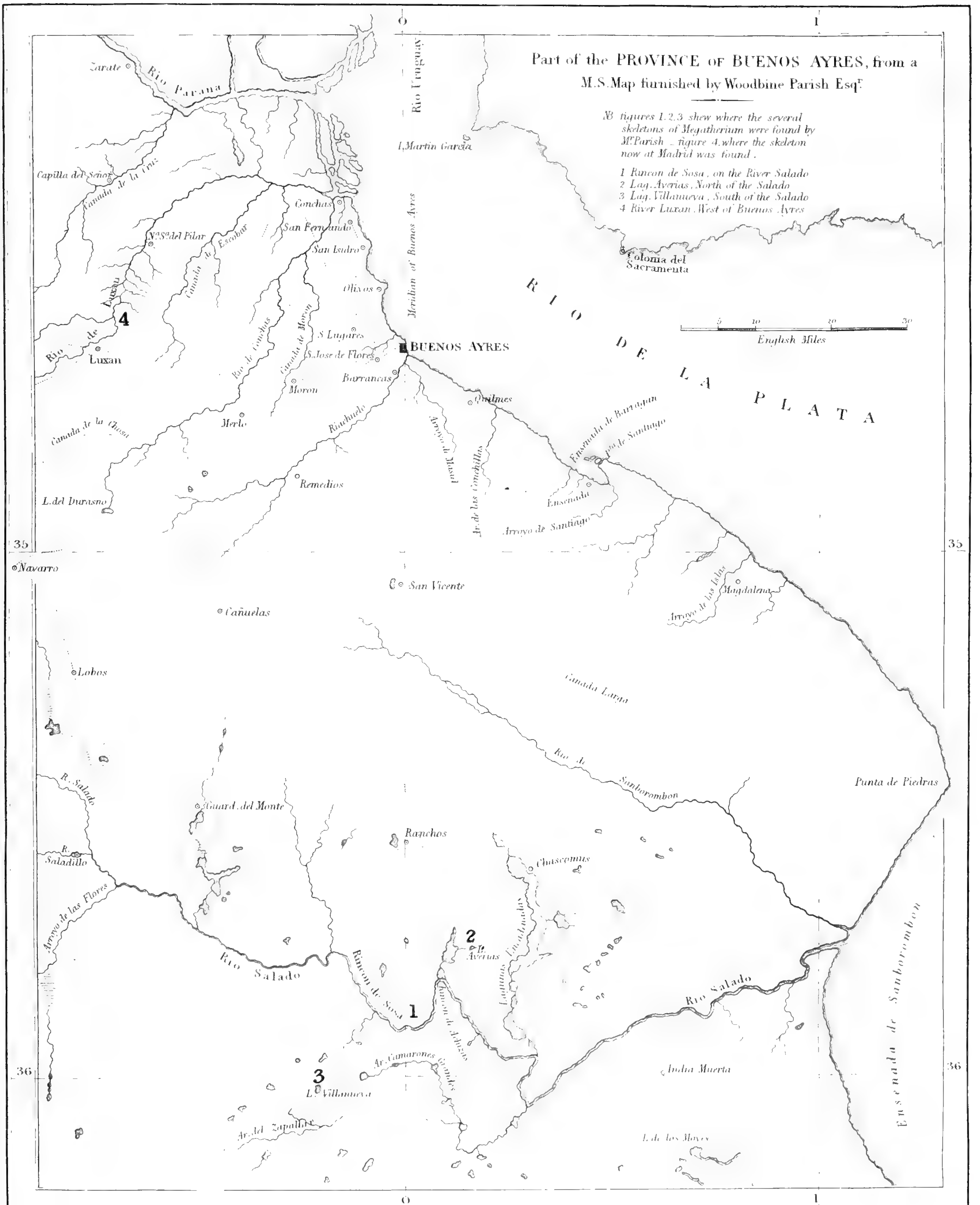
G. Scharf del et lithog.

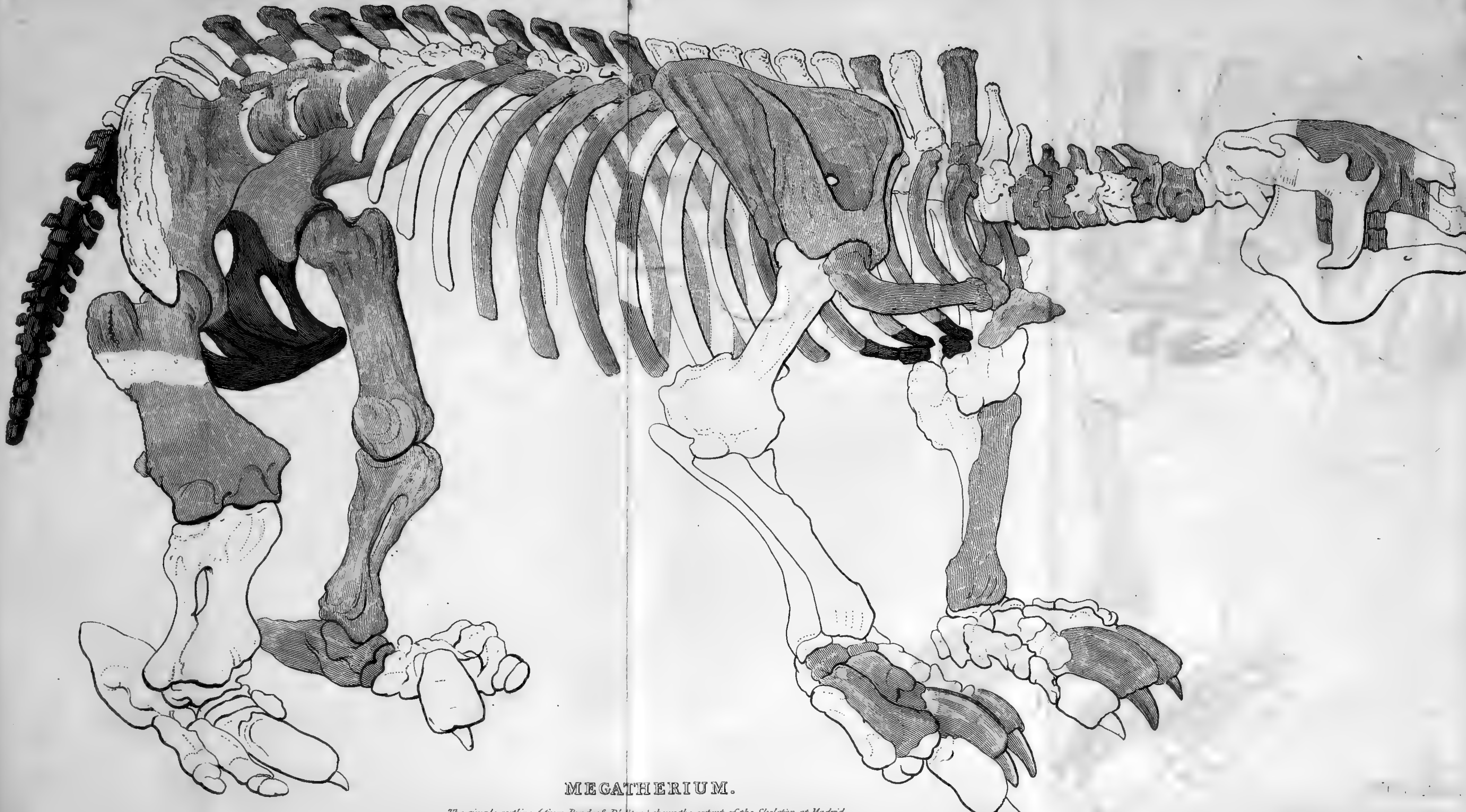
Printed by C. Hullmandel

1 & 2 Metacarpal Bone of Iguanodon from Sandown Bay, I. of Wight.

5. 6. Metatarsus of Megalosaurus, from Stonesfield, Oxon.
7. 8. Metatarsus of Crocodile, from Stonesfield, Oxon.


1563 Feet above High Water at Newport
1116 Canal Summit Level
937 Cwm Tilery Brook
843 Abersychan deep Level
708 Big Vein Level
Mynydd Blaen y cwm
Blaen Nant Ddu
Blaen Sychan
Mynydd Bwrgwm
Pen Rhiw Felin
1100 feet above canal
Craig Ddu
Tilestone
Building Stone
Pen Rhiw Sychan
Blaen Burwm
Pen Rhiw Firanc
Cwm Tilery Coal
Building Stone
Soap Vein Mine
Black Pins Mine
Red Vein Coal
Rock Vein
Yard Coal
Spotted Pins
Meadow Vein
Abersychan Iron Works
Black Pins Levels
The Old Coal
Pen Twyn Iron Works
The Bottom Mine
Engine Coal
Afon Llwydd
Pontnewynydd
PONTYPOOL
Limestone
MAP
of part of the Mineral District
North of
PONTYPOOL
MONMOUTHSHIRE
by R. C. Taylor Esq. F.G.S.
Coal Seams
Iron Stone
Audits or Levels
One Mile


Part of the PROVINCE of BUENOS AYRES, from a M.S. Map furnished by Woodbine Parish Esqr.
NB figures 1. 2. 3 shew where the several skeletons of Megatherium were found by Mr. Parish _ figure 4, where the skeleton now at Madrid was found.
1 Rincon de Sosa, on the River Salado
2 Lag. Averias, North of the Salado
3 Lag. Villanueva, South of the Salado
4 River Luxan, West of Buenos Ayres
English Miles
5
10
20
30
RIO DE LA PLATA
BUENOS AYRES
Rio Parana
Rio Uruguay
Meridian of Buenos Ayres
I. Martin Garcia
Colonia del Sacramento
Zarate
Capilla del Señor
Cañada de la Cruz
Conchas
San Fernando
San Isidro
Olivos
Nª Sª del Pilar
Cañada de Escobar
Rio de Luxan
Luxan
S. Lugares
S. Jose de Flores
Barrancas
Moron
Rio de Conchas
Cañada de Moron
Cañada de la Choza
Merlo
Riachuelo
Remedios
Quilmes
Arroyo de Maual
Ar. de las Conchillas
Ensenada de Barragan
Pta. de Santiago
Ensenada
Arroyo de Santiago
L. del Durasno
Navarro
San Vicente
Cañuelas
Lobos
Magdalena
Arroyo de las Islas
Cañada Larga
Rio de Sanborombon
Punta de Piedras
R. Salado
R. Saladillo
Guard. del Monte
Ranchos
Chascomus
Arroyo de las Flores
Rio Salado
Rincon de Sosa
1
2
Lª Averias
Lagunas Encadenadas
Rio Salado
3
Lª Villanueva
Ar. Camarones Grandes
Rincon de Achiras
Ar. del Zapallar
India Muerta
L. de los Moyos
Ensenada de Sanborombon
0
1
35
36



MEGATHERIUM.

The simple outline (from Pander & D'Alton) shows the extent of the Skeleton at Madrid.
The pale tint expresses the extent of corresponding parts sent to England by Mr. Parish.
The dark tint shows the additional parts, which are deficient in the Madrid Skeleton.

F. Basire. sc.

Fig 1

Fig 2

W Clift del. · Scharf lithog

1. Ungueal Phalanx of the Megatherium 2 Molar Tooth of the Megatherium.

Natural Size

Fig. 1

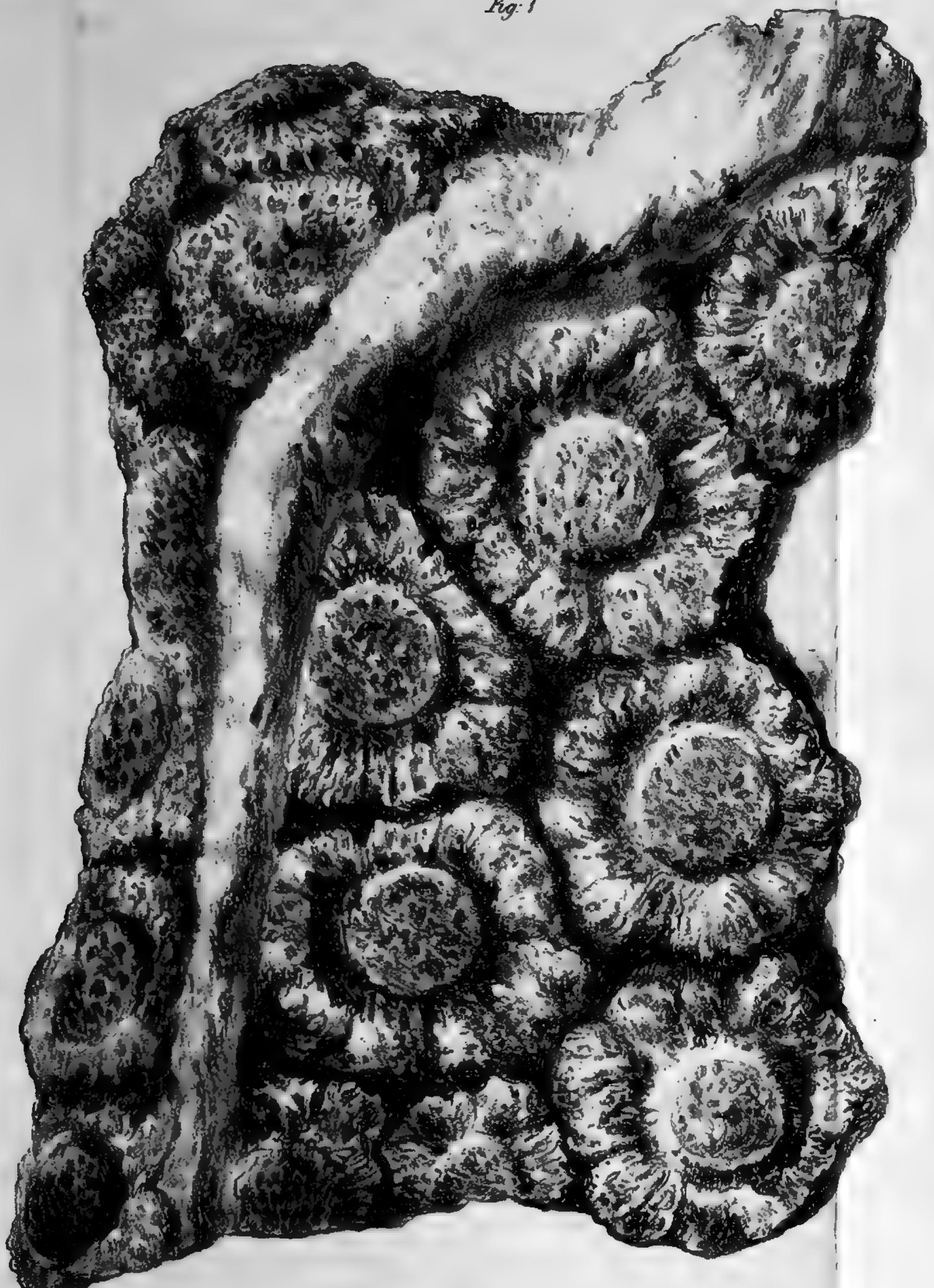


Fig. 2.

W. Clift del. G. Scharf lithog.

Printed by C. Hullmandel

1 Outside View of a portion of the Shell. 2. Inside View of a Portion of the Shell.

SECTIONS IN NORTH WALES, distinguishing Stratification from Cleavage