

The following Table exhibits a comparative view of the composition of the allied mineral substances alluded to above :—

		Silica.	Alumina.	Water.		
Allophane	Beauvais .....	21·90	29·20	44·20	Clay 4·7	Berthier.
	Charlton .....	18·89	33·52	42·73	Carb. lime 4·38	Dick.
Kollyrite	Ezquerria .....	15·	44·5	40·5	.....	Berthier.
Scarbritoite	Scarborough ..	10·50	42·50	46·75	Ox. iron ·25	Vernon.
Pholerite ..	Fins .....	41·65	43·35	15·	.....	Guillemin.
.....	? .....	41·78	36·99	14·26	Peroxide of iron 4·51, magnesia ·16, lime ·48	Dick.
Halloysite	Anglar .....	44·94	39·06	16·00	.....	Berthier.

3. *On the RED SANDSTONE and CONGLOMERATE, and the SUPERPOSED QUARTZ-ROCKS, LIMESTONES, and GNEISS of the NORTH-WEST COAST of SCOTLAND.* By JAMES NICOL, F.R.S.E., F.G.S., Professor of Natural History, Marischal College and University, Aberdeen.

CONTENTS.

Introduction.
Sections in the Northern part of the District.
Loch Broom (north side).
"    " (south side).
Loch Assynt.
Kyle of Durness and Loch Eriboll.
Sections in the Southern part of the District.
Gairloch and Loch Maree.
Loch Keeshorn.
Southern part of Skye.
Order of the succession of the rocks.
Organic remains and markings.
Distinctive physical characters of the rocks.
Probable age of the rocks.
Conclusion : Geological history of the north-western district of Scotland.

*Introduction.*—The Red Sandstone and Quartzite rocks on the north-west coasts of Sutherland and Ross possess many features of interest, which have long attracted the attention of geologists. The mountains, rising abruptly from the great table-land of lower hills in smooth rounded cones, spiry peaks, or long serrated ridges, their hoary summits shining in the sun like new-fallen snow, and sending down streams of rugged fragments to the deep sea-lochs that, running far up into the interior, wash their bases, present scenes of wild and varied grandeur unknown in other parts of the island. Nor does a closer examination lessen the wonder with which we regard these mountains. They are then found to consist, not of granite or igneous rocks, nor of the older so-called primary strata, crushed up and broken by some great convulsion, as their singular outlines might have led us to expect, but of stratified rocks of no great hardness, lying

almost horizontally in thin even beds, and moulded into these strange forms by the slow agency of natural causes. Many authors have consequently been induced to notice them, from the time when Pennant, deceived by their external aspect, described them as formed of white marble; and Williams, with a more accurate knowledge of mineralogy, as granular quartz\*. Of these it is sufficient to mention the memoirs 'On Quartz Rocks,' and the volumes on the Western Isles by Dr. Macculloch†, the very valuable memoir on the Conglomerates and other Secondary Deposits on the North Coasts of Scotland by Professor Sedgwick and Sir Roderick I. Murchison‡, and the 'Geognostical Account of Sutherland' by the late Mr. R. H. Cunningham§. These well-known works might be supposed to have exhausted the whole subject; but the discovery, in the winter of 1854–55, of better-preserved and more distinct fossils by Mr. Chas. Peach in the limestones of Durness invested these rocks with a new interest. Sir R. I. Murchison, wishing to verify his former observations, revisited this region in the autumn of 1855, and, having kindly requested me to accompany him, we examined several of the most important sections together||. Last summer I returned to the west coast, and visited several points which we had passed over in the previous year. As my observations now extend over almost the whole tract, from Cape Wrath and Durness on the north to Loch Alsh and Skye on the south, I am induced to lay the results before the Society, in the hope that they may throw some light on these interesting formations¶.

*Sections in the Northern part of the District.*—In describing the rocks I shall commence with the sections seen near Ullapool, on Loch Broom, as these are apparently typical of the relations in other localities, which they thus tend to explain. Measured from the outer headlands, this bay, or sea-loch, runs for more than twenty miles into the interior, intersecting successively all the various formations. Both shores are formed by ranges of hills, descending abruptly to the water, and generally very thinly covered either with

\* Pennant's 'Tour in Scotland'; Williams's 'Natural History of the Mineral Kingdom.'

† Memoirs 'On the Geology of Various Parts of Scotland,' and 'On Quartz Rock,' in Geological Trans. 1st series, vol. ii. pp. 388 and 450; Western Isles of Scotland, vol. ii. pp. 89, 508, 675.

‡ 'On the Structure and Relations of the Deposits contained between the Primary Rocks and the Oolitic Series in the North of Scotland.' Geol. Trans. 2nd series, vol. iii. p. 125.

§ In the Transactions of the Highland Society, vol. xiii. p. 73–114.

|| See Report of British Association (Glasgow) for 1855; Trans. Sect. p. 85.

¶ In justice to my predecessors I may mention, that at the time they examined the West Highlands there were even less facilities for visiting these remote parts of the country than at the present day, when steamboats have done so much to render them accessible. The uncertain climate, too, places a great bar to geological investigations; and Sedgwick and Murchison specially state, that the stormy and wet weather which they encountered in these districts prevented their full exploration of the mountains. Sir R. Murchison and myself, in 1855, were again impeded in our researches by the rains and mist that so frequently obscure the best and most instructive sections on this humid coast.

detritus or vegetation. The outcrop of the beds is thus very clearly exhibited, and the relation of the formations easily ascertained, not only in the cliffs on the shore, but to the very summit of the mountains. The village of Ullapool is situated on a flat promontory formed by the detritus thrown into the loch by the Auchal river; and, as it lies not far from the junction of the various formations, forms the most convenient point for investigating them. The section (fig. 1) represents the general relations of the rocks on the north side of the loch. It commences on the N.W. with an imperfect outline of the Coygach Hills, intended merely to show some of the peculiar features which the red sandstone mountains assume on this coast. Some of them rise into fine spiry or serrated summits, whilst Ben More, the highest, forms a long narrow and precipitous ridge, running to the north-east.

The part of the section specially examined begins at Loch Kennort. On its north-west shore, at the foot of Ben More, a thick mass of red sandstone, divided into numerous beds, dips to the south-east at a low angle ( $10^{\circ}$  to  $12^{\circ}$ ). This rock, with approximately the same dip, appears also to form Martin Island, lying in the mouth of the bay. On the south-east shore the red sandstone again crops out in thick craggy masses, with a dip of  $12^{\circ}$  to  $20^{\circ}$  to the south or south-west, the beds being apparently broken and curved. In the ridge to the east the rock is well exposed, dipping  $10^{\circ}$  to  $12^{\circ}$  to S.  $20^{\circ}$  E.\* This dip continues nearly constant, both in amount and direction, throughout the next range as far as the Auchal river, occasionally perhaps inclining a little more to the east. In some places, even where the rocks are well seen, the dip is obscured by the powerful glacier action which has smoothed, striated, and rounded the rocks of the entire region†. Throughout the whole of this range, the red sandstone is very uniform in aspect and mineral character. Most of it is a rather coarse grit, graduating into a fine conglomerate, with fragments rarely an inch or more in diameter. The fragments are not much water-worn, and consist especially of quartz, hornstone, and felspar,—the last often decomposed. The grits are composed chiefly of rounded grains of grey vitreous quartz and red felspar (orthoclase), but apparently with no mica‡. The general colour is dark brownish red; but some portions are of a lighter red, or yellowish tinge.

The Auchal river near Ullapool has cut a deep gorge in the sand-

\* From the large variation of the compass ( $30^{\circ}$  or more), I have thought it better to correct the directions throughout this paper.

† The violent pressure of the ice appears also to have occasionally altered the position of large masses of rock, thus vitiating direct observations made on the strata at their outcrop.

‡ Dr. Macculloch has already made the observation as to the West Coast sandstone generally—"In no instance have I observed it to contain mica, nor, with the exception of red jasper and that of the schist just mentioned, any substance but quartz and felspar." On the other hand, Sir R. Murchison (Trans. Geol. Soc. 2nd ser. vol. iii. p. 164) mentions the occurrence of mica in some beds of the red sandstone of Applecross, so that it is rather rare than unknown. Macculloch also says, "that in no instance hitherto has it been found to contain imbedded limestone."—Western Isles, vol. ii. p. 97.

stone, which forms the base of the next hill, and is well exposed, both on the road and on the shore east of the town. It is seen to be covered by the quartzite; but the continuation of the section is obscured by detritus, which has collected behind a rocky promontory projecting into the loch. This promontory consists of a massive intrusive rock, in some places a kind of syenite, or a felspar-porphry with hornblende, in others rather an impure serpentine\*. In one place it is covered by a bed of quartzite; but on the shore to the east the first strata seen are thin-bedded grey gneiss, dipping  $17^{\circ}$  S.  $5^{\circ}$  E., but the beds are often much twisted and contorted. On this line, therefore, the relations of the quartzite to the gneiss are not very clearly exhibited; but that it overlies the red sandstone is beyond doubt.

The valley of the Auchal river lays open a still more instructive section. The north-west side of the valley is the continuation of the same range which forms the coast; and, as shown in the section (from A to B), the red sandstone distinctly dips under the white quartzite forming the summit of the hill. The continuation of the same beds, with the same relations, is seen on the other side of the valley, followed by the road from Ullapool to the north-east. The lower and larger portion of the quartzite, that overlies the red sandstone, is of a pure white colour on the exterior, and often with a polish like glass, from the ice-action to which it has been exposed. In the interior the rock has often a reddish tinge, from a mixture of felspar. The principal constituent is however quartz, in very fine grains, rarely as large as mustard seeds. Mica seems wholly wanting, or very rare. Some of the beds of quartzite contain cylindrical bodies, simple or branched, and from a quarter to about half an inch in diameter, running vertical to the strata; whilst others contain similar bodies, but of a conical form,—both of them often in such numbers as to cover the entire surface. Higher in the series a fine-grained grey siliceous rock occurs, containing so much iron in layers or nodules, as to become brown and rotten when exposed to the weather. The surfaces of the thin layers of this rock are often marked by plant-like impressions, resembling a confused mass of fucoids. I now notice these markings chiefly from their importance in identifying the beds, reserving their supposed organic origin to a subsequent part of this paper. The quartzite is usually distinctly stratified, in beds of one to two or three feet in thickness. It is also divided vertically by “backs and cutters,” like those in the sandstones of the coal-formation. One bed is also divided into small oblong masses, like beds of clay-ironstone, but appeared to consist chiefly of quartz.

The quartzite is followed in the ascending section by a thick mass of limestone, quarried in several places and cut through by the river in a picturesque gorge. Even where not exposed, its presence may easily be recognized by the bright green pasture that covers it. The

\* From its variable character it is difficult to give this rock a name. Probably it is a felspar-porphry or binary granite, becoming a serpentine where in contact with the limestone of the quartzite.

limestone is of a bluish-white or grey colour, and intersected by so many minute veins as to give it a brecciated structure. It is very much hardened, and often siliceous. Interstratified with it are thin beds of finely laminar shale; the laminæ are often as thin as paper, and some of them light grey, others black and carbonaceous. The general dip of the quartzite and limestone series of beds is about  $15^{\circ}$ – $20^{\circ}$  to S.  $60^{\circ}$  E., thus at a higher angle and in a more easterly direction than the red sandstone on which they rest. In the valley of the river the limestone is followed by the same serpentine, or felspar-porphry rock, observed on Loch Broom, and this along Loch Auchal by gneiss, dipping to the south-east. The immediate relations of the rocks are, however, concealed by the lowness of the ground and the thick cover of moss and grass.

Any doubt on this point is removed by examining the hill between Loch Auchal and Loch Broom, in the line followed by the section. The quartzite just described forms the first low acclivity, resting on the red sandstone. Beyond a slight depression, the ground rises more rapidly; and, on the steep slope, first the limestone crops out, then the serpentine, and above all the gneiss, forming the summit of the hill, where it dips at  $10^{\circ}$ – $15^{\circ}$  S.  $30^{\circ}$  E., though with slight undulations. The rocks may be traced round the south side of the hill, placing their relations to each other beyond all doubt. A vertical section through the summit would pass in succession through the gneiss, serpentine, limestone, quartzite, and probably the red sandstone.

The section (fig. 2) on the south of Loch Broom is, if possible, still more explicit. The western portion was only seen in sailing along shore, as there is no road on this side of the loch, and the cliffs are in many places inaccessible; but the eastern, and most important part, was examined on the ground. At the north-west extremity the red sandstone dips out to the sea, but is soon interrupted by rocks represented as gneiss by Macculloch, and probably the continuation of those subsequently noticed near Loch Greinord. The red sandstone again commences dipping steadily to the south-east, along the whole loch, to beyond Ullapool. From the Ferry, its general dip is about  $8^{\circ}$  to S.,  $60^{\circ}$  E., or S.  $75^{\circ}$  E., in thick, regular beds. According to Macculloch's map, the red sandstone is immediately followed by gneiss; but, as the section shows, this is not the case. Before reaching Logie, it gives place to the quartzite, dipping at  $15^{\circ}$ – $20^{\circ}$  to S.,  $70^{\circ}$  E. Besides the common quartzite, I found both the beds with cylindrical bodies, and those with fucoid impressions observed on the north shore. I could not, however, discover the limestone, the quartzite being immediately succeeded by a thick mass of the serpentine or porphyry, running as a bold overhanging cliff, obliquely up the side of the hill, nearly in the dip of the beds. I traced it from the shore to the top of the ridge, and it apparently extends round into the valley at the head of Little Loch Broom, forming the cliffs beyond Dundonald. From its great hardness, it projects in a broad ledge or terrace, but is covered by gneiss, dipping at  $23^{\circ}$  nearly due east; and, like that on the north shore,

Fig. 1.—Section along the North side of Loch Broom.

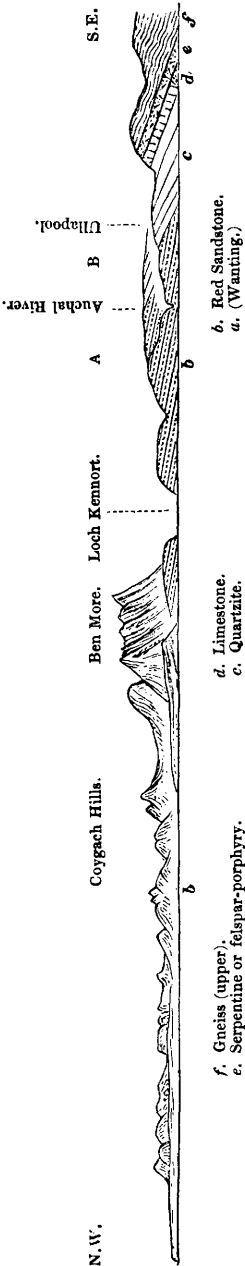


Fig. 2.—Section along the South side of Loch Broom.

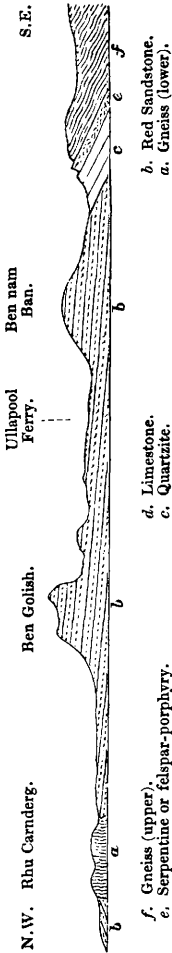


Fig. 3.—Section along Loch Assynt.

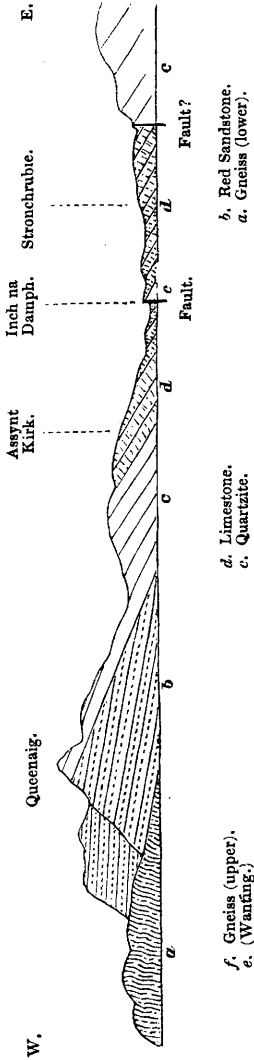
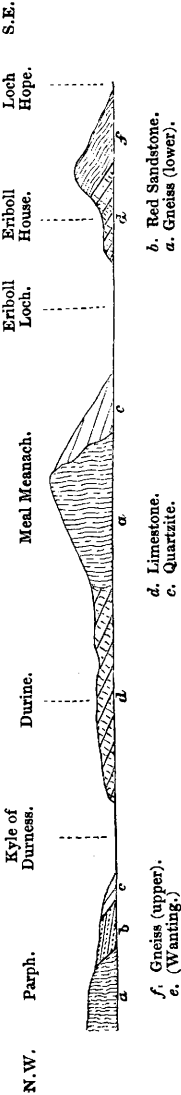


Fig. 4.—Section from Durness to Eriboll.



forming thin beds, often curved and twisted. Near the igneous rock the gneiss is in general very fine-grained, almost compact, and composed chiefly of quartz, with a little felspar and minute scales of mica. Many portions seemed almost like the more argillaceous beds in the quartzite series,—in a highly metamorphic state.

In this section there is thus the same, or rather a more complete, succession of the formations in the same relative order. The red sandstone, resting on gneiss, is covered in ascending order by quartzite, serpentine, and gneiss. The north side of Little Loch Broom exhibits these relations even more clearly, as the hills are more precipitous, and the superposition of the quartzite on the sandstone more fully exposed. I had not an opportunity of examining the junction of the quartzite and gneiss in the valley beyond this loch; but in the fine ridge of Kea Cloch, on its south side, the white quartzite is clearly seen running up over the red sandstone that forms the lower declivities. The red sandstone, dipping at a low angle to the south-east, continues along the coast for several miles, but is at length interrupted by a mass of serpentine or serpentinous gneiss, like that seen rising from below the sandstone mountains near Loch Greinord. Beyond this rock the sandstone, in thin slaty beds of a bluish-white colour, dips at  $10^{\circ}$  to N.,  $20^{\circ}$  W., forming the outer headland.

These sections in the centre of the formations may be regarded as typical of the phenomena in other localities; but several, both to the north and south, present some peculiarities worthy of notice. One of the most interesting of these is in the vicinity of Loch Assynt, where the precipitous sides of Queenaig, and the other mountains that surround that beautiful lake, expose some remarkable sections. I examined these in 1855 with Sir R. Murchison, and had thus the benefit of his former knowledge and experience in determining their relations. Though less clear than at Ullapool, probably from having undergone greater disturbance, the relative position of the formations appears to be essentially the same; see fig. 3. On the west, towards Loch Inver, the country consists of rounded, gnarled knobs and bosses of gneiss, separated from each other by small lakes and dark moors, and heaped together without any very apparent order. Near Loch Inver the gneiss often contains hornblende in place of mica; and some varieties are a granular compound of felspar and hornblende, containing large imbedded masses of light green fibrous hornblende, some of them two feet in diameter. These hornblendic varieties of gneiss are very characteristic of this formation in the west of Sutherland, as far north as Cape Wrath. On Loch Assynt the gneiss has often its common aspect; but coarse laminar hornblendic varieties, with no mica, and large nodules of quartz, still prevail. About half-way up the lake, the gneiss, dipping at  $55^{\circ}$  to the west, is covered by red sandstone, dipping at  $5^{\circ}$  or  $10^{\circ}$  to E.N.E. The lower beds of the sandstone are a conglomerate of quartz, felspar, and gneiss; the largest fragments are about two or three inches in diameter, and not much rounded. Higher up it is a dark, brownish-red, laminated rock, often containing large pebbles of quartz, and a



few traces of blue carbonate of copper. The sandstone is covered by the quartzite, the first beds being a coarse grit, with fragments as large as peas; and those higher up, a fine-grained white stone with a vitreous lustre. At Skiag Bridge, where the road turns north to Kyle Scow, the quartzite is of a red colour, and contains numerous cylindrical bodies, like those noticed near Ullapool. Ascending the hill by this road, we found brown slaty beds, with fucoid or plant-like impressions; and higher up again a bed with cylindrical bodies, thus identifying the strata with the Loch Broom rocks. On the line of section along the lake, the quartzite is succeeded by limestone, generally of a white or blue colour, and with a fragmentary or brecciated structure. Near Stronchrubie, east of the inn at Inch na Damph, the same limestone is well seen, ranging along the fine precipitous cliff. In this place it is often cherty, containing masses of siliceous matter like those common in the mountain-limestone, and also druses lined with quartz-crystals. Large lumps or masses of red felspar also occur in it; and a bed of greenstone, of augite and dark-red felspar, runs along the face of the cliff. The quartzite with cylindrical bodies again crops out at the bottom of the escarpment below the limestone, so that the whole series has probably been brought up by a fault. In the hills behind, according to Mr. Cunningham, the limestone is again covered by quartz-rock, as drawn in the section; but this locality I did not visit\*.

This section is evidently identical with that on Loch Broom, both in the mineral character and relative position of the beds. The only difference is in the apparently greater thickness of the limestone, and in this being again overlaid by quartzite. As on Loch Broom, also, the quartzite is unconformable to the red sandstone, and dips at a higher angle than the rock on which it rests. This is well seen on the south side of Queenaig, where the white quartzite creeps up, as it were, gradually over the red sandstone beds. The flank of the mountain on the south side of Loch Assynt, towards Canisp, exhibits the same arrangement. The gneiss on the west side is overlaid by nearly horizontal sandstone beds, which are in turn covered unconformably by quartzite, sloping down to the east at  $20^{\circ}$  to  $30^{\circ}$ . The relation of the quartzite to the gneiss, bounding it on its eastern side, was not visible on the line we followed, as a mass of red felspar-porphry intervenes near Loch Borolan. This rock is not unlike some portions of the Loch Broom serpentine, thus adding to the analogy of the two sections†.

On the north declivity of Queenaig the quartzite again appears, resting unconformably on the red sandstone; but the relations of the formations are obscure, probably from some fault near the line of junction. In Loch Glencoul the superposition of the quartzite to the red sandstone is very distinct, and both rocks are seen dipping away under the huge mountains on the east. In the recesses of this loch,

\* Probably it is only the lower quartz, brought up anew by a fault.

† Mr. Cunningham states, p. 96, that the quartzite of Ben More rests unconformably on the gneiss. The relations of this quartzite, both to the gneiss and to the limestone of Stronchrubie, require further investigation.

which we did not explore, Mr. Cunningham describes the gneiss as resting conformably on the quartzite and limestone. The same observer also figures and describes a very singular instance of this remarkable relation on Loch More. His section shows a lower highly inclined gneiss, covered unconformably by an ascending series of quartz-rock, limestone, and gneiss, all conformable to each other.

The next locality which I shall notice is the vicinity of Durness, where the limestone is distinguished by containing organic remains in considerable abundance. The general relations of the rocks are shown in fig. 4. The western shore of the Kyle of Durness consists partly of gneiss, partly of the quartzite in thin even beds, some of them full of the cylindrical bodies, but often more branched and coral-like in their forms than either at Assynt or Ullapool. This rock dips at  $20^{\circ}$  to S.  $60^{\circ}$  E., and, on the road to Cape Wrath Lighthouse, overlies red sandstone and conglomerate, dipping unconformably at a lower angle ( $10^{\circ}$  N.,  $25^{\circ}$  E.). The red sandstone exhibits no peculiarities, the lower bed being a not very coarse conglomerate of slightly rounded fragments of quartz and red or white felspar, in a reddish-yellow basis of sand. Mr. Cunningham noticed the quartzite in this place alternating with "strata of slate-clay of a character little differing from that which is associated with the red sandstone of the coal-series\*." On the east side of the Kyle the low country is chiefly limestone. On the shore near Balnakiel House, where it contains the fossils, it dips at  $10^{\circ}$  E., but in one place folds over in a low arch. The principal mass is of a dark-blue colour, very hard and siliceous, striking fire readily with the hammer. It contains large lumps of reddish-brown chert, with innumerable flinty concretions of singular forms; and, when weathered, the surface has a peculiar rough aspect, as if covered with broken corals or shells. Other beds are of a light-grey colour, and more arenaceous texture; and others again more argillaceous, and divided by a kind of cleavage into laminae from a quarter to half an inch thick. In general aspect it closely resembles some of the carboniferous limestones where altered by trap.

Beyond Durine, the limestone still dips east, but at a higher angle ( $20^{\circ}$  to  $25^{\circ}$ ), and alternates with beds of a more arenaceous character. Beyond the Smoo Cave it is cut off by gneiss in nearly vertical beds, with a W.N.W. direction. This rock forms the ridge running south-west from near Rispond to the Gualin. The eastern declivity of these hills is, however, covered by the quartzite, sloping down in vast beds to Loch Eriboll, and in some cases extending to the tops of the mountains. Many parts of this quartzite are soft, almost friable sandstone, not harder than the common grits of the coal-formation. The low ground on the eastern shore of Loch Eriboll, and the under declivities of the hills, are of limestone, in some places overlaid by a similar arenaceous quartzite. In the hills above Eriboll House this limestone series is overlaid by gneiss, which also dips south-east towards Loch Hope. The infra-position of the limestone to the gneiss in this locality has been recognized by many observers, from the time

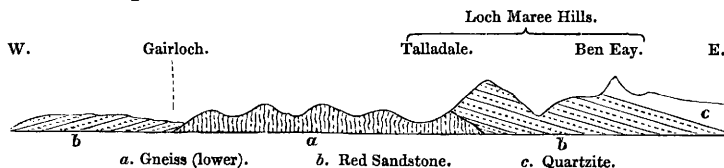
\* Essay, p. 92.

of Dr. Macculloch, who, in his 'Western Isles,' described it, and gave a section, in which however the gneiss of Rispond is represented as conformable to the quartzite and limestone. Professor Sedgwick and Sir R. Murchison in 1828, and the latter again in 1855, when we examined the section in company, and Mr. Cunningham in 1839, have all come to the same conclusion. It must also be observed, that the superiority of the gneiss to the limestone is not seen in one place only, or in sections of a few yards' extent, but along the whole escarpment, from the sea-worn precipices of Whiten Head\* to the picturesque Craig-na-Feulin, at the extremity of Loch Eriboll, a distance of more than ten miles in a straight line.

In this line of traverse there is one fact of considerable importance: the red sandstone which on the west side of the Kyle underlies the quartzite, and becomes far thicker and more extensive in the Parph Hills to the west, does not reappear on the east side of Durness or on Loch Eriboll. The quartzite there rests immediately on gneiss, the red sandstone having thinned out. To this remarkable feature we shall have again to refer in noticing the sections further south.

*Sections in the Southern part of the District.*—Returning from the extreme north, I shall now describe some sections in the range of the red sandstone and quartzite in the country south of Loch Broom. The interior of Loch Greinord is all coloured as gneiss by Macculloch, but consists partly of true gneiss, partly of a singular dark or light green rock, which appeared to me rather a serpentine or syenite, enclosing large angular fragments of gneiss. It forms a group of round-topped conical hills, with smooth, bald summits, destitute of all vegetation, which, though of no great altitude, have yet a remarkably wild and rugged aspect. From this place the gneiss appears to extend, in many peculiar varieties, continuously across the foot of Loch Maree to the Gairloch. Red sandstone, however, forms the outer headlands, and is well exposed on the shore of Loch Greinord, towards the Rumor, dipping at high angles, and covered unconformably by beds of a newer red sandstone†. At Gairloch and on Loch Maree the sandstone is well seen, and its relations, both to the inferior gneiss and to the quartzite, are very distinct, as shown in the accompanying section, fig. 5. The lowest rock is

Fig. 5.—Section across Gairloch and Loch Maree.



\* I did not visit Whiten Head, but both Dr. Macculloch and Mr. Cunningham mention the section.

† According to Macculloch, the only undoubted New Red Sandstone in Scotland.—Memoir on Map, p. 94.

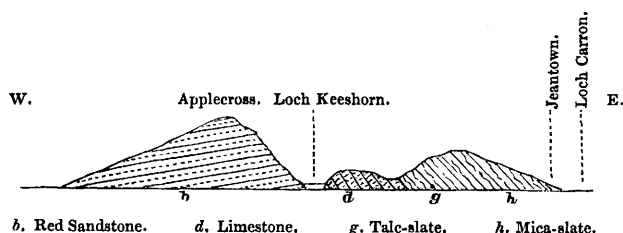
the gneiss, forming the rugged rounded hills between the Gairloch and the lower half of Loch Maree. The gneiss is in general of a light or dark grey colour, and finely granular; but other varieties are reddish, and more perfectly crystalline, or, again, contain distinct granular concretions of quartz or small garnets. Interstratified with it are beds of mica-slate, or fine-grained hornblende-slate. The strata are often contorted; but the general direction is nearly parallel to Loch Maree, or about N.W. (from N.  $40^{\circ}$  W. to N.  $60^{\circ}$  W.), and the dip almost vertical, or inclining to the south-west. The next rock is the red sandstone; the lower bed, where in contact with the gneiss, as on the shore near Gairloch Kirk and on Loch Maree, being a very remarkable breccia of quartz and gneiss in sharp angular fragments, not at all rounded or worn. The quartz is white and vitreous, or red and ferruginous, or a kind of blue hornstone,—the gneiss often like the finer varieties below. The largest fragment I saw measured sixteen inches long, by nine broad, and seven thick; but the generality are much smaller. In no place could I find any granite in this breccia. Above the breccia coarse gritty beds occur, interlaminated with finer materials; some of them almost a light-red, fine-grained quartzite. The breccia is everywhere exceedingly hard, and in many places closely resembles the gneiss; so that the broken, turned-over ends of the gneiss appear to pass almost imperceptibly into the sandstone. On the outer headlands, the red sandstone dips to the west or south-west, and forms a low undulating country, with the outcrop of the beds projecting through the moor. On Loch Maree the sandstone first appears as mere fragments of the coarse breccia, stuck in among the ends of the vertical red or grey gneiss. Near Talladale it becomes continuous, resting on, and as it were embossed in the hollows of, the gneiss hills. In mineral character it presents few peculiarities, except that a false bedding or lamination is not uncommon. From the uneven surface of the beds and the low angle, the dip is uncertain, but is about  $10^{\circ}$ – $15^{\circ}$  to S.,  $25^{\circ}$  to  $30^{\circ}$  E. In the mountains on the south-west of the lake, the white vitreous quartzite is clearly seen overlying the red sandstone, and often projecting in a kind of terrace on the side of the hill. In some of the lofty summits near Ben Eay, darker beds again rest on the quartzite, perhaps the equivalents of the grey siliceous beds of Loch Broom.

The red sandstone in this district has undergone enormous denudation. On the shore of Loch Maree it is often broken up into huge masses, or divided by gaps and fissures, some of them still twenty to thirty feet deep, though only a few (10 to 20) inches wide. The surface of the beds, too, is strewn with immense angular and ruin-like blocks, some of them poised on a single corner on the very edge of a cliff. All this indicates extensive destruction of the strata; and other proofs of the fact are not wanting. Detached fragments of the breccia are found in hollows of the gneiss hills far from the main masses, and evidently left in the general denudation. Several of these fragments appear on the shores of Loch Maree, and many of the beautiful wooded islands sprinkled over its surface are of the

same nature. All these evidently have once been continuous, and the red sandstone must have filled the valley of this most magnificent of Highland lakes, as deep as the lofty summits of Sleugach and Ben Eay, and have all subsequently been hollowed out and removed. The western hills, towards Gairloch, are still strewn with innumerable fragments of red sandstone, perched, like sentinels, in the most exposed and perilous positions, on the very edge of some lofty cliff, or on the polished summit of the domes of gneiss\*.

The red sandstone of Gairloch extends continuously into Applecross; and the whole of this vast formation must, therefore, be older than the quartzite. I examined the relations of the two deposits on Loch Keeshorn, in 1855, with Sir R. Murchison, and the section (fig. 6) represents the facts as seen by us. The great

Fig. 6.—Section across Loch Keeshorn.



mountain-district of Applecross consists entirely of red sandstone rising in terrace above terrace from the shore of the loch and valley. The general characters of the sandstone correspond to those already noticed; and, as a detailed section has already been given by Sedgwick and Murchison, need not be repeated here†. On the east side of the valley an entire change takes place in the rocks. The low green hill consists of limestone, of a light-blue colour, becoming white when weathered, and with the peculiar, fine-veined brecciated structure characteristic of the limestones of Ullapool, Assynt, and Durness. We examined this rock carefully for organic remains, but without success. The red sandstone dips at  $10^{\circ}$ – $12^{\circ}$  to W.S.W.; the limestone, in broken irregular beds, at a higher angle to the east. The narrow glen, followed by the Jeantown road, exhibits a series of talcose slaty rocks, some of a light-yellow, others of a dark-green colour, dipping at  $45^{\circ}$  E.S.E. (E.  $20^{\circ}$  S.) in thin even beds. These beds seem to overlie the limestone, though no immediate junction of the formations was seen. The relation of the limestone to the red sandstone of Applecross is more doubtful. The more natural interpretation would be that the sandstones had been deposited on the ends of the upturned limestone beds, and subsequently partially removed by denudation; but the

\* It is a curious fact, that on these gneiss hills by far the majority, probably nine-tenths or more, of these "perched blocks" are red sandstone.

† Geol. Trans. 2nd Ser. vol. iii. p. 154.

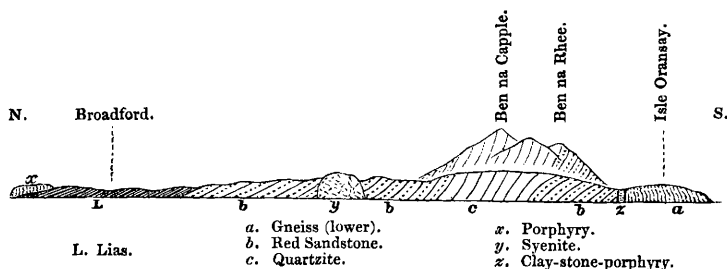
relations established at Gairloch and further north demand that we should regard the valley as a line of fault, bringing down the limestone beds to a lower level than the sandstones on which they were deposited. The sandstone, too, seems to have been thinning out here to the east, as the lofty mountains in the interior, seen both from Loch Keeshorn and on the road from Loch Carron to Auch na Sheen, appear to be capped only by the quartzite, covered in some places by darker beds, but without the red sandstone below.

The section from Kyle Aken Ferry to Balmacarra, and thence to the mountains of Kintail, appears to confirm these general relations. The red sandstone which occurs near the Kyle dips east under a peculiar group of slaty rocks, the representatives, according to Macculloch, of the quartzite series. It consists of blue or grey clay-slates and coarse grits, made up of quartz, felspar, and fine scales of mica, the whole in many respects not unlike some portions of the Silurian strata in the South of Scotland. The stratification is very well marked, and the beds are also intersected by distinct planes of cleavage—one set parallel to the bedding, others oblique at various angles. This group of rocks dipping E.S.E. continues to beyond the inn, but before reaching Loch Ling several veins of red felspar-porphry interrupt the succession. Near Dornie Ferry a large mass of dark-green dioritic serpentine forms some low hills or knolls. Near Totaig, on the south side of Loch Duich, an irregular broken and fissured bed of white crystalline limestone, mixed with actynolite, pyrite, and other minerals, occurs in connexion with a similar igneous rock or a syenite. Other larger masses of limestone crop out on the north-east shore of Loch Duich, probably in two or more courses, and dip at a high angle ( $50^\circ$ ) to the south-east. These limestones are connected with the true metamorphic rocks of the country; but it is impossible to avoid remarking that their proximity to the quartz series, and the great rarity of limestone in the gneiss of the north-west of Scotland, give some probability to the view that they may be only a more highly altered portion of the quartzite dipping under the great mountain group of the Beallock of Kintail\*.

*Skye.*—At this point, the great bands of red sandstone and quartzite terminate on the mainland, but, according to Dr. Macculloch, are continued through the district of Sleat in the south of Skye. This observer describes the relations of the rocks in that tract as exceedingly complex, and the sections drawn in his work on the Western Isles by no means lessen the difficulty. The section (fig. 7) from Isle Oransay to Broadford intersects the whole formations, from the gneiss on the one hand to the newer secondary deposits on the other. On the south coast at Isle Oransay, the gneiss, sometimes hornblendic, is seen dipping south-east towards the mainland. On the north of it, a mass of claystone, or felspar-porphry, occurs in a depression partially filled up by detritus concealing the rocks. Beyond

\* It is worthy of notice also, that in these mountains granite first appears in mass, on the west coast, in the whole range from Cape Wrath to the south.

Fig. 7.—Section through the southern part of Skye.



this hollow, red sandstone and conglomerate beds appear, at first broken and disturbed, but soon dipping regularly to W.N.W. at angles ranging from  $25^{\circ}$  to  $40^{\circ}$ . The sandstone is of a reddish-brown colour, with thin yellowish layers of finer materials, but is much hardened and altered, and at first sight might easily be mistaken for gneiss. In many respects it closely resembles the beds above the coarse breccia at the Gairloch. At the head of Loch Daal the sandstone is followed by thick beds of greyish quartzite, dipping N.W. at  $20^{\circ}$ . Further north, beds resembling greywacke, with light-yellow and blue slates, follow, dipping at  $40^{\circ}$  to  $60^{\circ}$  W.N.W. These beds have the general character of the Balmacarra slates, but are softer, and without cleavage. In Ben na Rhee and Ben na Cappie, on the east of the road, the beds appear to dip at a much higher angle, and to be more quartzose in character. The next higher group of strata is again red sandstone, but lighter in colour, and softer than the sandstones below the quartzite. The syenite or felspar-porphry of Ben na Charn interrupts this series, but without altering the direction of the dip. On the north of the igneous rock, the sandstone is of a whiter colour. On Broadford Bay the lias shale and limestones, full of *Gryphææ*, *Ammonites*, and other characteristic fossils, appear dipping  $8^{\circ}$  N.  $50^{\circ}$  W., and intersected by the most complex groups of trap-veins. Beyond Broadford Bay the lias is covered by beds of green-coloured columnar porphyry, both the igneous and stratified rocks being again intersected by vertical veins of grey greenstone.

This section, though the lower rocks are clearly identical, differs in many important points from those formerly described. The dip of the beds is now to the N.W. instead of to the S.E., as on the mainland. The quartzite is no longer the white granular quartz-rock of the northern sections, but in many parts rather a greywacke or slate. The limestones do not appear in the section, but the quartzite is now covered by soft red or white sandstones, and these by the shales and limestones of the lias, instead of the hard metamorphic gneiss of Ullapool and Loch Eriboll. The lower red sandstone is evidently the same rock with that seen on the mainland, and the quartzite may also be probably identified, though somewhat different in characters. How far the upper red and white sandstones belong to this group is more doubtful.



*Order of succession.*—This review of the red sandstone and quartzite as they appear in the long course of more than 100 miles along the west coast from Durness and Cape Wrath to Loch Alsh and Skye establishes the following important facts in the geology of this part of Scotland.

*First.* The red sandstone is the lower formation, resting only upon gneiss, and forming a narrow band along the western shore, never reaching to the watershed of the country, and not exceeding twenty miles in breadth in its widest portions, as on the Gairloch.

*Secondly.* The quartzite is a distinct and newer formation, resting unconformably on the red sandstone on the west, but on the east spreading out beyond it over the gneiss. Its present breadth, including outlying portions, does not exceed ten miles, and is generally much less. The limestone forms the upper portion of this band.

*Thirdly.* That the general dip, though at a different angle, both of the red sandstone and quartzite is to the south-east; and that at many points on its eastern side the quartzite and limestone have been ascertained to dip under gneiss inclined in the same direction.

*Organic remains.*—This inferiority of a vast series of sedimentary deposits—for what is true of the quartzite must be true also of the red sandstone on which it rests—to a highly metamorphic rock like gneiss has acquired additional interest from the discovery of undoubted organic remains in some of the beds. These remains I shall now notice in the order of the formations. In the red sandstone no organic remains have been found, partly perhaps from the nature of the beds, partly, we may presume, from the few opportunities they present, from quarrying or other operations, for their discovery. In the quartzite probable indications of organic beings are more numerous. In his first Memoir on Quartz-rock, published in 1814, Dr. Macculloch noticed the “imbedded cylindrical bodies” seen both on the surface and in the interior of the quartzite, and described them as “the remains of some animal, a *Sabella* or other marine worm.” The organic origin of these bodies has subsequently been denied, but as it appears to me erroneously. Consisting entirely of sand—and thus rather casts than petrifications—they can scarcely be expected to show any structure, so as to decide positively their true character. Their branched forms and their immense numbers, closely crowded together over wide spaces, are opposed to the view that they are the mere burrows of marine worms, as Macculloch suggested. Both in general aspect and mode of grouping the cylindrical forms much resemble the *Lithodendron* corals, whilst the conical, rounded or polygonal bodies in other beds have more similarity to *Cyathophyllæ*. I shall, however, leave to further investigation to determine their true nature, as at present we can draw no argument from them in regard to the age of the strata.

In other beds of the quartzite, I have mentioned plant-like impressions as occurring in abundance. But these are in general nothing



more than a confused mass of carbonaceous markings, more like fucoids than any higher forms. This, however, seems to have arisen in part from the changes the rocks have undergone, as we occasionally find straight, cylindrical fragments, like stems or branches of trees, 2 to 4 inches in diameter and 12 to 14 inches long. Some of these are marked with obscure scars, as of leaves or branches. Round or oval markings, like those on the *Stigmaria* of the coal, are also not uncommon, scattered irregularly over the surface of the rock. On a few specimens they were arranged quincuncially, as on the *Stigmaria*; but, from the imperfect nature of the specimens, I would not place much weight on this mere resemblance, though the indications of a higher terrestrial vegetation at this period are of much importance.

In his 'Western Isles,' Dr. Macculloch mentions his discovery "in a porous or incompact granular quartz, alternating with the limestone," on Loch Eriboll, of "conical bodies not exceeding a quarter of an inch in length, being evidently the fragments of Orthoceratites or some analogous fossil, possibly entire shells\*." These bodies have subsequently been noticed by other observers; and in 1855 Sir R. Murchison and myself found them in considerable numbers. The best-preserved specimens are, as Macculloch states, of a conical form, about a quarter of an inch long, and on the cross fracture show that they have been hollow at the broader end. Their minute size, and the nature of the stone in which they are imbedded, and from which they cannot be separated, render their character uncertain. The want of septa, of which I can discern no trace, shows that they were not Orthoceratites; and if shells, I should regard them rather as belonging to small Pteropod mollusca.

By far the most distinct fossils, however, are those found in the Durness limestone, for the discovery of which we are indebted to Mr. Charles Peach. When I visited this place in company with Sir R. Murchison, we found these fossils in considerable abundance, both in the beds described by Mr. Peach, and in others at a lower level. They are principally seen on the surface of the rock where wasted by the sea or weather, but the hard refractory nature of the stone renders it almost impossible to extract them in a state fit for description. The results of a careful examination of these fossils are thus stated by Sir R. Murchison. "It had been suggested that the fossils in question, being of a whorled form, might prove to be the *Clymenia* of the Devonian rocks; but although, according to Mr. Salter, one or two of them have a certain resemblance to that genus, and some even to *Goniatites*, the evidence of their being chambered shells is too obscure to decide the case. The principal fossil is probably a *Euomphalus*: it resembles the *Maclurea* or *Raphistoma* of the Lower Silurian rocks, except that the former, to which it most approaches, has a sinistral and not a dextral curve. Even should some of these whorled shells prove to be chambered, there is nothing about them to gainsay their belonging to the *Lituites*

\* Vol. ii. pp. 512, 513.

of the Lower Silurian rocks. Another fossil is certainly an *Orthoceratite*” \*.

I may further remark, that many of the singular forms brought out on the surfaces of this limestone by weathering are probably, as Dr. Macculloch long ago conjectured, of organic origin; “in particular the red vermicular forms very similar to many that occur in the well-known marble of Babicomb.” I have little doubt that these are truly corals. Better and more determinable specimens will probably yet be procured from some of the less altered beds of this series; but in the mean time the question arises, To what geological period do these organic remains belong? What age do they indicate for the beds in which they are found? The only certain genera are the *Orthoceras* and *Euomphalus*, but these characterize rather the Palæozoic beds in general than any of the formations in particular. The mere resemblance of others to *Lituites*, *Clymenia*, or *Goniatites*—to Silurian, Devonian or Carboniferous forms—is too uncertain a foundation on which to build any argument. Beyond the mere fact, therefore, that these formations belong to the great series of Palæozoic strata—and this fact is one of very high importance,—I do not think that these organic remains will as yet safely carry us.

*Distinctive physical characters.*—Being thus, as it were, thrown back on the general characters and relations of these deposits, the question arises, Do they furnish us with any aid in determining their age? The red sandstone has hitherto been generally regarded as of Devonian age; and so strongly are the characters of this formation, as seen in other parts of Scotland, impressed on it, that we may affirm no doubt would ever have existed on the question, except from its relation to the quartzite †.

As it is now proved to lie below the quartzite, its age must evidently be affected by our views regarding the latter rock, which, as I have shown, is a distinct and newer formation. Now the close analogy of this group to the mountain-limestone and associated sandstones, has forced itself on every observer, and in describing it comparisons with the coal-formation in the central districts of Scotland constantly recur. The mineral characters of the beds are almost identical—more so indeed than we might have expected, considering the distance of the localities and the changes the northern deposit has undergone. It consists of fine- or moderate-grained white siliceous sandstones, not harder than many in Fife or the Lothians in the vicinity of trap; disposed in regular beds of moderate thickness, with ripple-marked surfaces and false stratification; of thinly

\* Brit. Assoc. Report for 1855, Trans. Sect. p. 87. In addition I may mention, that a specimen of *Orthoceratite*, which I procured from these beds, measures 1·4 inch in length, with a diameter of ·4 at the upper and ·2 at the lower end. It is somewhat compressed, and quite smooth on the external surface.

† Dr. Macculloch seems to have been inclined to regard it as a primary red sandstone; Mr. Cunningham named it “Transition.” Professor Sedgwick and Sir R. Murchison in 1828 classed some portions as “Primary,” others as “Old Red.”

laminated, blue or grey shales, full of carbonaceous, plant-like impressions, and strongly impregnated with iron ;—and lastly, of blue or grey limestones alternating with shales, and in some places black, bituminous, and emitting a “fœtid odour similar to that detected in various mountain-limestone strata.” Even the external features of the fine cliff of Stronchrubie, with its beds of limestone, sandstone, and trap, are entirely those of the coal-formation : whilst those of the quartzites of Ben Spiannue and Loch Eriboll are just those of the sandstones in the south of Scotland or north of England. Now though the occurrence of one of these beds or groups alone—of a red sandstone and conglomerate, of a white sandstone and shale, or of grey and bituminous limestone—would furnish no strong indication of age, yet the coincidence of the whole three in their proper order is a far more powerful argument. It seems highly improbable that in such a limited region as Scotland there should have occurred in the palæozoic age two such complex series of deposits, so nearly identical in mineral characters and order, and yet that they should not be contemporaneous.

The chief objection to assigning so recent a date to these quartzites and limestones is the remarkable fact, that on the east they dip below gneiss. Now the gneiss of the central region of Ross and Sutherland, dipping, with few exceptions, continuously to the south-east, is observed passing under the Old Red Sandstone of Ross-shire and Caithness. This clearly appeared in three traverses of this region, from the east to the west coast, which I made in company with Sir R. Murchison in 1855, and is indeed admitted by the most competent observers\*. If, therefore, this gneiss, that overlies the quartzites of the west coast, is truly a portion of the great formation of the central regions which underlies the Devonian rocks on the east, and has been originally deposited and metamorphosed in the place where it occurs, it seems necessarily to throw the red sandstones and quartzites of the west coast into a much earlier geological period,—most probably into the Lower Silurian. This continuity of the overlying gneiss of the west with the underlying gneiss of the east coast has, however, not been established, and would indeed be a work of great difficulty in such a wild and pathless country. In those parts of Ross-shire, also, where the quartzite directly overlies gneiss, it is evidently the lower gneiss of the same age with that on the west coast of Sutherland, that forms the surface. The fact also of the overlying gneiss having been metamorphosed *in situ*, and not pushed up over the quartzite, is one requiring further investigation. The occurrence of igneous rocks—syenitic porphyries or serpentines, at many points along the line of union, seems to indicate a fault. On the other hand, the great extent over which this relation has been observed, of fifty or a hundred miles, is unfavourable to the view that it is the result of a slip or convolution of the beds. The quartzite also and the limestone have undergone

\* “It is generally, but not universally true, that the dip [of the gneiss] is to the south-eastward.”—Macculloch, *Mem. on Geol. Map of Scotland*, p. 63. See also the dips laid down on Mr. Cunningham’s Map of Sutherland.

great metamorphic action, which seems to have less affected the upper portion of the red sandstone; whilst the bottom beds of the sandstone again, as on the Gairloch, have been exposed to it in a much higher degree. In other words, the red sandstone and quartzite appear to have been more affected at the two extremities, above and below, than in the middle of the series\*.

*Probable Age.*—On the whole, therefore, though all doubt can only be removed by the discovery of better-preserved characteristic fossils, I regard the theory, that the red sandstones of the West Highlands are of Devonian age, the quartzite and limestone of Lower Carboniferous, as the more probable. Whether we consider the gneiss resting on the latter as a newer metamorphic group, or merely as a portion of the lower gneiss forced up over it in some great convulsion, we have still views of very great interest opened up to us in the history of these Highland mountains. They can no longer claim that remote geological antiquity which has hitherto been assigned to them, but belong, at least in their present form, to a far more recent period in the history of the earth,—to one posterior to the deposition of the horizontal coal-fields and sandstones of the south.

In offering to the Society, first a statement of facts, and then my views of the probable age of the quartzites and limestones, I wish it, however, to be understood that my Memoir has reference only to the north-west coast of Scotland. How far it may apply to the quartzites of other parts of the Highlands must be left to future consideration. It is also clear, that these facts in no way affect the accuracy of the Devonian classification of the great ascending triple series of the east coast,—of the coarse conglomerates and red sandstones, the dark bituminous Caithness flags, and the overlying red sandstones of Dunnet Head and the Orkneys,—as established by Sedgwick and Murchison in their most important memoir. I am fully convinced that Scotland contains red sandstones and conglomerates of various dates; and should it ultimately prove that the quartzite and limestones now under consideration are of Silurian age, I shall deem it no small matter to have established, as the facts now stated would then clearly prove, that the red sandstones of the west coast belong to a far different period from the corresponding rocks on the east, with which they have hitherto been identified.

*Geological History of the North-western District of Scotland.*—Before concluding, there are a few considerations on the succession

\* I have not referred in the text to Mr. Hugh Miller's views of the age of these beds, as I am not aware he has ever fully published them, except in an article in the 'Witness' newspaper printed before the discovery of the fossils by Mr. Peach. He appears to consider the whole as Devonian,—the red sandstones representing the lower conglomerate, the limestone the middle calcareo-bituminous flags of Caithness, and the quartzite the upper red sandstones of Dunnet Head. My reasons for not adopting this classification will be readily suggested by the text. [The lamented death of this distinguished geologist offers another reason for not controverting a theory which he is no longer spared to defend.—J. N. January, 1857.]

of geological phenomena in this portion of Scotland which I would wish to introduce. The oldest formation is undoubtedly the gneiss seen underlying the red sandstone, from Cape Wrath to the Gairloch and Skye. Its chief mineralogical peculiarity is the prevalence of hornblende and the comparative rarity of mica, though the more ordinary kinds are far from being unknown. Though granite-veins often intersect this rock, there is no mass of granite which can be assigned to this first period. Indeed the fragments in the red sandstone, and the composition of its grits, would lead us to conclude that granite was not an abundant rock in this region, more especially the regular compound of quartz, felspar, and mica, which appears to have been chiefly formed at a more recent period\*. This older gneiss, in the region indicated, has a general direction to the N.W., apparent not only in the strike of the rocks, but also in many of the lakes and valleys. In the mountain ranges this direction is far less marked, having, it appears, been obliterated by subsequent denuding action.

Over the gneiss thus elevated, a large deposit of red sandstone has been thrown down. Where the bottom beds are a coarse angular breccia, intercalated amidst the broken ends of the gneiss, as on the Gairloch, the deposition of this rock must have immediately succeeded some violent convulsion, either local or general. The red sandstone on the west forms a narrow band along the shore, and never extended far into the interior; still less over the whole country, as has often been imagined. This is proved by its thinning out on the east, below the quartzite; whilst the conglomerates on its margin in Caithness and Easter Ross also appear to indicate proximity to the shore on that side of the island. The thickness of this deposit must be very great,—from 2000 to 3000 feet being still exposed in the mountains of Applecross, Gairloch, Loch Broom, and Assynt, whilst the dip of the strata implies that its original dimensions were far greater.

At the close of this period the country must have been still more depressed towards the east, allowing the quartzites to extend much farther into the interior. At present the quartzite-fragments unconnected with the red sandstone stretch from five to ten miles beyond its boundary, but may probably have once reached much farther over the gneiss. A change in the mineral character of the deposits also took place, the red sediments ceasing and others more favourable to organic life coming in their place, as shown in the fossiliferous limestone above. The quartzite including the limestone has no great thickness, probably not exceeding from 300 to 500, or at most 800 feet. To this, however, must be added the quartzite of Ben More Assynt, if truly overlying, and also the upper gneiss, so far as this has been metamorphosed in place.

\* Micaceous granites are also rare in the Old Red Conglomerates in many parts of Scotland, and the granite-boulders in the Silurian conglomerates on the Ayrshire coast rarely contain this mineral; thus showing that they have not been derived from the granite-mountains in the vicinity, but from an older formation.—See Murchison on the Silurian Rocks of Scotland: Journ. Geol. Soc. vol. vii. p. 153.

The termination of the quartzite-period seems again to have been marked by convulsions. To these we must ascribe the action by which the higher portions were converted into gneiss; or this gneiss, if a pre-existing rock, forced over the quartzite. At the same time we may suppose that those serpentinous felspar-rocks were formed which we have mentioned as occurring at Loch Alsh, Ullapool, and Assynt, and which probably exist in other places. In the same period also we may place the serpentinous rocks mixed with the gneiss of Loch Greinord. The effect of this action has been to raise up the strata along a N.E. and S.W. line, running nearly parallel to the west coast, from a point between Cape Wrath and Durness on the north, by Loch Greinord and Loch Keeshorn, to near Kyle Rhea in Skye. The red sandstone dips west from this axis on the west side, and on the east side east, with all the superior strata. The watershed of the country is a parallel line, but lies much farther in the interior; and the influence of this line of elevation may also be traced in many other physical features of the north-west Highlands\*.

The next great action to which this region was exposed has been that process of denudation by which the mountains have been cut out into their present forms. If the newer red sandstone on Loch Greinord be, as Macculloch supposed, red marls or triassic, this action must have begun shortly after this elevation, as it is chiefly made up of fragments of these older strata. At the same time, or soon after, the lias of Skye may have been forming in the deeper and more distant parts of the sea. But at whatever time this denudation took place, we may form some idea of the manner in which it was effected. The whole west coast seems to have been slowly and uniformly rising, until it stood like a long mural ridge above the waters. But these waters were not idle,—breaching this rampart from point to point along the old lines of fracture, and hollowing out those great sea- and land-lochs by which the country is now intersected. Even after this process was completed, the elevation seems still to have gone on,—carrying the mountains far up into the regions of ice and snow, when those enormous glaciers were produced which filled their deepest valleys, and polished their hardest rocks, from the sea-level to many hundred feet above it, as with a lapidary's tool.

But the land must have again gone down, even below its present level, leaving only the mountains, like islands, rising up out of the ocean. In no other way can we explain the peculiar forms of the low rounded gneiss hills between Loch Enard and Loch Inchar, and the singular detritus with which they are covered. The innumerable islands lying off the coast of Edderachyllis are only a portion of such

\* These two lines of elevation which I have thus noted in the rocks of this region, it will be observed, correspond with two of the most ancient lines described by M. Élie de Beaumont, in his "Notice sur les Systèmes de Montagnes." The N.W. line may be referred to the system of Morbihan, which at Milford has the direction of W.  $36^{\circ} 35'$  N.; the N.E. line to the Longmynd System, with a direction N.  $21^{\circ} 24'$  E. at Milford. The order of succession is not, however, the same, and my observations are not sufficiently numerous to make a more precise comparison worth while. So far as they go, these coincidences may be regarded as favourable to the more ancient date of the beds.

land, not yet raised out of the ocean. At this time, too, has taken place the transport of those innumerable "perched stones" which we have noticed throughout all this region, apparently floated away on icebergs from the mountains on the east, and deposited on the tops of the lower hills as they again rose above the waters to their present elevation.

It is an important fact in connexion with all these great and repeated changes of level, that this district is remarkably free, for Scotland, of igneous rocks. No large masses of any of them are seen at the surface, and even veins are by no means common. The granite-veins at Cape Wrath, and near Lochs Inchard and Laxford, are the most important exceptions; and then the porphyries and serpentines of Assynt, Loch Broom, and Loch Greinord. Trap-veins occur rarely in Assynt, but seem scarce known on the mainland, either to the north or to the south. This is the more remarkable when we consider the proximity of Skye, where these rocks, of many different ages, are so fully developed; or contrast this part of Scotland with the west coast of Argyll, where they break out almost every hundred yards.

It thus appears that this portion of Scotland has formed a peculiar isolated region, even from an early period. Perhaps a still more important lesson to the geologist may be found in the fact, that changes so singular in character, and so immense in extent, have taken place in this country, and yet almost no trace of the powerful agent by which they were effected appears on the surface.