
Chapter 29 Post-Cambrian igneous rocks of older date than the great thrust-movements of the region — their distribution

By B. N. Peach and J. Horne, with notes supplied by W. Gunn, C. T. Clough, and L. W. Hinxman. The district described in this chapter is comprised in Sheets 101, 102, 107, and 108 of the Geological Survey Map of Scotland, on the scale of 1 inch to a mile.

I Assynt

The remarkable development of igneous rocks associated with the Torridon Sandstone and Cambrian strata in Assynt, Sutherlandshire, aroused the attention of several of the older observers, who recognised the intrusive character of some of these masses and the contact metamorphism which they produced. In 1856 and again in 1860, Nicol noted the conspicuous sill of greenstone in the cliff of limestone south of the Inn at Inchnadamff and the large intrusion of igneous material, which he termed felspar-porphry, near Loch Borrolan. He further observed that the Canisp porphyry not only breaks through the quartzite overlying the Torridon Sandstone, but forms a mass more than a mile in diameter in the quartzite within a few hundred yards of the Inn at Inchnadamff. From these facts he correctly inferred that the igneous intrusions must have been later than either the red sandstone (Torridon) or the quartzite.<ref>*Quart. Jour. Geol. Soc.*, vol. xiii., p. 25, and vol. xvii., p. 99.</ref>

Confirmatory observations were made by Murchison, who, in 1859, called attention to the band of syenitic greenstone intercalated in the grey limestone about a mile west from Inchnadamff, which, though apparently regularly bedded, had, in places, converted the overlying rock into a crystalline marble. The igneous rocks in the east of Assynt near Loch Borrolan, though termed porphyries, were regarded by him as syenites, that break through the quartzites far above the limestones of that region.<ref>*Quart. Jour. Geol. Soc.*, vol. xvi., pp. 221 and 232.</ref>

Special attention was given to the lithological characters and distribution of these rocks by Professor Heddle, who published the results of his researches in various papers in the *Mineralogical Magazine* from 1881 to 1884.<ref>*Mineralog. Mag.*, vol. iv., pp. 233, *et seq.*; vol. v., pp. 136 to 144, 144 to 295.</ref> He regarded the Canisp intrusion as one of the most striking porphyries of Scotland, and noted the occurrence in it of porphyritic crystals of orthoclase with albite and augite. He referred to the distribution of the igneous rocks in the quartzites and dolomites in the neighbourhood of Inchnadamff, and indicated the varieties from the Canisp porphyry to the more basic types found in the calcareous series, in which hornblende is more abundant. He took exception to the application of the term porphyry to the igneous intrusion of Loch Borrolan, as it does not possess true porphyritic structure, but consists essentially of two ingredients, felspar and quartz. While indicating the localities of the marbles, he noted the important fact that they are all more or less contiguous to the mass of red felspar rock on Cnoc na Sroine or its branches, and he inferred that the marble is merely a portion of the limestone series of Assynt. Unfortunately, he somewhat impaired the value of these correct observations by suggesting that the red rock of Cnoc na Sroine is a mere variety of the "Logan Rock", which, in the localities referred to by Professor Heddle, has been proved beyond doubt to be a portion of the Lewisian gneiss.

Subsequently Dr. Callaway<ref>*Quart. Jour. Geol. Soc.*, vol. xxxix., p. 409.</ref> alluded to some of the igneous rocks in the Assynt series, particularly between Ledmore and Loch Ailsh, noting the granitoid texture which is characteristic of the Loch Borrolan mass, and an exceptional garnetiferous variety on the slope north of the road east of that lake. In an appendix to Dr. Callaway's paper, the microscopic characters of some of these rocks were described by Professor Bonney.<ref>*Quart. Jour. Geol. Soc.*, vol. mix., p. 420.</ref>

In 1886 Dr. Teall described the characters of some hornblende-bearing rocks of this series near Inchnadamff, arranging them in three groups and giving analyses of three specimens. Regarding the most basic type, which differs from the others in containing a large amount of colourless pyroxene, the author remarked that "in all probability the pyroxene is a nearly pure lime-magnesia bisilicate, and one is therefore tempted to ask whether it may not be due to the absorption by the igneous magma of a certain amount of the dolomitic limestone into which the rock has been intruded".<ref>*Geol. Mag.*, 1886, p. 386.</ref> In 1892 Dr. Teall gave a detailed petrographical account of a group of rocks which he termed

borolanites, obtained in the neighbourhood of Cnoc na Sroine, in the course of the Geological Survey of the district.

He described the typical rock as a granular aggregate of orthoclase and melanite, with biotite, pyroxene, alteration products after nepheline and sodalite, with sphene and apatite, as subordinate and variable constituents. He pointed out the affinities of borolanite to the elaeolite-syenite family, the nearest allied rocks being the elwolite-syenites of the Christiania district, investigated by Professor Brögger. <ref>*Trans. Roy. Soc. Edin.*, vol. xxxvii., Part I., p. 163.</ref>

The crystalline rocks illustrating this phase in the geological history of the North-West Highlands are all intrusive, no contemporaneous volcanic materials having been detected within the area examined by the Geological Survey. They occur (1) as plutonic masses, (2) as intrusive sheets, and (3) as dykes.

It is noteworthy that this outbreak of igneous activity in these ancient sedimentary systems has a comparatively local development. Although the Torridon Sandstone and the overlying Cambrian strata can be traced continuously for a distance of 90 miles across the counties of Sutherland and Ross, the rocks now to be described are confined to a limited portion of this belt. In the area lying immediately to the west of the post-Cambrian terrestrial movements, they extend from Loch Assynt to near Elphin, a distance of about nine miles, but in the region affected by these movements they stretch from near Beinn Lice, about a mile south of Loch More, to Ullapool — a distance of 27 miles. Originally they must have penetrated far to the east, for they have been carried westwards with the associated sedimentary strata along the higher thrust-planes. It is worthy of note also that deformed igneous rocks allied to some of the members of this series have been recorded from the shore of Loch Broom and east of Kinloch Ailsh, where they are intercalated in the Moine schists. Seeing that the dolomites of the Durness series have been converted into marble by these igneous rocks, and that the intrusive sheets are truncated by the numerous thrusts or lines of displacement traversing the region, it is obvious that the period of igneous intrusion to which they belong is later than the Cambrian dolomites and older than the post-Cambrian movements.

i. Plutonic mass of Cnoc na Sroine and Loch Borrolan

The igneous material attains its greatest development in the southern portion of Assynt, where it covers an area five miles in extent from Ledbeg eastwards to a point near the road leading to Loch Ailsh. It is traceable also from the peat-clad moor south-east of Loch Borrolan northwards to the slopes of Sgonnan Mor.

Along the north-western and western margin of the plutonic rocks near Ledmore, Ledbeg, and Cnoc-an-Leathaid-Beg, their relations to the marble are complicated by the occurrence of various outliers of materials resting above the Ben More thrust-plane, originally continuous, but now forming isolated patches, which cover portions both of the igneous rocks and of the marble. The prominent escarpment that skirts the range of hilly ground from Loch Borrolan to the west slope of Cnoc na Sroine does not mark the western limit of the mass, for the igneous rocks occur in association with the marble in the Ledbeg River and high up on the slope of Cnoc-an-Leathaid-Beg to the west. At the latter locality both the granitoid rock and the marble are buried underneath the basal quartzites and the pipe-rock, which, resting unconformably on a slice of Lewisian gneiss, form together with it an outlier separated by denudation from the displaced masses that come above the Ben More thrust-plane.

Along the northern margin the boundary-line sweeps eastwards by the south side of the Ledbeg River to Ruighe Cnoc, two miles east of Cnoc na Sroine, where there is a fine escarpment of the syenite. For most of this distance the junction of the intrusive mass with the thrust Cambrian strata is buried under peat and drift. Typical examples of borolanite occur at the margin of the mass and within a short distance of the marble on the south side of the Ledbeg River, and not far from the shepherd's house at Loyne. Again, on the south-west slope of Sgonnan Mor, four small streams, which unite to form an important tributary of the Ledbeg River at Luban Croma, display excellent sections of borolanite penetrating the marble between the 1000 and 1250 feet contour-lines. Not far above this level both the marble and the intrusive rocks are truncated by the Ben More thrust-plane, which has brought forward a great slice of Lewisian gneiss covered unconformably by Torridon Sandstone and Cambrian strata.

The eastern limit of the plutonic mass can be approximately defined by means of rocky knolls that project through the peat and drift in the neighbourhood of Strathsheaskich, near Loch Ailsh, where the igneous rock is bounded by massive

white marble, apparently resting upon it, and dipping towards the east at angles from 30° to 70°. This boundary can be traced through the gap close by the Kinlochailsh road to the high road leading to Inchnadamff.

The southern limit of the igneous mass is to a large extent obscured by the extensive covering of peat which stretches continuously from the Kinlochailsh road westwards to Loch Urigill and Ledmore, but occasional exposures of rock are to be found in the streams that cut through the peat and drift. The same rock extends far to the south of the road between Loch Borrolan and Allt a' Mhuilinn, for it is visible in small burn-sections about three-quarters of a mile south of the latter locality, where it is again overlapped by the Cambrian quartzites and Lewisian gneiss lying above the Ben More thrust-plane.

Though the material of this extensive plutonic mass in the south of Assynt is generally massive, a distinctly foliated type of borolanite appears to the east of Aultnacallagach Inn in a small stream (Aultivullin) which drains Loch-a-Mheallain and flows southwards into the Allt an Loin Dubh. The same type occurs also on the hill-slope to the east of these localities, and has been traced in the burn-sections on the moor south of Aultivullin as far as the slopes of Cnoc-na-Glas-Choille. The foliation-planes dip towards the east at an angle of 15°, thus coinciding with the general inclination of the post-Cambrian planes of movement.

ii Sills and dykes

In the undisturbed area south of Loch Assynt, the igneous materials appear as intrusive sheets in the Torridon Sandstone on Beinn Gharbh, on Canisp, and on Suilven. The well-known albite porphyrite of Canisp rises from the old platform of Lewisian gneiss on the west face of that mountain, thence passes upwards into the overlying red sandstones, and spreads along the bedding planes of the strata. Indeed, it is not improbable that the porphyrite sills on Suilven, now isolated by denudation, may have been originally continuous with those on Canisp. The sill-like character of these igneous rocks is strikingly exemplified in the area occupied by the Cambrian strata in Assynt, where detailed mapping shows that the intrusive sheets are more or less confined to certain horizons, though they not unfrequently appear in higher or lower portions of the same sub-division. In that region the sheets vary in thickness from ten to fifty feet.

From the accompanying vertical section (Figure 18), it will be seen that one sill, which has a wide extension on the Ben More range, has been intruded at the junction between the quartzites and the Lewisian gneiss where the Torridon Sandstones have been removed. The other sills have a vertical range from the lower part of the arenaceous to Group II. of the calcareous series. The most persistent are those in the basal quartzites, in the third sub-zone of the pipe-rock, in the fucoïd-beds, and near the base of the Ghrudaidh dolomites. The materials of these intrusive sheets consist of diorites, including vogesites and spessartites, albite-porphyrates, and egrine-felsites. It is worthy of note that the more basic varieties (diorites) are associated with the fucoïd-beds and overlying dolomites, while the more acid types appear in the quartzites.

The clearest evidence can be adduced that these intrusive rocks were introduced and distributed locally before the beginning of the post-Cambrian movements. The field-work has shown that they occupy their respective horizons in the folded and piled-up Cambrian strata west of the Glencoul and Ben More thrusts, in the displaced masses overlying these great disruption planes, and again close to the Moine thrust. (Sheets 107 and 101, one-inch) The sills, as well as the strata which they traverse, have been truncated by the major and minor lines of displacement, and in certain cases the intrusive sheets become schistose, the planes of foliation being parallel to those produced by the post-Cambrian movements. As an instance of the wide distribution of the sills that lie on certain horizons, it may be mentioned that those in the displaced basal quartzites can be traced from the south end of the Breabag range north to Gleann Dubh, a distance of twelve miles, and from the head of the River Cassley to Cnoc-an-Droighinn, about seven miles.

The occurrence of borolanite in the form of a thin intrusive sheet is extremely rare, only one instance having been recorded, which occurs in the thrust Eilean Dubh limestone, about half a mile E.N.E. of the village of Elphin.

Special allusion may here be made to the sheet of igneous material which, covering about three square miles of ground near Kinlochailsh and east of Sgonnan Mor in the Oykel valley, is associated with the rocks that overlie the Ben More thrust-plane. The evidence in the field leads to the conclusion that this mass has been brought into conjunction with the

displaced Lewisian gneiss and Cambrian quartzites by means of a thrust. Along its eastern margin, for part of the distance, it is in contact with the fucoïd-beds and Loch Ailsh marble, and over the remaining portion it is truncated by the Moine-thrust. It consists mainly of a syenite, a typical specimen of which shows under the microscope much micro-perthite and carbonates after a Ferro-magnesian mineral, possibly augite and iron-ores. The rock is closely related to the Loch Borrolan mass. In Allt Creag na Fearn, a stream draining the south-east slope of Sgonnan Mor, basic patches which appear in the syenite show the modifications which take place within the mass. To illustrate the gradation of the igneous material, specimens of one of these knots were examined under the microscope, when the core was found to consist of a dark massive rock containing pale-green pyroxene, greenish biotite, and a little colourless alkali felspar. The rock surrounding the core is coarse-grained and massive, and is composed of micro-perthite, oligoclase, green augite, and biotite, with sphene and apatite as accessories. Dr. Teall terms , the latter an augite-biotite-syenite, which has affinities with the augite syenites of the Christiania district. It is evident, therefore, that syenites of the type of the Cnoc-na-Sroine mass must have extended far to the east of their present limits, as the Loch Ailsh sheet has been driven westwards with Lewisian gneiss, Torridon Sandstone, and Cambrian strata by the Ben More thrust.

Along its eastern margin, where the igneous mass presents a basic phase, being a hornblendite with pyroxene, merging in places into an augite-biotite-diorite, it comes in contact with the fucoïd-beds and dolomite, and greatly affects them. The fucoïd-beds become there a brecciated hornfels, and pass into a rock composed of oligoclase, carbonates, biotite, hornblende, and possibly quartz. The overlying dolomite is changed into an opicalcite, and the isolated patches in the basic intrusion contain green biotite, diopside, and other contact minerals.

The dykes associated with this outbreak of igneous activity in the west of Sutherland and Ross are comparatively rare. Close by the western margin of the Loch Ailsh sheet, in a burn a quarter of a mile north of the top of Sgonnan Mor, and in a crag west of Loch Coire na Meidhe on the west face of that mountain, two examples of orthophyre occur, which Dr. Teall regards as the dyke phase of the syenite magma.

Again, a dyke of the Canisp porphyrite type, showing spherulitic structure. pierces both divisions of the quartzite on the south side of that hill, and has been traced at intervals across the Lewisian gneiss plateau by Lochinver Bridge to the promontory south of Achmelvich Bay.

Of special importance are the dykes of borolanite referred to by Dr. Teall (Chapter 30) which traverse the Torridon Sandstone in the Coigach district. The best examples of these appear on the west side of the peninsula at Camas Eilean Ghlais, in Rhu More Coigach, about three-quarters of a mile north of Reiff. The largest of them, which is from 25 to 30 feet wide, may be followed from a point 300 yards east of the house down to the shore of the bay. Its direction is about 10° north of west, and it is apparently shifted by N.N.E. faults. Another of the same type, with a parallel course, occurs about 125 yards to the north, and though only about 15 feet wide sends out three small branches. The felspathic matrix of this intrusion shows marked spherulitic structure.

iii. Possible volcanic vent connected with the Assynt Sills

By B. N. Peach

Although, as above stated, all the crystalline igneous rocks of Assynt are of intrusive origin and do not of themselves definitely prove that their intrusion was accompanied by any actual volcanic eruption of material to the surface, their behaviour as sills and dykes affords ground for the belief that they may not improbably have been attended with the opening of one or more volcanic vents. The only evidence of such a possible escape of material to the surface during the epoch of the sills has been detected in the bed of the River Oyke at a point about three miles above Loch Ailsh. The stream when low there exposes the two uppermost sub-divisions of the Cambrian quartzite, together with a small outlier of the overlying fucoïd-shales. The quartzites are traversed along their bedding-planes by two sills of hornblende porphyrite or vogesite resembling those intercalated in the Cambrian rocks near Inchnadamff. All these rocks, together with a portion of the Lewisian gneiss on which they rest, have been brought into their present position upon a minor thrust-plane, and have been truncated above by the great Ben More thrust, which has here carried forward the Lewisian gneiss, together with the overlying unconformable Torridonian and Cambrian strata involved with it. At the exact point of the river-bed just referred to, as shown in the accompanying plan (Figure 19), drawn approximately to scale, the hard

"piped" quartzite is pierced by a mass of breccia 22 yards long by 15 yards wide, which is almost entirely composed of limestone or dolomite fragments belonging chiefly to the Eilean Dubh group. The breccia is arranged in layers of coarser and finer texture, dipping steeply towards the edges of the hole in which the breccia lies. The walls of this cavity or pipe are clean cut and practically vertical. A sill of hornblende porphyrite lies between the bedding-planes of the quartzite, which here dip: towards the north and east at angles of from 15° to 20°. This sill where it reaches the breccia sends tongues into it. The molten material has also risen in places between the breccia and the vertical walls of quartzite that form the edge of the pipe. Moreover, it has flowed in between fragments of the breccia and floated them off, so that they are now found totally enveloped in it. A large mass of the "pipe-rock" has been isolated by the porphyrite, which is often vesicular and slaggy. The limestone-breccia has here been converted into a marble, the interstitial fine-grained material being affected as well as the enclosed blocks of limestone. There has likewise been a production of metamorphic magnesian minerals, indicating that some of the blocks were dolomitic at the time of the igneous intrusion.

As the vosgesite and porphyrite sills have been shown to have been intruded prior to the period of great earth-movements, the materials of the breccia must have fallen into this hole in the pipe-rock from above and from a height of more than 200 feet, because the base of the Eilean Dubh dolomite is more than that distance above the top of the pipe-rock. The formation and infilling of this orifice took place before the intrusion of the sills, and probably long anterior to the time of the great stresses in the terrestrial crust which produced the thrust-planes. The appearances here observable afford plausible ground for believing that this orifice in the quartzite was a true volcanic vent, whence only gases may have escaped, and which was filled up by the descent of fragments from the walls of limestone above.

II Region to the north of Assynt

By C. T. Clough.

The sills so well developed in Assynt continue for some distance to the north of that district. In the thrust area between Loch More and Beinn Uidhe (Sheets 107, 108), besides the intrusions in the granulitic schist series, many others have been noted in the Cambrian rocks and the Lewisian gneiss. These may be divided into two classes according as they are older or later than the thrusts. Only two of the observed examples are likely to belong to the younger class. These are two thin dykes of mica-trap which occur in the Cambrian limestone in the valley a little above Loch na Creige Duibhe (north of Glendhu). They are both much decomposed, but not sheared or crushed. Of the older series, many representatives have been detected. None of them occur quite so far north as the mica-traps near Loch na Creige Duibhe. The most northerly example at present known is a dioritic rock ([S2735](#)) [NC 31 29], which is doubtless an extension of the Assynt sills. It occurs in the Grudie limestone about a third of a mile slightly west of south of Beinn Lice, on the south side of Loch More. The exposure of it is very small, but the intrusion probably takes the form of a thin sill. In the extensive quartzite area which lies to the west, and which has presumably been pushed forward in the same thrust, no igneous intrusions have been observed.

A thin intrusion probably occurs near the base of the quartzite about half a mile slightly west of south of the Ordnance Station on Beinn a' Bhùtha (north-east of Glendhu), but, as the section was not understood when it was examined, we are unable to speak with confidence about it. A little further north, however, both on the south side of Gleann Dubh (Sheet 107) and near the foot of Loch Strath nan Asinnteach, thin intrusive sills, from one or two up to ten or twelve feet thick, are usually to be observed either at the base of the quartzite or only a few feet above the base, and also other thin sills at higher horizons in the quartzite, as in Assynt. The sill at the base of the quartzite is exposed about three-quarters of a mile slightly east of south of Glendhu, and in various places near the little loch rather more than a mile south-east of Glendhu. Possibly it may continue to the north-east side of Glen Coul, but, as it decomposes more headily than the adjacent rocks, it is not often seen. Sills appear on the same horizon further south — for instance, near the north end of Loch nan Caorach and about 700 yards S.S.W. and 700 yards south of the south end of this loch; but in an intermediate area, in Glencoul, and also near the foot of Loch Strath nan Asinnteach (about two miles east of Glendhu), the intrusive rock has generally found a place not at, but a little distance above, the base of the quartzite.

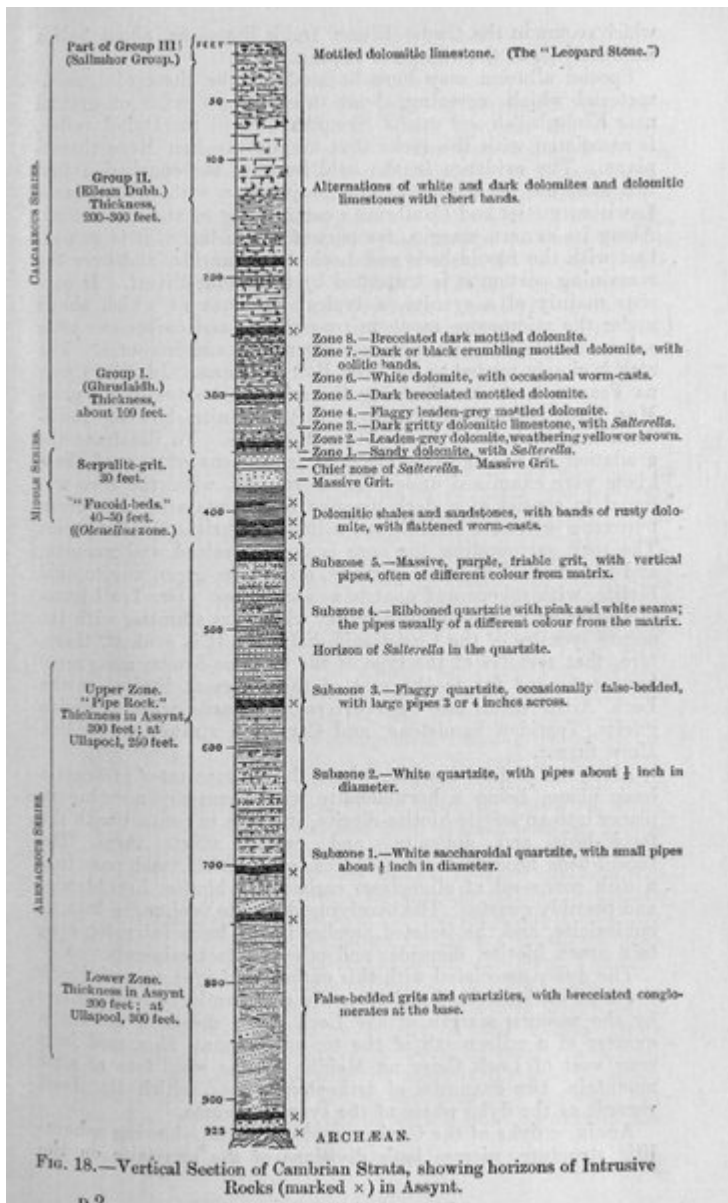
The other horizons in which sills are most commonly found here are a little below the base and a little below the top of the pipe-rock. In the former position are the sills which appear in several places near the foot of Loch Strath nan

Asinnteach, on both sides of Glen Coul, and about half a mile west and 700 yards slightly west of south of the south end of Loch nan Caorach (Sheet 107). On the higher horizon are the sills about a mile and 700 yards south-east of Glendhu, half a mile N.N.W. of the north end of Loch nan Caorach, the east side of Loch nan Caorach, half a mile west and two-thirds of a mile south of the south end of Loch nan Caorach. At the last-mentioned place the sill is sometimes as much as 40 or 50 yards wide, with a high dip. This unusual width does not seem due to repetition by thrusts. Some other sills in the basal quartzite in the same neighbourhood are also unusually wide.

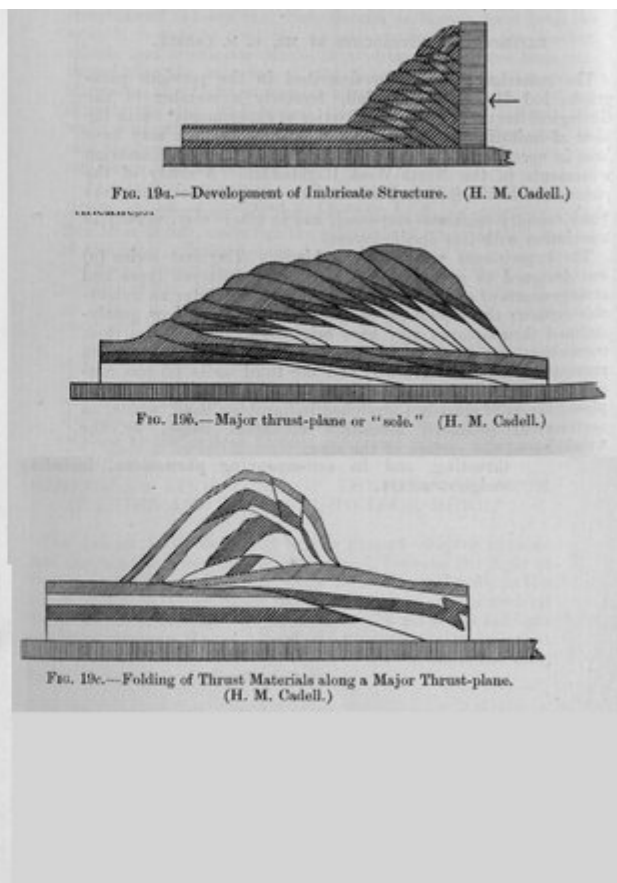
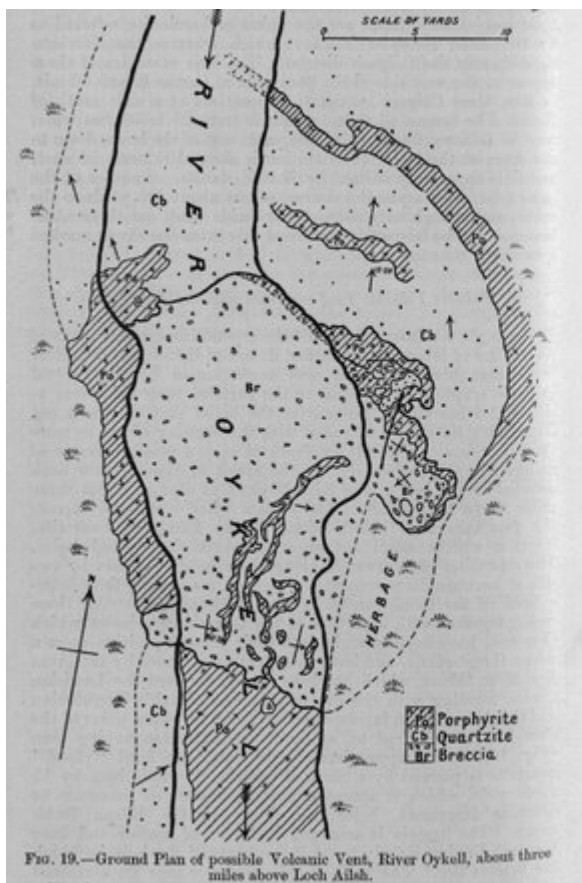
In this district no sills have been noticed within the fucoidshales. A sill has invaded the serpulite-grit a third of a mile S.S.E. and about half a mile south-east of the south end of Loch nan Caorach. Besides the intrusion already mentioned as occurring in the Grudie limestone near Beinn Lice, sills appear in the same limestone on the east and south-east sides of Loch nan Caorach.

In the unthrust area between Loch Inchard and Loch a' Chaim Bhàin (Sheets 107 and 113), the only intrusions that seem likely to be of post-Cambrian age are (1) some thin sheets of mica diabase near Rudh' an Tiompain, on the coast south-west of Loch Laxford; (2) three or four north-east-south-west dykes of olivine diabase on the coast near Loch na Claise Iuchairich (two and a half miles south-west of Rhiconich), and a thin sheet of chocolate-coloured porphyrite on the coast about a mile west of Glendhu. None of these have much resemblance to the intrusions which, in Assynt and elsewhere, are affected by post-Cambrian thrusts.

An intrusion which lies within the Lewisian gneiss on the west side of the quartzite half a mile west of the south end of Loch nan Caorach (Sheet 107) seems to be connected with the sill at the base of the quartzite, and the sill about three-quarters of a mile slightly east of south of Glendhu appears at one place to run off into the gneiss. In the glen south-east of Loch Beag, of Loch Glencoul (Sheet 107), are many intrusions, which, though confined to the gneiss area, present much the same Ethological character as the sills in the Cambrian rocks. They have been partly sheared. The best exposures of them may be seen on the south-west side of the glen from about half a mile west to a mile and a half S.S.E. of the head of the loch. They often form rather conspicuous green ledges and recesses in scars. One of them was traced, with an interruption, in a north-westerly direction for about a mile. The others also have generally nearly the same trend, though liable to rather sudden twists. Sometimes two of them unite at a considerable angle. Perhaps for the most part they may be regarded as low-angled sheets. They often cut the gneiss and the Scourie dykes, and even where the strike of the gneiss is not north-west this continues still to be their prevalent direction.



(Figure 18) Vertical Section of Cambrian Strata, showing horizons of Intrusive Rocks (marked x) in Assynt.



(Figure 19) Ground Plan of possible Volcanic Vent, River Oyke, about three miles above Loch Ailsh. Figure 19a. Development of imbricate structure (H. M. Cadell). Figure 19b Major thrust plane or sole (H. M. Cadell). Figure 19c. Folding of thrust materials along major thrust-plane. (H. M. Cadell).