XX.—*On the Coal-field of Brora in Sutherlandshire, and some other Stratified Deposits in the North of Scotland.*

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THE peculiarities of the Brora coal-field had excited considerable interest among geologists, a few specimens of its more remarkable fossils having been occasionally sent to England. My attention was particularly called to this tract, by the Rev. Dr. Buckland and Mr. C. Lyell, who having visited Brora in the year 1824, expressed an opinion that the strata there were wholly unconnected with the coal-formation below the new red sandstone, and were in fact the equivalent of part of the oolitic series*. I was thus led to devote last summer to an examination of the district: and for the purpose of comparing its structure with that of certain parts of England and Scotland, which appeared to have the same physical characters, I previously surveyed the coast of Yorkshire, from Filey Bay to Whitby, comprising the coal-tract of the Eastern Moorlands; and afterwards some of the islands of the Hebrides. I

* The only printed notice of the Brora coal, with which I am acquainted, is contained in a general account of the Clackmannan and other Scottish *coal-fields* by Mr. Bald (Memoirs of the Wernerian Society, Edin. vol. iii. p. 138.) But it ought to be mentioned that a manuscript sketch of this tract has been read before the Philosophical Society of Inverness, by Mr. Anderson of that place; and if the avocations of this gentleman had permitted his examining analogous deposits in England, the present memoir might have been anticipated.

On the Yorkshire coast I had the great advantage of being accompanied by Mr. William Smith, whose accurate acquaintance with the different oolitic formations has enabled him to detect in Yorkshire, nearly all the beds belonging to that series in the south of England. Professor Sedgwick had established the general relations of these strata in a paper published in the Annals of Philosophy for May 1826; and the Rev. Wm. Vernon has since pointed out the existence, along the south-western boundary of the Wolds, of several of the beds discovered by Mr. Smith near Scarborough (Annals of Phil. June 1826.) In procuring illustrative fossils, with a view to comparison, I was kindly assisted by Mr. Williamson of Scarborough, a most accurate and zealous collector. For a detail of the order of beds in this district, see p. 297, note †.

now submit to the Society the result of this comparison, with some of the illustrative fossils of each tract, accompanied by a map and sections.

I shall commence with a description of that district which was the prime object of my research, and which is of the greatest importance in its mineral contents. The Brora coal-field forms a part of those secondary deposits which range along the S. E. coast of Sutherlandshire, occupying a narrow tract of about 20 miles in length, and 3 in its greatest breadth. The strata connected with it begin to rise from the sandy shore between Golspie and Dunrobin, and extend to the mountain called the Ord of Caithness. For the purposes of geological illustration, this tract may be said to be divided into three semi-elliptical valleys, separated from each other by the successive advance to the coast of the interior mountain range, which in retiring, forms their W. and N.W. boundary. These valleys diminish in size from S.W. to N.E., and in this distribution they stand thus:—

1st. Brora.
2nd. Loth.
3rd. Navidale.

The first is bounded on the S.W. by the mountain of Ben-a-Bhraggie, and on the West by the hills of Uppat, Loch Brora, and Clyne; all of which are composed of that red conglomerate which covers so large a portion of the North-eastern Highlands. Here it is formed of fragments of all sizes derived from the adjacent and more ancient rocks, passing into and alternating with a fine-grained red sandstone, occasionally schistose, highly micaceous, and variegated in colour. It is generally horizontal on the summits of the hills, or deposited on their sides with a slight inclination to the East. It is quarried as a building-stone at the base of the Craigton Hills, and the more fissile schistose beds on the summit of Ben-a-Bhraggie have even been employed as roofing-slates. On the N.E. of Loch Brora this red conglomerate gradually passes inland in a N. W. direction, forming the cap of some of the higher mountains. The low country of the coast is thenceforward bounded by an unstratified granitic rock, which is first seen near the church of Clyne, whence it sweeps down to the coast at Colyburn, there interrupting the stratified beds hereafter to be described, and thus inclosing the vale of Brora. Again retiring from the coast it continues to mark the interior boundary of the vales of Loth and Navidale, separating them by its advance at Portgower, and terminating the secondary series at the Ord of Caithness. This rock is throughout the greater part of its extent composed of reddish felspar and gray quartz, which are more or less accompanied by a decomposed green substance which may have been mica. It is always unstra-

tified, in some localities fine-grained, compact, and of a deep red colour: in others a coarse aggregate of pale-coloured felspar and gray quartz; whilst, at the points of junction with the secondary strata, it is usually in a decomposed state. In external character as well as in that internal structure which resists a fresh fracture, it strongly resembles the syenite of the Malvern Hills, (described by Mr. Leonard Horner,) to which it presents a further analogy by splitting under the hammer into cuboidal fragments, the interstices of which are sometimes coated with oxyd of iron.

The surface of the greater portion of the valleys is covered with vast quantities of diluvial gravel, principally derived from the adjacent mountain ranges, and diversified with numerous conical and tabular eminences. The strata beneath this diluvium are only occasionally visible; sometimes in low cliffs upon the coast, at other times where the plains are intersected by a stream; and an acquaintance with many of the beds, is only to be acquired by an examination of the reefs exposed at low water. (See Pl. XXXI. fig. 1.)

The relations between the superior strata and the red conglomerate cannot be observed in the Brora district; because the lowest beds of the former dipping under the sea, are considerably above the base of the series, which will elsewhere be described, in contact with the red conglomerate on another part of the coast.

The junction, however, between the granitic rock and the superior strata is seen in several places along the interior boundary of the valleys, where the sandstone and shale rest highly inclined or dislocated upon the edge of the mountain range. A striking example is afforded near Clyne church; where a stream forcing its way down the mountain side has cut several deep chasms, exposing alternations of stratified primitive rocks, nearly vertical and much contorted, consisting of quartz-rock and chloritic and micaceous schist, which last is accompanied by small portions of specular iron and galena. The granitic rock is here and there seen in the bed of the rivulet; whilst, at the base of this defile, the sandstone and shale of the coal-field rising gradually from Inverbrora, are suddenly elevated in the proximity of the same unstratified rock, which affects the primitive strata in the higher part of the ravine. (See Section on the line C, D. Pl. XXXI. fig. 1, and also fig. 2.)

I now proceed to detail more particularly the structure of the first of the three valleys before mentioned.

The district of Brora is about eight miles in length from Golspie to Colyburn, and about two miles and a half in its greatest breadth, where it is intersected by the river Brora; which flowing in a north-easterly direction from the loch of the same name, cuts through the diluvium of the plain, and pre-

sents on its northern bank, for nearly a mile and a half above its mouth, a broken succession of low cliffs, consisting of yellow micaceous sandstone, and dark coloured micaceous shale with belemnites, &c. At the first emergence of these cliffs, the river quits them and bends to the south, incircling in its course a trough of low land called the Pool, bounded on the south by table-shaped hillocks covered with diluvium. It then enters a narrow gorge, where the sandstone and shales are exposed on each bank to the height of 30 or 40 feet, and are visible from thence without interruption during the remainder of its course, which continues for about half a mile.

The highest eminences in the vicinity are the rounded hills of Braambury, situated a mile and a quarter from the sea. A portion of their surface, unlike that of every other elevation near them, is bare of diluvium; and the exposure of the valuable freestone of which they are composed, has led to the extensive quarries now worked there by the direction of the Marquess of Stafford*. Though probably not less than 200 feet above the level of the sea, with a dip conformable to that of the inferior strata containing coal, this stone is not to be traced beyond the hills where it is quarried, and may therefore be considered as an isolated portion of a stratum, the continuation of which has been removed, probably by denudation.

The exterior surface of this rock is channelled into undulating grooves, and the dip of the beds is easterly, at an angle of 25° to 30°. Where quarried for use they consist of a remarkably white quartzose sandstone, without admixture of iron or any discolouring matter. In other beds the cement and grains are united into one homogeneous quartzose mass, the thinner layers of which are of so compact a structure as to have been used for gun-flints: the extreme whiteness of some of these beds is strongly contrasted with small black portions of lignite imbedded in them. Numerous casts of fossils abound, with large stems of plants; some of the former, particularly three new species of pecten, are remarkable for the sharpness and minuteness with which they have retained the impressions of the shells, it being difficult to imagine how the siliceous grains of which this rock is composed, could be united into so uniform a paste. All the fossils now presented to the Society for the illustration of this memoir have been examined by Mr. J. Sowerby; and with his kind assistance I have annexed a tabular view, referring them to their analogues in England.

The freestone of Braambury and Hare Hills is in some places overlaid by

* This white freestone is in actual use for the construction of the interior of London Bridge, for which purpose it seems admirably adapted by the compactness of its structure and the vast size of its blocks.

a rubbly limestone, an aggregate of shells, leaves, stems of plants, lignite, &c. The prevailing fossils of this bed and the casts in the freestone are referrible to the calcareous grit or base of the coral rag of the oolitic series of England: viz. ammonites vertebralis, A. perarmatus, A. cordatus, the pecten of Marcham Field, Oxfordshire; gryphæa bullata, G. nana, &c.; Lucina crassa, modiola bipartita; most of which occur in the calcareous grit on the summit of Scarborough cliff*. It is remarkable, however, that the bivalve hitherto called the Venus of the Portland stone is found in the upper beds at Braambury Hill. It proves to be a cardium, and has at length been figured as C. dissimile, in Min. Con. tab. 553. (For further details see the Table of Fossils.)

A similar transition takes place at Abingdon, from a rubbly limestone into a siliceous rock, where many of the fossil shells are of the same genera and species as those now described.

If this sandstone of Braambury be not exactly similar to any rock in England, there is a complete identity between its fossils and those of the calcareous grit of the N. E. coast of Yorkshire; and the inferior strata in both cases have a close mineralogical resemblance. At the southern edge of the Eastern Moorlands, the lowest beds of the coral rag formation lose entirely their calcareous oolitic structure, and form lofty escarpments of white and yellowish sandstone: these are succeeded by shale containing belemnites and ammonites, from beneath which the great coal and sand formation rises to the North. A like succession takes place at Brora: in descending from the Braambury quarries to the coal-pit, some of the strata are obscured by diluvium; but these it may be inferred are the equivalents of those formations which intervene in Yorkshire between the calcareous grit and the strata containing coal; because beds with the fossils of those formations are exposed in various reefs along the coast of Sutherland, and the micaceous sandy beds with thin courses of shale, on the banks of the river above the coal-pit, represent another part of the same series†.

The coal-pit now in work is situated at the base of the sand and shale cliffs

* The beautiful casts of several new species of pecten in the quartzose sandstone of Braambury, are very similar to those of the calcareous grit of Malton, and Scarborough, recently figured in Mineral Conchology, tab. 543.

† On the coast of Yorkshire the strata appear in the following descending order, from Filey Bay to Whitby. 1. Coral rag. 2. Calcareous grit. 3. Shale with fossils of the Oxford clay. 4. Kelloway rock (swelling out into an important arenaceous formation). 5. Cornbrash. 6. Coaly grit (of Smith). 7. Pier stone (according to Mr. Smith, the equivalent of the great oolite). 8. Sandstone and shale with *peculiar* plants and various seams of coal. 9. A bed with fossils of the inferior oolite. 10. Marl-stone? 11. Alum shale or Lias.—All the above strata are now identified by abundant organic remains.

near the gorge, through which the river flows, and the shaft is sunk to the depth of 230 feet*. An account of the beds cut through in 1811 is annexed in the Appendix, but unfortunately the fossil remains were not at that period scientifically distinguished. One of these beds only is now exposed to view on the sides of the shaft, and is a compact calcareous ironstone, very similar to that which is so largely distributed throughout the coal-formation of the Scarborough coast. The first beds which are open to examination, form the roof of the coal, and are about 2 feet 7 inches in thickness: the upper part is an aggregate of fossil shells, cemented together with calcareous matter and quartzose grains: the lower part is made up of a compressed assemblage of leaves and stems of plants, crossing each other, and passing into shaly coal.

The broken and decomposing shells are mixed with carbonaceous matter, grains of quartzose sandstone, much pyrites, some crystals of sulphate of iron and selenite. I refer to the tabular view (p. 318.) for a detail of all the fossil shells; remarking that this bed alone has afforded 24 different species, of which 16 are well-known fossils of the oolitic series of England: amongst the hitherto undescribed shells, Mr. J. Sowerby has upon this occasion named and figured two species of the new genus pholadomya, one ammonite, one cardium, and one sanguinolaria. (Min. Con. tab. 545, 546, 548, 549.)

Many of the fossils of this bed are analogous to those of the pier stone near Scarborough, which there overlies the main coal-seams: the Gervilliæ, trigoniæ, univalves and ostreæ of these two beds, so far removed from each other, are identical; and perhaps the most remarkable feature in this coincidence is, that a bivalve not yet figured, (which Mr. Sowerby is inclined to refer to the new genus Pullastra,) is most abundant at Brora, and likewise characterizes all the strata above the coal on the N. E. coast of Yorkshire.

I am indebted to my friend Mr. König for the following account of the plant from the roof of the Brora coal, which he has identified with one of the fossil vegetables collected by me on the Yorkshire coast†.

"The vegetable remains in sandstone, slate-clay and clay-ironstone from the

* The section of a shaft, subsequently sunk at the engine pit 780 yards distant from the above, is also placed in the Appendix. This account as revised by Mr. Bald, was given by that gentleman in the Memoirs of the Wernerian Society. By comparing these two sections, it will be seen that the beds vary much less than might have been expected, when the distance between the shafts is considered.

† This plant has been figured in a work containing much valuable detail, viz. Messrs. Young and Bird's "Survey of the Yorkshire Coast:" but its botanical characters never having been scientifically given, I avail myself of Mr. König's description, and have annexed drawings of it, as seen in the sandstone of Yorkshire and the coal-shale of Brora. (See Plate XXXII.)

oolitic formation in the vicinity of Whitby, appear to me distinct from any which are known to occur in the true coal-formation. Most of these plants are undescribed, and deserve to be characterized from more perfect specimens than those before me.

"In most of the fragments of the slate-clay which I have seen, two or three distinct plants, or rather parts of plants, might be distinguished. One of these appears either in the shape of carbonaceous expansions exhibiting acute regular furrows of various lengths, gradually diminishing in width, and running out into linear grooves; the intermediate space, in the more perfect specimens, being marked with depressed dots; or in the shape of elevated rays or ribs having a pretty acute ridge and gradually tapering, from the width of $\frac{1}{16}$ of an inch, into a fine, more or less lengthened, raised line. The latter appearance is produced by a counter-impression from the grooved expansions. Together with these are seen well defined composite leaves: they are bipinnated, with pinnatifid ovate leaflets, having veins proceeding from the base, without a distinct mid-rib. They might, on account of their regular juxtaposition, be considered as having belonged to the abovementioned grooved and radiated expansions, could not the origin of these latter be traced to an order of plants which does not seem to admit of such a foliation; I mean, the arundinaceous vegetables found in the sandstone above the slate-clay. These consist of portions of jointed stems from one to two inches in diameter, and of various length; they are either cylindrical or collapsed and flattened; their joints, from one to three inches distant from each other, appear as bulging rings, and, if broken at the places of junction, exhibit traces of a dissepiment, which also appears to be indicated in some specimens by a slight depression round the middle of the projecting ring. The surface of the cylindrical fragments is nearly smooth and even; but at some distance from the joints fine grooves appear, which are widest near and on the tubercular swelling, where they assume the form of equidistant narrow slits, each formed by two planes meeting under a rather obtuse re-entering angle. Above the articulations, in some specimens, may be observed traces of a single impression or cicatrix; those which are not furnished with this may possibly belong to the root of the vegetable.

"Now, on comparing many of the grooved joints of these reeds in the sandstone with the ribbed leaf-like expansions in the shale, it will be found that there is no difference between them, except that in the former, though reduced to a thin film of coal, the shape of the stem has been more or less preserved by the hardened sand in their interior; while in the latter the carbo-

naceous rind has yielded to some external force, and adopted the form under which alone it is observed in the clayey mass.

"I should also mention that in these specimens of shale some other vegetable parts are occasionally observed, in the shape of small sub-triangular or inversely-cordate carbonaceous plates, which seem to have been membranaceous involucra, connected with the inflorescence of a plant. Those botanists who take it for granted that the composite leaves above alluded to are those of ferns, and that the reed-like stems are related to Equisetum, will of course be quite satisfied that the plates in question can have nothing to do with either. I cannot disprove that supposition.

"With regard to the coal from Sutherlandshire, I am (in corroboration of Mr. Murchison's views respecting its geognostic relations) decidedly of opinion that the above reed-like striated plant must have largely contributed towards the formation of that variety of coal. Its original structure is indeed nearly obliterated, but is nevertheless recognizable in the regular striation on the rifts; and in one specimen I have seen, it is partially exhibited with the same distinctness as in the reeds themselves.

"The plant under consideration may possibly be referrible to the same natural order with Equisetum, but it cannot be considered as a congener of the striated, reed-like fossils which have been comprised under the faulty name of *Calamites;* it is distinct from them by its peculiar striation, by the solitary impression above the joints, placed in such a manner as to indicate distichous alternating branches, and by the very striking callosity at these joints, which latter character has suggested the generic name of *Oncylogonatum.*

"The following phrase may, in the present state of our knowledge of this plant, serve both for its generic and specific character:—Caulis cylindricus articulatus, articulis annulato-gibbosis, gibbis internodiisque longitudinaliter sulcatis, sulcis acutis.—Species: *O. carbonarium.*"

From the coal-shale composed of the above plant, the next transition is into a purer bituminous substance approaching to jet, which constitutes the great bed of coal. This is from three feet three inches to three feet eight inches in thickness, and is divided nearly in the middle by a thin layer of impure indurated shale charged with pyrites, which, if not carefully excluded from the mass, sometimes occasions spontaneous combustion * upon exposure to the

* Inattention on the part of the workmen in the year 1817, in leaving a large quantity of this pyritiferous shale to accumulate in the pit, occasioned a spontaneous combustion, which was only extinguished by excluding the atmospheric air: the coal-pit was closed in, and remained unworked during four years. I have just learned (Feb. 1827) that fires have again broken out in the pit.

atmosphere; and so much indeed is that mineral disseminated throughout this district, that the shales might generally be termed "pyritiferous."

Although 14 or 15 slight dislocations are connected with the pit now in use, the present level was driven nearly 900 yards before the great fault was met with, which limits the coal-field upon the West, where lower beds containing nodules of blue limestone with septaria, are brought up near the salmon cruives. It is probable that from this place have been derived those boulders which are seen at the mouth of the river Brora, and which so resemble the cement stones of the alum shale at Whitby. Some of these faults are occupied by a white quartzose, and highly indurated sandstone, having a conchoidal fracture. Sinkings subsequently made below the working level, passed through beds of bituminous shale for upwards of 90 feet, when sandy clays of a loose structure stopped the works by occasioning a great influx of water; and therefore the whole depth of the sand and shale below the coal has never been ascertained.

The beds in contact with the granitic range are about one mile and a half distant from the coal-field, if the application of this term be restricted to that area in which the mineral has been discovered: indeed all attempts to work coal resting upon granite, would be impracticable, on account of the dismemberment of the strata which invariably accompanies such junctions.

For an analytical view of the chemical changes in the various lignites, from those of the highest formations down to the more perfectly bituminized substances similar to this under consideration, I refer to the Works of Dr. MacCulloch. With respect to the Brora coal, the purer part of it differs in no respect from the coal of the carboniferous series when subjected to chemical analysis; but it offers a mineralogical distinction upon being pulverized, assuming like all lignites a red ferruginous tinge, and thus differing from the true coal which works into a black powder *. The laminæ between the seams of the latter are generally coated with pure carbonaceous matter, whilst those in the Brora coal are occupied by bituminous shale. It may be considered one of the last links between lignites and true coal, approaching very nearly in character to jet, though less tenacious than that mineral; and when burnt, only slightly exhaling the vegetable odour so peculiar to all imperfectly bituminized substances. The fossil remains of shells and plants prove the Brora

* The same test does not strictly apply to *all* specimens of the coal, either at Brora or on the east coast of Yorkshire, which, although it occupies the geological place of lignite, is in some places not to be distinguished mineralogically from ordinary coal.

coal to be analogous to that of the Eastern Moorlands of Yorkshire, although the extraordinary thickness of the former, compared with any similar deposit of the latter, (which never exceeds from 12 to 17 inches,) might have formerly led to the belief that it was a detached and anomalous deposit of true coal, rather than a lignite of any of the formations above the new red sandstone: such misconception might more easily arise at a period when the strata were not identified by their fossil organic remains.

An epitome of the history of these coal-works is given in the Appendix, p. 323 *.

Coast Section.

I will now briefly describe the appearances on the coast, proceeding from S.W. to N. E.; as the beds exposed at ebb-tide, and in the low-cliffs, best explain the general stratification of the district.

The shore between Loch Fleet and Golspie consists exclusively of blown sand; and although the interior to the westward is very soon occupied by the red conglomerate, there are no traces of it upon the coast.

The first appearances of those strata which alternate throughout the Brora district, are seen at low water near Dunrobin Castle, where calcareous sandstones are succeeded by beds of pebbly calciferous grit, (upon which the pier is built,) and which are overlaid by shales containing limestone with fossils. The coarser varieties of the calciferous grit have in a remarkable degree that structure which is so frequently observable in all concretionary rocks; the planes of fracture coinciding with the cleavage of the grains of which the mass is chiefly composed, and exhibiting a silky lustre in one direction. The beds on this part of the shore occupy from 400 to 500 yards in breadth, with a N. E. dip of about 20° or 25°. The grits are overlaid by sandstone and micaceous shales, the latter containing numerous and flattened impressions of ammonites and small belemnites with indications of coaly matter. These are succeeded by black and white sandstone and shale, including a dark coloured limestone, the latter being an aggregate of fossils, including gryphæa nana, terebratula inconstans, serpula, pullastra, plagiostoma, pecten, &c. &c. The highest shales contain a dark blue limestone with septaria and very small sack-shaped pyritous nodules.

* For these documents and much kind assistance during the prosecution of my inquiry, I am indebted to the Marquess and Marchioness of Stafford, to whom belong all the tracts of country laid down upon the map; and their agent at the Brora works, Mr. Robertson, was most zealous in aiding my examinations.

The fossils of these reefs are for the most part referrible to the Oxford clay, and in general aspect the micaceous shales strongly resemble those already described in that part of the series on the N. E. coast of Yorkshire. It is probable, as I have elsewhere stated, that these same beds occur immediately below the quarries of Braambury, and would there have been seen overlying the sandstone of the cliffs, had they not been obscured by diluvium. These ledges of rock at Dunrobin are quite detached, and the sandy beach is resumed to the N. E., the eminences upon which the castle stands being diluvial, although the existence of sandstone below with subordinate coal has been ascertained by borings in that neighbourhood, and beds of shale basset out near the road from thence to Inverbrora.

A low coast of blown sand extending for about a mile towards the N. E. leads to the cliffs, which, in rising, exhibit a yellowish white micaceous sandstone; and, at this place, coal has been partially worked, probably a higher seam than that at Inverbrora.

At Strathsteven, the sandstone is quarried to the depth of 30 feet: it is here of a pure white colour, very friable when first raised, but hardening by exposure, and then acquiring partial ferruginous stains on the surface. In mineralogical structure it is identical with many beds of the great sandstone formation of the Eastern Moorlands; and thin courses of coal, differing somewhat in structure as well as in position from that of Inverbrora, indicate that here, as upon the Scarborough coast, there are several seams of that mineral. These quarries are valuable from their contiguity to the sea, and the facility with which the stone is worked. The cliff lowers gradually from hence, into trivial hillocks covered with blown sand, at the links of Inverbrora, where are still the remains of several old coal-pits. (See Appendix.)

The reefs which are exposed along the coast between Strathsteven and Inverbrora, with the exception of one fault, rise to the W. N. W. being prolongations of the strata of the Inverbrora coal-field; the beds of which being thus shown to be conformable throughout so considerable a space, their dip and inclination, viz. E. 25°, may be assumed to be those of the deposit. Coal has occasionally been worked at low water near the old salt-pans under a bed of fossils, agreeing precisely in contents and thickness with that which has been described as forming the roof of the coal at Inverbrora. The fossils are here found in a high state of preservation, and, in their ferruginous aspect, strongly resemble those of the pier stone of Scarborough. This bed, like that which overlies the coal at the Inverbrora pits, is covered by a suite of sands and shales, the latter containing flattened ammonites, and a large variety of the belemnites sulcatus. (Geol. Trans. 2nd ser. vol. ii.

Pl. VIII.*) These are overlaid by an indurated white quartzose sands which runs out into a long *scar* from the south bank of the river Brora. The stratification of the coast reefs at Ardasie Point on the north bank of the river is indistinct, and there appears to have been a great subsidence from thence, by which the highest beds of the district have been depressed below the level of the sea: hence no rocks are to be seen throughout the sandy bay north-east of the river Brora, the low grounds between it and Clynemilltown being covered with blown sand and gravel.

At Kintradwell are the first appearances of beds differing from any previously mentioned: some of these resemble the cornbrash limestone, and others the forest marble; the prevailing fossils being the avicula inequivalvis and the terebratula inconstans. One of these beds of shelly limestone is overlaid by shale in a low hillock on the shore, and below it are reefs of bluish calciferous grits containing a few fossils, among which the nerita lævigata was observed. These grits are traversed by a vein two feet and a half wide, in texture resembling quartz-rock and having a conchoidal fracture: the tilting of the strata in opposite directions at this point indicates some powerful disturbing cause. After a short interval of low shore, the sandstone and shale above the beds of shelly limestone form cliffs, near Colyburn, higher than those of any other part of the Brora coast. Here the granitic rock advances from the mountain range, occupying both sides of a precipitous ravine; and the secondary strata near it are much dislocated: the sandstone is in some places indurated, and accompanied by brown hæmatite; and porcelain clay (Kaolin) is dug in the cliff, probably derived from the decomposition of felspar. This advance of the mountain range forms a natural division between the vales of Brora and Loth.

Loth.

This vale is about six miles in length from S.W. to N.E., and varies in breadth from half a mile to one mile and a half. It is trough-shaped: the strata, which are highly inclined against the mountains of the interior, sink in the centre of the vale, and again rise on the exterior into low hills towards the sea. This coastward rise of the beds is apparently owing to the proximity of the granitic rock, which is here and there seen through the accumulations of blown sand. In the lowest or central part of the valley, black shale

* I have the authority of Mr. Miller, who has examined my specimens, for stating that the variety of B. sulcatus from these shales at Brora is identical with the belemnite of the Oxford clay.

is at present exposed in cutting drains, but the surface of the whole is partially covered by hillocks of diluvium.

At the mouth of the Loth-beg-burn, the cliffs on either side consist of black and white soft sandstone in very fine laminæ, and much carbonaceous matter is there visible in the underlying shale. At Crachaig Point the sandstone is of a coarser structure, and, in the sandy shale of the shore beyond that place, I found a large mass of a singular variety of a black carbonate of lime.

At Kilmot the shelly limestone first noticed at Kintradwell re-appears: here the beds dip in opposite directions and are highly inclined, owing probably to the proximity of the granitic rock. At Kilgour Point the reefs consist of the shelly limestone and grits, and the coast hills increasing in height are composed of shale occasionally seen through a cover of diluvium, and particularly at the mouths of several small streams between this and Portgower. The same order of superposition is apparent throughout the coast from hence to Navidale, wherever the superior strata are not obscured by diluvium; the shelly limestone and calciferous grit being the lowest rocks, and the shale the highest. Hence, if the former be the equivalent of cornbrash and forest marble, the latter may represent the Oxford clay.

The finer portions of the shelly agglomerate are burnt for lime at Portgower, Helmsdale and Navidale. At these places it is a mass of broken shells, agglutinated by an impure calcareous paste, and forming beds from a few inches to two feet in thickness; besides the terebratulæ and aviculæ mentioned at Kintradwell, there are found in it univalves, ostreæ, and other shells; with echinital spines, flustræ, &c. These remains are intermixed with abundant minute portions of black lignite, the fossil beds are frequently separated from each other by thin micaceous sandy shales, and the whole are in general based upon bluish calciferous grits. Near the limekilns at Portgower, the dislocations are most remarkable; the dip changing in the space of a few yards from an angle of 25° to one of near 70°, and the line of direction being as suddenly altered from E. to N. In consequence of the powerful disturbing forces which have been in action, some of the beds most affected here and along the shore to Kilmot, are made up of portions of shale and sandstone mixed with the shelly limestone, thus forming a conglomerate, of which more will be said hereafter. (See Map, Pl. XXXI: Portgower.)

At a short distance to the N. E. of that place the sandstone and shale, with a bed containing some imperfect fossils, are exposed in the coast hills, and much dismembered by contact with the granitic rock. In the centre of a wild ravine stands a conical hill, at the base of which two mountain torrents

unite. The lower part of this cone and bed of the stream are composed of the granitic rock; while the sides are covered by fragments of sandstone and shale, derived from the beds which rise from the ravine. (See Section, Pl. XXXI. fig. 2.)

It may now be remarked that the uniformity of dip which prevails in that part of the district of Brora where coal is worked, is not observable where the superior strata are in immediate contact with the granitic rock.

From Portgower to Helmsdale, the coast hills are again covered with diluvium, concealing at that place the strata on both banks of the river; but the shelly limestone is extended into ledges on the north bank of the harbour, and the worn surfaces of some of these beds expose a mass of flustræ, mingled with univalves and spines of echini.

Navidale.

The granitic mountains retire gradually from Helmsdale, and again advance to the coast at the Ord of Caithness, thus inclosing this little valley. The solitary House of Navidale is placed upon a green knoll, flanked by narrow glens, and overlooking a small pier. The base of the cliff is composed of the shelly limestone, which very much resembles certain beds of the oolite near Bath. Above the limestone, and immediately below the House of Navidale, the sandstone is in contact with the granitic rock, the latter in various stages of decomposition, and the former highly inclined. In proceeding to the N.E., the place of the shelly limestone on the shore is occupied by a conglomerate much more coarse than that near Portgower, and apparently derived from all the strata which have been described as occurring from Kintradwell to Navidale; viz. micaceous shales, calciferous grits, and indurated limestone and sandstone. The admixture of finely comminuted shells disappears, but an occasional ostrea, or other fossil of firm texture, is still included between the fragments, which are united by a sandy calcareous cement; the whole mass bearing much the appearance of an old and weathered wall.

The indurated shales of this conglomerate might, in hand specimens, be mistaken for grauwacke: but, upon a careful inspection of the whole coast, and, after observing the change of character which occurs in the beds at and near their contact with the granitic rock, a conviction follows, that, in proportion as the disturbing causes have become more active, a breccia has been compounded from the whole suite of the superior strata of the deposits upon this coast, and that the portions of it which resemble grauwacke are only the sandy shales of the oolitic series in an altered state.

Other geologists may be of opinion that some of these indurated shales with

an associated limestone have been derived from the slate of Caithness, which is very largely developed to the north of the Ord; but such an inference can hardly be admitted, since the latter alternates with the sandstone of the red conglomerate, elsewhere shown to be composed of those granitic and older rocks, of which latter there is not a vestige in this singular breccia.

The beds of limestone near the Ord have also an altered character. They are very compact, of a semi-crystalline structure, void of fossils, much charged with ferruginous matter, highly elevated, and traversed by veins of crystallized carbonate of lime.

Here the cliff is generally from 80 to 120 feet in height, divided by numerous ravines, in the bottoms of which the granitic rock is disclosed by the streams flowing from the mountains of the interior. Irregular conical masses, chiefly consisting of a highly ferruginized cellular sandstone, in which all traces of stratification are lost, stand up in the mouths of these narrow defiles.

These are terminated by a peninsulated terrace, called the "green table," which serves as a pedestal to the Ord of Caithness; and, at its base, the breccia rising from the sea with a rapid inclination, forms an admirable breakwater against the waves of the German Ocean, to the violence of which this promontory is fully exposed. (See Section, Pl. XXXI. fig. 2.)

It has been frequently remarked that, wherever the granitic rock appears, the beds in contact with it are elevated, and, in many instances, shattered into fragments; hence it would seem that such phænomena can only be explained by supposing the former to have been thrown up at periods subsequent to the deposition of the latter.

East Coast of Ross and Cromarty.

I could discover no portions of the oolitic series to the north of the Ord of Caithness; and, to the south of the district described, the low coasts of Sutherland and Ross are composed exclusively of the sandstone of the red conglomerate, occasionally accompanied by a lamellar sub-crystalline limestone. My attention, however, was directed by Sir George Mackenzie to certain beds with fossils which occur near those remarkable headlands the Sutors of Cromarty.

At the northern extremity of a narrow mountainous ridge which there occupies the coast, the red conglomerate rises from its horizontal position in the plain of Easter Ross*, where it is for the most part in the state of a fine-grained

* These plains of Easter Ross are celebrated for their fertility and abundant production of wheat. This agricultural distinction is very remarkable in so northern a latitude, and affords a

sandstone, and, swelling into hills which bound Shandwick Bay upon the s. is recumbent with a highly inclined dip upon a granitic rock, very similar that of the Ord of Caithness. Near this junction, beds of dark coloured micaceous shale, only visible at low water, dip away from the coast, resting unconformably upon the edges of the sandstone of the red conglomerate. These shales extend about three quarters of a mile from N. to S., and, at low ebbs, are developed through an equal space from W. to E. They are remarkably curved in one situation, where the softer portions having been washed out, the harder shales with limestone rise one above the other, and thus present the appearance of seats in an ancient theatre.

The laminated beds contain a compact blue argillaceous limestone marked by veins of carbonate of lime; and nodules identical with the cement stones of the alum shale are not unfrequent. The fossil shells which I procured during one ebb of the tide are those of the lias; viz. gryphæa gigantea, G. incurva; ostreæ, belemnites, ammonites, &c.

These beds are cut off upon the south by lofty cliffs, the insulated and broken peaks of which continue to distinguish this bold coast on both sides of Cromarty Bay. These cliffs are composed of various primitive rocks, much elevated and contorted, traversed by numerous veins of the granitic rock. (See Pl. XXXI. fig. 3.)

Passing to the south of Cromarty Bay, the coast is still chiefly occupied by cliffs of the granitic rock; but the black shales and blue limestone beds reappear in Ethie Bay, where a fine-grained whitish variety of the red conglomerate composing that large peninsula of Ross-shire, called the "Black Isle," is elevated into lofty hills. Many of these beds at Ethie, although principally composed of granitic detritus, contain much calcareous matter: others, it must be stated, strongly resemble the old red sandstone of South Wales, particularly in having a subordinate bed of red limestone which is very similar to the cornstone; and the whole suite is interspersed with much mica, chlorite, and indistinct corbonaceous markings. The shale beds on the shore are clearly a portion of the same series as those beyond the North Sutor, from which they are distant about eight miles. They dip away from the coast at about an angle of 30°; and, with the exception of some partial dislocations and contortions, they

slight ground for presuming that the sandstone of these districts may be the equivalent of the newer red sandstone which is so uniformly distinguished in England and elsewhere by the richness of its soil; the sandy tracts of the old red being usually marked by their sterility. The stone of the Red Castle and Tarradale quarries strongly resembles some beds of the new red sandstone near Bristol; and sulphate of strontian, a mineral characteristic of that formation, is found at Clachnacarrich near Inverness: which place, although to the South of the Murray Firth, may still be considered within the range of the red conglomerate.

are nearly conformable to the inferior red conglomerate, although their junction with that rock is obscured by boulders and shingle. The shale here contains blue limestone nodules, much lignite and carbonaceous matter, numerous casts and impressions of ammonites, very slender belemnites (a variety of the belemnites abbreviatus of Miller), and scales of fish of a rounded form, some of which are converted into bitumen. The most remarkable bed is a calcareous aggregate of fossils, amongst which is an ammonite, (probably the A. Königi,) gryphæa incurva, a new species of plagiostoma, and an undescribed bivalve. In the more compact blue limestone are clusters of young ammonites, resembling those of Watchet in Somersetshire, and of so minute a size as scarcely to be distinguishable by the naked eye. These beds, as well as those near the North Sutor, are clearly of the lias formation, and therefore may be regarded as the base of the series described at Brora, where the inferior oolite with its subordinate coal-seams dips below the level of the sea.

The elevated coast ridge near Cromarty displays upon its eastern side not only the relation of that series to the red conglomerate, but also proves the latter to have been the only intermediate deposit between the lias and the primitive rocks.

Although in several places near Cromarty an unstratified granitic rock resembling that of the Ord is occasionally seen in contact with the red conglomerate (this latter in such cases being always highly inclined), yet the greater portion of the cliffs on the southern part of this coast consists of the stratified primitive rocks. Thus between Ethie and Rosemarkie, micaceous and hornblende schists alternate with talcose, white quartz and red felspar rocks, most of which are highly elevated and much foliated.

I examined a great part of the east coasts of Inverness, Moray, Banff, and Aberdeen, without discovering any traces of the stratified beds with fossils above described: and, if the comparison which I have instituted between them and those of the Yorkshire coast be correct, these two deposits, though apparently separated from each other by an interval of more than 250 miles, must have originated in the operation of similar causes, and are consequently referrible to the same geological epoch.

Western Islands.

Skye.

In the "Geology of the Western Highlands," vol. i. p. 339, Dr. MacCulloch, after remarking upon the secondary strata of this island, adds, "other analogies will also readily suggest themselves to English geologists," &c. I will

therefore proceed to notice those beds which came under my observation, and which further confirm the analogy between these deposits in the Highlands of Scotland and the oolitic series in England.

On the north-eastern side of the Harbour of Portree, the lofty trap rocks which occupy the cliffs upon the coast, retire from the sea, and bound a small elevated vale called Beal, of about half a mile in length and 200 yards in breadth. The beds of which the higher part is composed, consist of a calcareous agglomerate of fossils, not to be distinguished from many portions of the English cornbrash and forest marble, whilst, in some parts, it resembles those fissile beds of oolite, which cap the cliffs at Bridport in Dorsetshire, overlying the sandstone of the inferior oolite. The characteristic fossils, like those of the shelly limestone on the coast of Sutherland with which it is identical, are the terebratula inconstans and the avicula inequivalvis, and the beds containing them here, as well as at Brora, are overlaid by a yellowish white sandstone. These beds present a mural escarpment to the coast dipping slightly to the N.W. in conformity with the arenaceous strata containing large nodular calcareous concretions upon which they rest. This Beal limestone is fissured to its summits by several dykes of greenstone, both compact and amygdaloidal. Most of these are empty, but one is still filled with zeolitic greenstone, having numerous small veins ramifying from it, but the regularity of dip is not in this case altered by the intruding rock.

On approaching Holm, the sandstone is seen rising to a considerable height from beneath the fossil limestone, but is obscured by the trap towards the higher parts of the cliffs, though it exhibits greater regularity of structure near their bases; containing those calcareous concretionary nodules with fossils, which elsewhere mark the lines of stratification in the sandstones of the inferior oolite. Amongst these fossils are the mya V. scripta, pectens, serpulæ, encrinites, belemnites, &c.

To the N. E. of Holm the sandstones and shales retiring from the coast, ascend into a lofty escarpment, over which the cascade of Eas-veririg falls, at a few hundred yards from the beach. Impressions of vegetables found in these sandstones belong apparently to the same family of plants which has been described in treating of Brora, and ostreæ are here also found attached to carbonized wood.

At the base of the sea cliff, beds of sandy micaceous shale contain compacted masses of the large belemnites abbreviatus, so characteristic of the inferior oolite, with limestone nodules, masses of ammonites, and some undescribed bivalves: amongst the ammonites is a new species figured in Min. Con. tab. 550.

That the strata of this series were originally continuous from the high cliffs between Portree and Holme to the low coast on the opposite side of the island, as stated by Dr. MacCulloch, I can confirm, having found several fossils in blue shale through which a deep canal has recently been cut by Lord Macdonald, to drain the lake of Mugsted. Among these shells are the ammonites Königi, ostreæ in masses, many belemnites, flattened tellinæ ? &c.

The features of this island and the extraordinary relations of the secondary strata to the trap-rocks, have been so fully described in the "Geology of the Western Islands," that I abstain from any further detail, and simply refer to the tabular arrangement, (p. 321,) for a list of the fossils which I collected in various parts, viz. on the N.E. coast, at Loch Sligachan, and also in the Isles of Scalpa and Pabba. In addition to many acknowledged shells of the corn-brash, inferior oolite and lias, there are several new species : of the latter, the gryphæa which pervades the lower shale and limestone of the Hebrides, and has been named after the geologist who first described it, is particularly to be mentioned. (See Min. Con. tab. 547.)

The gryphite limestone of Broadford and that of Sconser, containing ammonites, encrinites, pinnæ, &c., are members of the lowest formation in the series, which may now safely be assigned to the lias of English geology, the superior strata having been shown to belong to the overlying oolites.

Mull,

The most southerly part of the Western Islands in which the strata of the oolitic series have been noticed, is upon the S. coast of Mull ; on a part of which I examined the beds in detail. From beneath the low and insulated promontories of greenstone and amygdaloidal trap on the W. of Loch Buy, sandstone and limestone rise into lofty cliffs at Carsaig House, below which extensive beds of micaceous shale accompanied by veins of dull blue limestone are uncovered upon the shore at ebb tide. Their structure resembles exactly that of the shales of Pabba and Scalpa ; and the beds in these different places contain many of the same fossils, viz. belemnites, gryphites, pectens, two or three ammonites, including the A. Conybeari of the lias and a new species, A. Jamesoni (Min. Con. tab. 555), which, although never previously described, is found in the lias shale of Robin Hood's Bay near Whitby. The shale is overlaid by a yellowish micaceous sandstone, distinguished here, as in the Isle of Skye, by large calcareous concretionary nodules containing fossil shells ; by which, and by immediate superposition to the gryphite shale, these beds are at once recognized as belonging to the inferior oolite. The best general section of the strata is seen upon the west side of the defile near Carsaig

House, where the sandstone with calcareous spheroidal nodules re the shale; and the former rising high in the precipitous cliff, is overla broken by trap and basalt. The structure of this sandstone is identical that of many beds upon the Yorkshire coast, and natural caves are of 1. quent occurrence in it *.

Limestone containing imperfect fossils occurs in the uppermost beds, and also a lignite which has been partially worked for fuel: but I could not distinctly ascertain the order of superposition in the higher parts of the cliff; for here, as well as upon the N. E. coasts of Skye, it is in the lower part only that there is any regularity of stratification, the summits being invariably obscured by superincumbent trap.

The strata on the S. coast of Mull reach to nearly as high elevations as in Skye; but to the west of the rugged shore of the Inimore of Carsaig they are gradually brought down, and are obliterated by the basaltic rocks which form the wild and gigantic promontories of Ben Macquarrie and MacCullum's Point †.

The preceding details have shown that upon the N. E. coast of Scotland, the strata above the lias are visible only in low cliffs, or in beds exposed at ebb tides; the distance which they occupy at intervals from N. to S. being about 40 miles, and their greatest breadth from E. to W. about 3 miles.

On the N. Western coast, different members of the same series are to be traced, through a space of 120 miles, from the Shiant Isles on the N. to the S. coast of Mull, frequently swelling into cliffs of great height. They are, however, so traversed and overlaid by trap and basaltic rocks, that the precise relations of one bed to another are in many situations rendered equivocal, although the fossil remains of the whole suite are clearly referrible to various oolitic formations, which are seen to be based upon the lias.

In the Brora district, however, each bed has been distinctly assigned to its equivalent in England. The strata containing the coal have been shown to be identical with those of the Eastern Moorlands of Yorkshire, which are the

* One of the largest and most remarkable of them is called the Cave of the Nuns; and the spheroidal nodules above described project from its sides and roof. The sandstone is quarried near the cave, which is used as the abode of the workmen. Communication with this sequestered habitation can only be made by sea.

† For a picturesque sketch of this unfrequented spot, I refer the reader to the Earl of Compton's Views, illustrative of his memoir on the *trap-rocks* of this coast. (Geol. Trans. vol. v. part 2.) and for the singular changes which some of the stratified beds undergo in contact with these basaltic masses, the geologist must consult the "Western Islands" of Dr. MacCulloch.

connecting links with the oolites of the midland counties of England: and without their intervention as terms of comparison, much obscurity might still attach to the geological place of these northern deposits; for the apparent anomaly of the latter, in having lost the oviform structure or usual type of formation, is reconciled, when it is seen that in the beds of the district with which they have been compared there are few or no traces of oolite.

Red Conglomerate.

The entire absence of the carboniferous series in the N. E. of Scotland, renders it difficult to determine the age of the red conglomerate which in those districts, is *alone interposed* between the lias and the primitive rocks; since it is now admitted that the new red sandstone cannot, in some situations, be mineralogically distinguished from the old, when these two formations are not separated from each other by the carboniferous or mountain limestone, which being wanting, all inferences respecting the age of this conglomerate must be deduced from its internal characters. The different appearances which it assumes in Sutherland and in Ross-shire have already been described. Near the North Sutor of Cromarty it has been stated to be unconformable to the lias, to which it succeeds: but this fact can lead to no conclusion, because the strata there are much disturbed, the beds of lias being much contorted, and the red sandstone, which is but slightly inclined throughout the adjoining country, is in this place nearly vertical, owing to the proximity of the elevated granitic ridge. On the other hand, at Ethie Bay, where the strata are less disturbed, the beds of lias are conformable to the general range of the inferior sandstone.

Although the latter deposit in Ross-shire and in Sutherland does not, as far as my observation went, contain any substances sufficiently peculiar to mark its date, still it should be stated, that in some parts of those counties there are traces of carbonaceous matter; and the great fertility of the plains of Easter Ross (see note, p. 308) affords also some slight ground for presuming that this great deposit may be referred to the age of the newer red sandstone. More decided conclusions can, however, be drawn from certain remarkable organic remains recently observed in the bituminous schists of Caithness, which appear to be subordinate to, or contemporaneous with, the same conglomerate.

The extensive plains of Caithness forming the N. Eastern extremity of Scotland and succeeding in that direction to the E. coast of Sutherland described in this memoir, are composed of bituminous schists; in some places accompanied by beds of compact lamellar sub-crystalline limestone; in others by a close-grained calciferous and micaceous grit; whilst the promontories of

Dunnet, Thurso, &c., consist of a moderately fine-grained red sandstone overlying and alternating with schists, and a lamellar limestone in the adjoining bays*; the whole deposit seldom deviating from slight inclinations to the east or west of North.

The horizontal beds forming the rock of Dunnet Head, the most Northern point of Great Britain, are made up of an uniform mixture of quartzose sand with particles of mica, the structure distinctly stratified and the folia thin. The colour is there of a brownish red, but in other places the sandstone exhibits patches and stripes of bright red alternating with yellowish gray; these markings are in some instances parallel to the strata, but are frequently irregular, and in these particulars the specimens are almost identical with the variegated or new red sandstone. It is presumed that this deposit must be of the same age as the red conglomerate of the East coasts of Sutherland and Ross-shire, since the flooring-slate of Caithness, though of superior quality, is mineralogically the same with that which is included in the red conglomerate of Sutherland and Ross; and the associated lamellar limestone throughout the conglomerate of the three counties is identical, whilst the general inclination of the strata is nearly the same.

At Banniskirk, where the slate is extensively quarried, abundance of fossil fish have been found for many years past; but the attention of the Geological Society was led to them by M. Culley, Esq.†, who last year sent specimens from thence. I have since visited these quarries; they are about eight miles south of Thurso, and near the rise of a low range of hills, which bound upon the South the extensive plains that are spread out from thence towards the Pentland Frith.

The fish occur exclusively in a schistose bed of a few inches in thickness, about three feet below the uppermost stratum, and immediately overlying the slate which is quarried for use. The bed containing them is rejected by the workmen, and it is from the fragments scattered around the quarry that specimens are to be obtained. When first brought to light these fish are of the

* The most valuable and extensive quarries of these Caithness slates, are at Castle Hill in Dunnet Bay (the seat of Sheriff Traill). The slate of these quarries, though chiefly composed of alumine with some silex and mica, &c., contains pyrites and also a portion of lime, as most of the specimens effervesce slowly with acids. The shale which alternates with the calcareo-siliceous schists of Barrogill Bay is so highly bituminous, that it burns with a bright flame. In the sandstone quarries of Thurso a much purer black bitumen is found, generally associated with crystals of carbonate of lime.

† Mr. Culley has been for some time zealously occupied with the geology of the *primitive* and central districts of Sutherland and Caithness; and, I believe, will shortly offer to the Geological Society his observations, accompanied by sections from the East to the West coast.

same dark gray colour with the slate itself; but after exposure to atmospheric influence they generally acquire a purplish blue tinge, whilst the surrounding matrix is externally changed to a light brown.

No icthyologist has yet determined the family to which these very singular remains belong. Having forwarded specimens of two or three distinct species to Baron Cuvier, I shall not upon this occasion say more respecting them; but may here state generally, that the red sandstone of Caithness, the lamellar limestone, and the schists containing the fish, have all strong resemblances to the copper slate of Thuringia and its associates, and may probably prove to be the equivalents of that formation; whilst the fish, though not of the same species, may belong to the same family as those found at Mansfeldt.

Whatever may be our conclusions respecting this deposit, the preceding pages afford, it is hoped, a good exemplification of the value of the geological evidence to be derived from organic remains; since the existence of strata, which must be regarded as the representatives of a large portion of the *oolitic series* of England, has been clearly shown by the identification of their shells and vegetables, although at the extremes of that series in Great Britain the mineralogical character of the beds is perfectly distinct.

Concluding Remarks.

The following remarks, which are of a nature partly theoretical and partly practical, appear to flow naturally from the facts detailed in the preceding paper.

1. A constancy in the mineralogical character, and the order of superposition of the strata of any country, are undoubtedly the first facts upon which its geological structure must be determined. That the great deposits superior to the carboniferous order are capable of being divided into groups; that many of these groups range in the form of natural terraces from one side of our island to the other; that even their subordinate beds preserve through considerable portions of their range, a great uniformity of structure and of external character,—are facts now established by a great accumulation of direct evidence. It would not perhaps be too much to assert, that the physical structure of many parts of England might be determined by these characters alone, without the help of any zoological considerations. But the foundation for a true arrangement of our strata being once established, we are by no means precluded from the use of any other characters with which Nature may supply us. The organic remains imbedded in the successive secondary strata are not only essential to all theoretical speculations, but enable us to determine the true place of many deposits in districts where we have not the advantage of

any good natural sections. The progress of investigation has enabled us to go still further. Certain genera and species of fossil shells have been shown to be so characteristic of deposits of a particular geological æra, that we have in many instances been enabled to fix the epoch of a formation by zoological characters alone; where (in consequence of some local causes) all other evidence has been wanting. The history of the Brora coal-field is a new instance of this kind of generalization. The several parts of this deposit have been brought into comparison with certain portions of the English oolitic series, solely by the help of zoological characters. This generalization is fully confirmed by the phænomena presented on the Yorkshire coast. We have there a repetition of the peculiarities of the Brora coal-field and some of the same fossil plants; but still under circumstances which seem to put the great relations of the deposit entirely out of doubt.

2. If the preceding remarks show the great importance of attending to the fossil history of our several formations, the facts stated in the former part of this paper at the same time prove the absolute necessity of examining the mineralogical structure and relative position of the subordinate beds, wherever they are exhibited in natural sections. It is only by a comparison of all such characters, that geological induction can be established on a firm basis. Several of the organic remains in the annexed catalogue are entirely new. It is, therefore, probable, that, in remote parts of the European basin, there may be formations of lignite of the same age with the Brora coal, in which the suite of fossil remains will be found to present very few analogies with those which distinguish the oolite of England. Every thing with which we are acquainted tends to show, that Nature in modifying the solid parts of the earth's surface has acted by very general laws. There appear to be no sudden transitions in the zoological history of the same formations during their range through different latitudes. Every new fact in their natural history becomes therefore of importance; inasmuch as it may give us a new term of comparison between our own strata and those in distant countries. And we may venture to hope, that, as minute details become multiplied, many more new terms of comparison will be discovered, which may form so many connecting links between distant contemporaneous deposits; so that we may not only generalize with more certainty in neighbouring regions, but be enabled to extend our inferences to the remotest parts of the Earth.

3. If we assume that the coal-fields at Brora and on the Yorkshire coast are contemporaneous, and also the equivalents of the several formations which intervene between the Oxford clay and the lias; we must at the same time admit, that the causes which produced the oolitic deposits in the central and

southern parts of England, must in some other regions have been modified by the simultaneous operation of certain powerful disturbing forces. One exception to the common structure of a formation would point to no general conclusion. But two exceptions of the same kind, occurring at a considerable distance from each other, and precisely on the same line of deposit, almost compel us to speculate upon the causes which have produced them, and to regard them as the result of some general law. Are there then many carboniferous deposits, subordinate, like those described in this paper, to the inferior portion of the great oolitic series? This question is of great theoretical and practical importance. In some parts of Somersetshire, beds of clay containing much carboniferous matter are associated with the forest marble. In the well-known quarries of Stonesfield there is an extraordinary development of vegetable fossils, and, at the same time, the ordinary type of formation is greatly modified. Again, in the range of the oolites through the North-western parts of France, a similar development of vegetable fossils has been discovered in beds which are immediately inferior to the Oxford clay*. If the mode of distribution and the generic characters of these fossil plants be ever reduced under general laws, they will no longer be regarded as anomalies; but will form an important addition to the natural history of the beds with which they are associated. The preceding account therefore, of the fossil vegetables of Brora and of the East Coast of Yorkshire, may help us to the conclusion at which we seem now to be on the point of arriving, by means of the labours of Mons. Adolphe Brongniart, and some other naturalists.

Whatever may have been the nature of those destructive agents which attacked the existing materials on the earth's surface, and spread them out in numerous alternations of sand, mud, and vegetable matter, thereby laying the foundation for future carboniferous deposits; it is quite certain that their operation was not confined to one particular epoch. Their greatest effects appear undoubtedly to have been produced at a time anterior to the deposition of the newer red sandstone; but the details above given, prove that they have also come into action at subsequent periods: nor can we, in the present state of our information, pretend to affix any precise limits to the extent of their operation. In all the greater carboniferous deposits, of whatever epoch, there appears however to be that similarity of mineralogical composition which implies a similar mode of formation. Hence, in the oolitic series, where these peculiarities are wanting, and where the several strata are developed in conformity with the more ordinary type of those formations, we may venture to

* Annales des Sciences Naturelles, Avril 1825.

predict with certainty, that no carboniferous deposits of any great value will ever be discovered, at all events in Great Britain. A want of such knowledge has induced many persons to make trials for coal in beds subordinate to the English oolites, and even superior to them, in places where the type of formation did not offer the least warrant for such attempts. These speculations have ended, and always must end, in disappointment and ruin.

TABLE OF FOSSIL SHELLS.

The Figures refer to "Mineral Conchology," and the new species have been named by Mr. Sowerby.

List of Species and their Localities in SCOTLAND.	*Formations and Localities in which the same Species occur in* ENGLAND.
Braambury Hill quarries or highest beds in the Brora district, consisting of rubbly limestone and siliceous sandstone.	Calcareous grit and sandstone, or base of the coral rag formation.
Chambered Univalves.	
Ammonites vertebralis. Tab. 165	In a siliceous limestone of the calcareous grit beneath the coral rag at Dry Sandford and Marcham, Oxon.—Base of the calc. grit, Sevenbeck, Eastern Moorlands of Yorkshire.
——— cordatus. Tab. 17, fig. 2 and 4 .	In the calc. grit of Shotover Hill, Oxon; Cayton Bay and Scarborough Cliff, Yorkshire.
——— perarmatus. Tab. 352	Abingdon, Oxon.; Malton and Scarborough Cliff, Yorkshire.
——— new species, not figured, resembling a nautilus.	
——— new species, with bifid ribs.	
Bivalves.	
Cardium dissimile. Tab. 553, fig. 2	Portland, Tisbury, Aylesbury, &c.—It is remarkable that this fossil, hitherto called the Venus of the Portland-stone, is found at Brora in a mass of fossils of the calcareous grit.
Cucullæa, 2 species, not determined . . .	The genus cucullæa is found in almost every formation above the lias.
Gryphæa nana. Tab. 383, fig. 3	In groups in the calcareous grit, Scarborough; also at Shotover Hill, Oxon.
——— bullata. Tab. 368	Horncastle, Lincolnshire; also at Scarborough?
Lucina crassa, new species. Tab. 557, fig. 3 .	Horncastle, Lincolnshire; Feldmarsham, Oxon; Scarborough Cliff?
Modiola bipartita. Tab. 210, fig. 3 and 4 . .	Bedford Castle; Scarborough Cliff, &c.
Pecten, large ribbed species, not yet figured .	Marcham Field, Oxon; and Scarborough Cliff.

SCOTLAND.	*ENGLAND.*
Pectens; two new species not figured, but much resembling P. of Malton. Tab. 543. fig. 1 & 2.	
Plagiostoma obliquata; new species to be figured in Min. Con.	Malton?
Large casts of a gibbose bivalve, either a Venus or Cytherea.	

Reefs at Dunrobin, &c.	
Shale and grit	Oxford clay, &c.
Chambered Univalves.	
Ammonites, (flattened impressions of) . . .	Similar ammonites in the Oxford clay.
Belemnites sulcatus. Geol. Trans. vol. ii. Pl. VIII. fig. 5.	This variety of belemnite is characteristic of the Oxford clay.
Bivalves.	
Astarte, resembling elegans	The A. elegans is found in various oolitic formations from the coral rag to the inferior oolite inclusive.
Avicula, new species, not figured	This species occurs on the Yorkshire coast.
Gryphæa nana. Tab. 383.	Oxfordshire and Scarborough.
Modiola pallida. Tab. 8.	Green sand Fonthill, Wilts.
Pecten, smooth species.	
Plagiostoma pectenoides. Tab. 114. fig. 4. . .	Pickeridge Hill.
Pullastra? not figured	The same bivalve is found in abundance near Scarborough, and in all the fossil beds above the coal on the Yorkshire coast.
Serpulæ	Oxfordshire, and the Yorkshire coast.
Terebratulæ	

Portgower, Helmsdale, and Navidale.	
Shelly limestone and calciferous grit	Cornbrash, &c.
Univalves.	
Nerita lævigata. Tab. 217.	Dundry.
Turritella muricata. Tab. 499. fig. 1 & 2. . .	Steeple Ashton, Wilts; and also on the Scarborough coast.
Many spires of univalves.	
Bivalves.	
Astarte elegans (small variety). Tab. 137. fig. 3.	In many of the oolites.
Avicula inequivalvis. Tab. 244. fig. 2 & 3. .	Cornbrash and forest marble.
Terebratula inconstans. Tab. 277. fig. 3 & 4.	Cornbrash, and also in Oxford clay.
Ostrea deltoidea? Tab. 148.	
Smooth spines of echino-cidaris	Stonesfield slate, &c.
Tooth of Saurian?	
Coralloids. Flustræ?	

SCOTLAND.	*ENGLAND.*
Small belemnites.	
Pentacrinus?	
Inverbrora coal pits, and beds overlying coal upon the shore.	
Sandstone, limestone and shale	Eastern Moorlands of Yorkshire.
Chambered Univalves.	
Ammonites Gowerianus, new species. Tab. 549. fig. 2.	
———— three new species, not figured.	
Belemnites sulcatus. Geol. Trans. 2d. Series, vol. ii. Pl. VIII. fig. 3.	Oxfordshire; also at Dundry.
Univalves.	
Buccinum, species not decided	These univalves occur in the pier stone of Scarborough above the coal.
Rostellaria composita, new species. Tab. 558.	
Corbula, new species not figured.	
Bivalves.	
Astarte elegans. Tab. 137. fig. 3.	Oolite near Bath; Babling Hill near Yeovil; in the coral rag of Steeple Ashton; Robin Hood's Bay, Yorkshire.
Avicula?	
Cardium striatulum, new species. Tab. 553. fig. 1.	
———, new species, resembling C. truncatum.	
Cucullæa, 2 undescribed species.	
Gervillia (formerly Perna aviculoides. Tab. 66. fig. 3.	Scarborough coast in the pier stone and other beds above the coal; Osmington, Weymouth, &c.
Lucina, species not yet figured	The same species is found in Oxfordshire.
Modiola cuneata. Tab. 211. fig. 1.	Scarborough Castle Cliff; oolite near Bath.
Mya depressa. Tab. 418.	Horncastle, Osmington, Shotover Hill, &c.
—— literata. Tab. 224. fig. 1.	Scarborough coast.
Ostrea deltoidea	The same O. is in the Scarborough pier stone.
Pholadomya Murchisoni, new species. Tab. 545.	Very nearly resembling the P. of the Scarborough pier stone.
Plagiostoma obliquata, new species, same as in the sandstone of Braambury: to be figured in Min. Con.	
———— acuticosta, new species. Tab. 546.	Oxfordshire.
Pullastra? new genus	Found in *all* the beds above the coal upon the Scarborough coast.
Pecten lens. Tab. 205. fig. 2 & 3.	Oxfordshire.
——— new species ribbed, not figured.	
——— new species smooth, not figured.	
Sanguinolaria undulata, new species. Tab. 548.	
Trigonia clavellata. Tab. 87.	Abundant on the Yorkshire coast; also at Weymouth.

SCOTLAND.	*ENGLAND.*
Trigonia, new species, not yet figured, resembling T. costata.	
Tellina ?	
A gibbose, transversely undulated bivalve; genus not yet decided, but a marine shell.	
Venus, new species, orbicular, not figured.	

East Coast of Ross and Cromarty.	
Blue shale and limestone	Lias shale and limestone.
Chambered Univalves.	
Ammonites biplex. Tab. 193.	Lias ?
——— Königi. Tab. 263.	Lias; Charmouth. N.B. The A. Königi and the new species are so grouped as to resemble the *Marston stone.*
———, new species ? not figured . . .	
Belemnites elongatus. Miller. Geol. Trans. vol. ii. part 1. new series	Lias; Lyme and Whitby.
——— abbreviatus. Miller. Geol. Trans. vol. ii. part 1. new series	Inferior oolite and lias.
Bivalves.	
Gryphæa gigantea. Tab. 391.	Lias; in Gloucestershire.
——— incurva. Tab. 112. fig. 1 and 2. .	Lias; Dorsetshire and Whitby.
Plagiostoma concentrica, new species. Tab. 559. fig. 1.	Lias.
Sanguinolaria, new species, not figured.	
Other bivalves not yet described. Scales of fish of a rounded form	Lias shale at Lyme.
Clusters of very minute young ammonites . .	Watchet, Somerset; in the lias limestone.

WESTERN ISLANDS.	*ENGLAND.*
N. E. Coast of Skye.	
Shelly limestone of Beal near Portree, resembling that of Navidale, Sutherlandshire . .	Cornbrash, forest marble, &c.
Bivalves.	
Avicula inequivalvis. Tab. 244. fig. 2. . . .	In the cornbrash of Oxfordshire and Gloucestershire; also in Kelloway roc &c.
Terebratula inconstans. Tab. 277.	In Oxford clay, cornbrash, &c.

WESTERN ISLANDS.	*ENGLAND.*
Micaceous sandstone with calcareous concretions, &c.; at Holm, Scorr, &c. near Portree .	Middle and inferior oolite, &c.
Chambered Univalves.	
Ammonites Königi, in blue clay at Mugsted. Tab. 263.	In Kelloway rock and in lias.
——— Murchisonæ, new species. Tab. 550. Holm Cliff	This species was found in the inferior oolite at Allington, near Bridport, in 1826.
Belemnites abbreviatus. Miller, Geol. Trans. vol. ii. part 1.	Dundry, Somersetshire, inferior oolite.
Bivalves.	
Mya V. scripta. Tab. 224	Somerford, Scarborough; Claydon, Oxon.
Ostreæ, species not decided.	
Terebratula tetraedra. Tab. 83.	Aynhoe, Northamptonshire, inferior oolite; also near Scarborough.
Tellina?	
Gryphææ compressed in masses and associated with tellinæ? a Venus and the A. Königi in blue clay, near Duntulm.	
Various bivalves with ammonites in nodules near Eas Veririg.	

Micaceous shale with inferior beds of argillaceous blue limestone. Isles of Skye, Scalpa, Pabba, Mull, &c.	Lias shale, limestone, &c.
Chambered Univalves.	
Ammonites Conybeari. Tab. 131. Carsaig, Mull	Lias; Lyme Regis and Bath.
——— Jamesoni, new species. Tab. 555. Mull	Lias shale, Robin Hood's Bay, Whitby.
——— brevispina, new species. Tab. 556. Pabba.	
——— acutus. Tab. 17. fig. 1	Lias?
——— new species not yet figured.	
——— two or three new species not sufficiently perfect to figure.	
Belemnites elongatus. Miller. See Geol. Trans. vol. ii. part 1	Dorsetshire and Somersetshire; lias.
Bivalves.	
Aviculæ in groups. Pabba	Resembling the A. of the lias.
Cucullæa, species not determined.	
Gryphæa incurva. Tab. 112	In all parts of the lias formation.
——— MacCullochii, new species. Tab. 547. Pabba, Broadford, Mull.	

WESTERN ISLANDS.	*ENGLAND.*
Gryphæa obliquata. Tab. 112. Scalpa . . .	Lias, Glamorganshire.
Pecten equivalvis. Tab. 136. Scalpa . . .	Gloucester, Ilminster, Yeovil (lias).
—— Cygnipes. Scalpa. (Figured in the Survey of Yorkshire Coast, by Young and Bird) .	Near Whitby.
——, new species, in Pabba and at Carsaig, Mull.	
Plagiostoma, species not determined . . .	Lias.
Pholadomya, species not determined. Pabba and Mull.	
Pinna granulata. Tab. 347. Sconser, Skye .	Somersetshire lias.
Sanguinolaria, species not decided: (in the upper beds).	
Casts of modiolæ and many other bivalves in the shale.	
Encrinites in the blue limestone of Sconser, Skye	In the lias at Lyme.

Note.—Of the two following fossils from the Braambury-Hill sandstone, Brora, the first has been named, and the second has been discovered, since the above table went to press.

Ammonites Sutherlandiæ—Described in the table p. 318. as a new species resembling a Nautilus: a cast of this Ammonite will be figured in Min. Con.

Avicula Braamburiensis in groups—A new species; but much resembling the Avicula echinata of the cornbrash, remarkable as being the only fossil in the Braambury sandstone which has preserved its shell; this will also be figured in Min. Con.

APPENDIX.

Brora Coal-Works.

Sir Robert Gordon states that in 1598, Jane Countess of Sutherland opened the first coal pit; probably near the old Salt Pans. In 1614 her son John, fifth Earl of Sutherland, re-opened the works; and the shaft is yet visible about 200 yards north of the old Salt House.

In the early part of the last century, the Earls of Sutherland continued to work the Inverbrora coal, sinking four or five new pits *, in one of which fifteen men lost their lives by the falling in of the roof: one of these shafts is said to have been 12 yards deep.

About the year 1764, the working of the coal was undertaken by Mr. John Williams, to which circumstance there is no allusion in his "Mineral Kingdom." He re-opened one of the pits above mentioned, which is reported to have been 26 yards deep, and sunk another near it. Also subsequently, two others N. E. of these; one 30, the other 20 yards in depth. In consequence of not excluding the pyrites, the coal was found unfit for domestic use, and liable to heat and ignite when exposed to the air. A cargo of it going to Portsoy took fire, and so much alarm was excited by this spontaneous combustion, that the sale of the coal was materially injured; and in 1769 Mr. Williams resigned his lease.

In 1770 a boring was made near Dunrobin, where two thin seams of coal were proved; but not deemed workable.

In 1777 the colliery and salt-works at Inverbrora were abandoned.

Since the Marquess and Marchioness of Stafford commenced their improvements, the following have been the operations.

In 1810 Mr. W. Hughes sunk a shaft on the north bank of the river to the depth of 83 yards, and found a thick seam of coal. (See Sutherlandshire Agricultural Report, page 148.)

In 1811 borings were made contiguous to the shaft now in use. No. 1. is a section of the strata cut through upon that occasion.

Subsequently the engine-pit was sunk about 780 yards distant from the old pit. No. 2. is a section of the beds in this sinking.

N.B.—About 70,000 tons of coal have been extracted from the pit now in use since the year 1814.

* See Memoir, p. 303.

Copy of a Journal kept whilst boring for Coal at the Water of Brora.

(Coal-pit now in use.)

No.	Date.	Description of the Beds.	Depth of each Bed. Ft.	In.
	1810.			
1	Oct. 23	Soft gray stone in this layer, containing ironstone balls	63	0
2	31	Soft dark gray sandstone in thin layers, and stones as above	18	6
3	Nov. 1	Dark, very soft coal metal in thin layers, with partings of yellow pyrites and water, which rises to the surface	2	0
4	15	Dark gray stone in thin layers, with soft partings	6	10
5	19	Dark hard stone with strong sulphureous smell	1	8
6	22	Soft sandy stone, rather lighter coloured than the above	9	7
7	29	Lightish coloured sandstone, containing marine petrifactions	14	10½
8		Very hard ironstone	0	5½
9	30	Hard gray clunch	2	9
10	Dec. 13	Light coloured metal stone, rather soft in boring	2	6
11	18	Lightish coloured clayish strata, soft in boring and containing a considerable portion of calcareous matter and marine petrifactions	2	9
12	20	Ditto, still darker, containing more of the white spar; sulphureous, effervesces briskly, but does not contain any slack after burning (calcareous)	4	0
13	25	Ditto, light coloured	11	10
	1811.			
14	Jan. 17	Ditto, still lighter coloured than the above	11	2
15	23	Ditto, much darker, containing white powdery matter	11	8
16	28	Dark clunch, a clayish strata	7	11
17	Feb. 6	Ditto Ditto	4	10
18	13	Very dark coal shale, rather soft in boring	2	7
19	20	Ditto Ditto	5	11
20	26	Ash-coloured metal stone (calcareous)	12	6
21	28	Very hard ironstone	0	5
22	Mar. 2	Ash-coloured clunch and bind	5	4
23	8	Dark bituminous shale, with soft partings	7	11
24		Very hard close-textured sandstone (quartzose sandstone)	0	8
25	April 1	Sandstone with blue streaks, soft in boring	12	9
26	17	Very hard blue grit limestone, mixed with freestone	2	3
27	18	Gray shivery sandstone, rather soft	0	6
28*	20	Sandstone, mixed with limestone, very hard in boring	0	7
29*	23	Ash-coloured metal stone, rather soft	2	0
30	May 14	Hard caking coal (main seam)	3	2
31	16	Black clunch, pavement of coal	2	0
32	18	Hard splent coal	1	4
33		Black burning shale, like Kannel coal	6	7
34		Very hard stone	1	2
35	29	Black shale	2	0
36		Very hard stone	0	2½
37	June 1	Soft black shale, speckled with white powdery matter	0	2
38	5	Hard black burning shale, came up in the auger in large pieces, very promising and not yet cut through	4	2
		Total depth bored . . . Feet	250	11½

* No. 28. and 29. are Fossil Beds, and form the roof of the coal.

Section of the Coal Strata at the Engine Pit, Brora Colliery, by Mr. William Hughes. 1814. Corrected by Robert Bald, Esq.

	Ft.	In.
1. Dark coloured schistose sandstone, containing ironstone balls and belemnites	64	2
2. Soft gray sandstone, with a little clay in the composition containing belemnites	23	2
3. Bituminous shale, fine in the texture, containing belemnites and fossil wood, the *bark of which is pure coal*	26	6
4. Dark argillaceous schistus, containing many belemnites, marine plants, impressions of large shells and some hard ball stones	6	6
5. Claystone, very fine in the texture, with smooth glossy partings, with a number of small and large petrified shells	18	4
6. Hard gray sandstone, containing fine streaks of coal with petrified wood in long pieces; some belemnites and marine shells	15	6
7. Ash-coloured hard and large-grained sandstone, sulphureous containing large pieces of fossil wood, hard balls, and a few belemnites; decomposes when exposed to the air	7	10
8. Very hard *unstratified* limestone, being a mass of shells, wood, belemnites, and a few streaks of bright coal, all concreted with lime cement	2	7
9. Very hard *ferruginous limestone*, with calcareous spar in the joints or partings	0	6
10. Dark argillaceous schistus, with smooth joints or partings, and some broken marine shells	32	6
11. Hard argillaceous schistus, the bottom composed of petrified shells and a few belemnites	0	6
12. An uniform mass of muscle, cockle and oyster shells, all concreted with lime cement	1	6
13. Dark argillaceous schistus, with smooth soft partings and a few shells	36	6
14. Very hard large-grained sandstone, with large shells and wood; this is the *roof of the coal*	5	0
15. Fine cubical coal, with smooth glossy backs, and transverse cutters; burns to a white ash, and has a peculiar smell	3	8
16. Bituminous shale, containing *natural oil;* burns, but does not consume	2	0
17. Slate coal with pyrites, not workable	1	4
Bored 15 fathoms in fire clay, alternating with argillaceous schistus	90	0
Total ascertained depth . . Feet	338	1

PLATES XXXI. & XXXII.

Illustrate Mr. Murchison's paper on the Brora Coal-field, and some other Stratified Deposits in the North of Scotland.

Plate XXXI.

Fig. 1. A map of all that part of the S. E. coast of Sutherlandshire in which any members of the oolitic series have been traced, including the coal-field of Brora; showing also the nature of the mountain chain which bounds the Vales of Brora, Loth and Navidale.

In the lower part of the same figure is a sectional view of the coast laid down in the map.

Fig. 2. Consists of transverse sections. The first is ideal, explaining the entire order of superposition on the east coast of Sutherland, Cromarty and Ross; followed by six actual sections from the shore to the mountain chain,—of which that on the line C, D of the map particularly explains the relations of the Brora coal-field.

Fig. 3. A sectional view of part of the east coast of Ross and Cromarty, to explain the relations of the lias, as seen at low-water near Shandwick and Ethic bays. The second section from the left in *fig.* 2. relates also to this tract, showing the red conglomerate to be alone interposed between the lias and the primitive rocks.

Fig. 4. A sectional view of part of the Coast of Skye near Portree. The small valley of Beal inclosed by mountains of trap, is composed of cornbrash limestone, &c. resting upon the inferior oolite. This limestone of Beal is traversed by fissures, one of which is still occupied by compact zeolitic greenstone.

Plate XXXII.

Fig. 1. Part of the irregularly tuberculated stem nearest to the root of oncylogonatum carbonarium.

Fig. 2. Part of the same more regularly jointed, traversing the sandstone of the eastern Moorlands of Yorkshire.

Fig. 3. Specimen of micaceous shale, representing impressions of the jointed stems of the above plant, with their grooved expansions, and of the roots,—both flattened by pressure.

Fig. 4. A portion of the bed immediately above the coal of Brora; exhibiting striated delineations similar to those of *fig.* 3.

Fig. 5. Subtriangular carbonaceous plates, occasionally found in the micaceous shale of *fig.* 3.

Fig. 6. The expansions of *fig.* 3. magnified, exhibiting the raised dots between the grooves.

Fig 1.

MAP OF
Part of
the S.E. Coast of
SUTHERLANDSHIRE

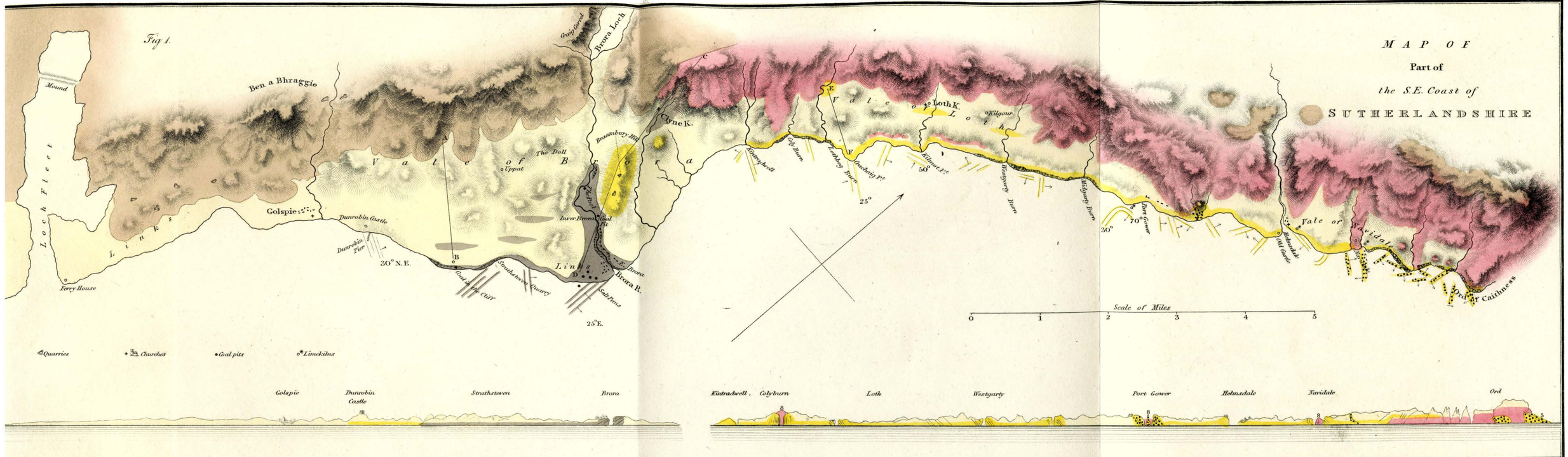
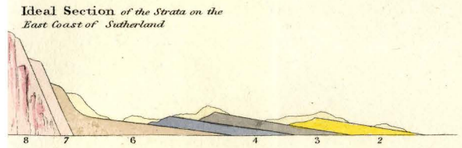


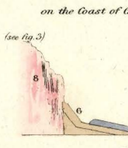
Fig 2.

TRANSVERSE SECTIONS

Ideal Section of the Strata on the East Coast of Sutherland

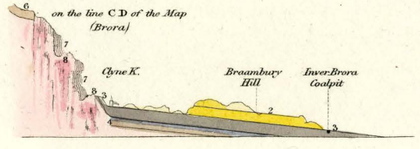


on the Coast of Cromarty (see fig. 3)

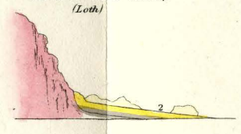


on the line A B of the Map

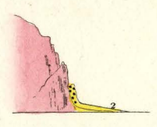
on the line C D of the Map (Brora)



on the line E F of the Map (Loth)



Port Gower



Ord of Caithness

Fig 3.

EAST COAST OF ROSS AND CROMARTY

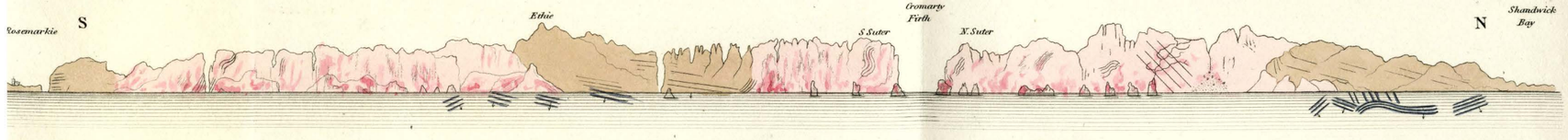
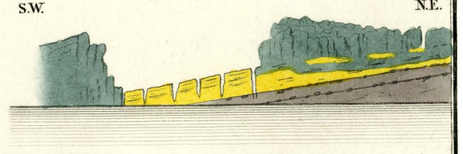


Fig 4.

BEAL NEAR PORTREE I. OF SKYE



Oolitic Series

1 — Diluvium & blown Sand.

2 — Scotland: Rubbly Limestone. White Sandstone & Shale. Shelly Limestone. | England: Cale-grit (below the) Coral Rag. Oxford Clay. Cornbrash, &c.

3 — Scotland: Sandst. & Shale. Ironstone. Limestone with Shells & Coal. | England: Sandstone. Coal & Shale of the E. Moorlands of Yorkshire. Inferior Oolite.

4 — Scotland: Shale and Argillaceous Limestone. | England: Lias

5 — Scotland: Breccia composed of Nº 2 3 & 4. | England.

6 — Scotland: Red Conglomerate. Sandst. Limest. & bituminous schist. | England: New Red Sandstone? or Old ?

7 — Primitive Rocks Talcose &c.

8 — Granitic Rock

9 — Trap Rocks of Skye

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