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No. XXII.—A New Occurrence of Picrite in the Ballantrae District and its Associated Rocks.

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I. *Introduction.*

The rocks described in this paper occur on Littleton Hill, 3½ miles N.E. of Ballantrae. This hill is the western prolongation of Balhamie Hill, where the famous bronzite-serpentine is obtained. On Sh. 7 of the Geological Survey of Scotland Littleton Hill is mapped as four small intrusions of basic rocks piercing the great mass of serpentine stretching from the shore N. of Ballantrae in a north-easterly direction to Millenderdale. The igneous rocks of this district are regarded as the plutonic phase of the Arenig vulcanicity. Their débris is conspicuous in the conglomerates and grits of the immediately succeeding Llandeilo and Caradoc beds.

The field relations of the "intrusions" of Littleton Hill are very obscure. Small isolated exposures occur at several places on the hill, rarely presenting continuous sections of more than 10-15 feet in length; and the junction with serpentine is not seen. The four small masses mapped by the Geological Survey form distinct knolls, diversifying the otherwise rather featureless contours of the hill.

These exposures consist of a fine grained grey to black rock, occasionally sparingly porphyritic with felspar, which in hand specimens would be called dolerite or basalt. A more or less parallel, banded or schistose structure, is seen on the north face of the hill, near the 500′ contour; and about 200 yards N.W. of the summit,[1] there occurs a small exposure of a dense black rock, very tough and resistant to the hammer. A fresh fracture shows glistening flakes of dark mica. On sectioning, this rock is seen to be composed essentially of hornblende and biotite, with subordinate olivine, felspar, and iron ores. Petrographically it is a hornblende-mica-picrite. Its relations to the less basic rocks of the hill cannot be traced in the field, but the petrographical evidence renders it probable that it is a local ultrabasic modification of these rocks.

II. *Microscopic Characters of the Picrite.*

The minerals present are hornblende, biotite, alteration products of olivine and felspar, magnetite, and apatite, in order of abundance.

The hornblende occurs mainly in dense aggregates of small granules of a deep reddish brown colour. Occasionally there are larger crystals of a pale, bleached yellow tint, crowded with magnetite dust, and passing on the margins into the granulitic condition, which is free from separated magnetite. The colour of the granulitic hornblende is therefore probably due to the absorption of magnetite. The pleochroism is as follows:—X, pale yellow; Y, brownish green; Z, deep reddish brown.

The large bleached plates of hornblende are sometimes seen in polarised light to break up into small, vaguely-outlined, rounded areas, which seem to foreshadow the granulitic condition.

Almost as abundant as hornblende is biotite of a peculiar and intense pleochroism. The scheme is as follows:—X, very pale yellow; Y and Z, reddish brown to a peculiar purplish red (beetroot colour). From the optical tests possible in such small sections it appears that the mineral is an anomite, similar to the deep red anomites peculiar to some soda-rich rocks.

The hornblende and mica each tend to aggregate in certain areas, so that the coloured mineral in one field may be almost entirely hornblende, in another mica. There is a tendency

[1] *See* Ord. Survey, 6-in. quarter sheet, Ayrshire, 61 S.W.

for the large plates of hornblende to enclose the small flakes of biotite.

Some small, rounded areas are occupied by a chloritic mineral, highly pleochroic in shades of yellow and green. It frequently has a strong cleavage and bent lamellæ, and is probably a ferriferous variety of chlorite. There is difficulty in regarding it as derived from hornblende or mica, as both are perfectly fresh in the rock. It probably represents a vanished pyroxene.

Olivine is represented by roughly hexagonal areas of spongy iron ore surrounded and enclosed in a greenish serpentinous substance. Magnetite occurs primarily in small ragged crystals; also as dust, and as a grating-like skeletal aggregate in the interior of the larger plates of hornblende.

Finally, there are some areas of a whitish or yellowish semi-opaque, apparently crypto-crystalline substance, which gives rather bright polarisation tints. These are thoroughly epidotised felspars, as in a few places the mineral clears a little, so that albite twinning, in one case crossed by pericline, is still to be seen. They contain small, dark, indeterminate inclusions, at one place arranged in a swirl or eddy-shaped form.

The specific gravity of this rock is 3·03. It differs somewhat from other picrites in the predominance of hornblende and biotite over olivine and pyroxene. The large, bleached plates of hornblende above described have probably been derived from original pyroxene.

III. *The Granulitic Hornblende Diorites.*

These are dense, fine-grained rocks consisting of a granulitic aggregate of hornblende, felspar, mica, and perhaps quartz, with a little magnetite.

In a specimen from above the 500′ contour, a little W. of the line of shooting-butts on the south face of the hill,[2] the hornblende and felspar are aggregated into little elongated areas, which have a parallel arrangement. The hornblende shows precisely the same characters as the granulitic hornblende

[2] *cf.* Silurian Rocks of Britain. Vol. i. Scotland (1899). *Mem. Geol. Sur.*, p. 477-479.

of the picrite, but is not found in large plates. The felspar is clear, fresh, granular, and, for the most part, untwinned. The majority of the granules have a higher refractive index than Canada balsam, as determined by the Becke method, but a few have a lower index. The latter are probably orthoclase or albite. The twinning, when visible, is too minute to give satisfactory extinction determinations. Quartz may occur among the water-clear granules of the ground mass. Occasionally the felspars contain numerous small, yellowish-green granules of epidote. Biotite occurs very sparsely as compared with the picrite. Magnetite occurs in minute specks. The specific gravity of the rock is 2·94.

On the S.W. slope of Littleton Hill, about ½ mile north of Bougang Farmhouse,[3] occurs a slightly different variety. It is composed of granulitic hornblende and plagioclase, as in the rock described above, but there are also phenocrysts of plagioclase and pyroxene. The granulitic felspar is water-clear, usually untwinned, but occasionally with fine, closely-set twin lamellæ, giving a maximum extinction angle of 15 degs. The refractive index is higher than that of Canada balsam, and the mineral therefore belongs to andesine.

The phenocrysts of plagioclase range up to 3 mm. in diameter. They are sometimes bent, or even broken across. The twin lamellæ are also frequently curved, and, locally, a secondary set of twinning planes have been developed. The crystals are usually quite fresh, and only slightly zonal—occasionally, however, they are somewhat epidotised. In one or two cases they have been thoroughly granulitised, and nearly all the phenocrysts show strings and patches of granulitic felspar. The maximum extinction angle in symmetrically cut albite-twinned crystals is 31 degs., corresponding to a composition Ab_2An_3—a medium labradorite.

In one part of the slide there are two idiomorphic phenocrysts of pyroxene, the larger of which is 1·3 mm. in diameter. The latter is nearly a basal section, showing (110) well, but (010) and (100) very poorly developed. It is penetrated by little strings of granulitic hornblende, and is bordered by a zone of these granules, especially where it abuts on a felspar. A closely-set diallagic striation parallel to a pinacoid is still to

[3] *cf.* Silurian Rocks of Britain. Vol. i. Scotland (1899). *Mem. Geol. Sur.*, p. 479.

be seen, and there is a distinct bronzy sheen if the mineral be viewed in reflected light. Reddish brown biotite occurs in moderate amount, and magnetite in small grains sparsely but uniformly distributed. The specific gravity of the rock is 2·85.

IV. *Conclusions.*

The granulitic hornblende-felspar rocks of Littleton Hill have been briefly described by Dr. Teall in the Geological Survey Memoir on the Silurian Rocks of Scotland (1899).[4] He considers the granulitic structure entirely secondary, and makes the guarded suggestion that it is due to contact metamorphism. He remarks, "If they represent an altered phase of the porphyritic diabase lavas, then the matrix must have been entirely recrystallised." In the last volume of these *Transactions* Mr. F. Mort[5] has described the rocks of Littleton Hill, especially from the point of view of their passage into true schist. He obtained a true olivine dolerite near the summit, still retaining ophitic structure between augite and felspars, and showed by a graduated series of specimens that the augite breaks up into the granulitic brown hornblende, the ophitic structure disappears, and the rock finally takes on the structure of a true hornblende schist. Only one of my own slides shows any recognisable pyroxene, and that in very small quantity. I have therefore called the rocks diorites, although they have certainly been derived from pyroxene-plagioclase rocks. Mr. Mort describes and figures phenocrysts of fresh olivine with well-marked reaction rims in the rock from the S.W. flank of Littleton Hill.

These rocks bear little resemblance to the ordinary types of basic igneous intrusions. Many features connected with them suggest that they are the products of metamorphism. The granulitic structure, the freshness of the constituents, and the peculiar nature of the coloured minerals suggest that the agent involved is heat. Many instances of the contact metamorphism of igneous rocks have now been described. The augite-andesites on the west side of the Shap granite, according to Mr. Harker,[6] have been entirely recrystallised by contact-metamorphism, the ground mass becoming a fine textured

[4] Pp. 478-480.

[5] Vol. xiii. (1908), pt. ii., pp. 187-190. I am indebted to Mr. Mort for the kind loan of his slides.

[6] *Q.J.G.S.* Vol. xlvii. (1891), p. 296; vol. xlix. (1893), p. 362.

mosaic of clear granules, whilst the felspar phenocrysts have been replaced by granules of new felspar substance. Diabases metamorphosed by a granitic intrusion in Cornwall had had their augites altered to a greenish hornblende, which in the neighbourhood of iron ore is sometimes brown.[7] This is paralleled by the granulitic reddish-brown hornblende of the picrite and diorite described in this paper, which clearly owes its colour to the resorption of magnetite dust. Although these rocks have undergone some degree of strain, as indicated by bent lamellæ, secondary twinning, and faulted crystals among the plagioclase phenocrysts, yet the survival of olivine and the retention of ophitic structure, as described by Mr. Mort, indicate that this dynamic action cannot have been severe, and still less can the peculiar appearances in these rocks be ascribed to it.

Further examination of the rocks of Littleton Hill does not support the idea of their derivation from the porphyritic diabase lavas of this district. The presence of phenocrysts of plagioclase, olivine, and diallage, with traces of ophitic structure, indicates that their true affinities are with rocks similar to the intrusive dolerites and gabbros so common in the Ballantrae district. The augite has been transformed, first into a pale, uralitic hornblende, then by further metamorphism and resorption of magnetite into the granulitic red-brown variety. The comparative scarcity of magnetite may perhaps be explained in this way. The felspar has been recrystallised with the formation of a water-clear mosaic. The survival of olivine is a puzzling phenomenon. I have not been able to obtain any data as to the behaviour of olivine during contact-metamorphism. There is no reason, however, to believe that a mineral of the simple composition of olivine would be broken up. Perhaps the reaction rims described by Mr. Mort represent the utmost effect of contact-metamorphism on this mineral.

The local modification into a picrite on the north side of the hill is explicable on the hypothesis that the original rock was a basic intrusion similar to those common in the district, for these tend to pass into ultrabasic types.[8] The diabase-porphyrite lavas, on the other hand, are essentially felspathic rocks of very uniform composition, with only a small content

[7] Allport. *Q.J.G.S.*, vol. xxxii. (1876), p. 420.

[8] *Mem.* on Silurian Rocks of Scotland (1899), p. 469-470.

of femic minerals. Moreover, they are exceedingly amygdaloidal, and Mr. Harker has shown, in the case of basic lavas metamorphosed by plutonic masses in Skye, that the amygdaloidal structure is very persistent, the amygdules appearing as rounded, eye-like structures even when the rock has been entirely recrystallised.[9] No such appearances have been detected in the rocks of Littleton Hill.

If the foregoing inferences be sound, then, instead of being intrusive, the rocks of Littleton Hill must be regarded as relics of an older mass of dolerite or gabbro enveloped by the later serpentine. The dynamic effects noted above may perhaps be regarded as due to the disruptive action of the serpentine intrusion. Many of the dolerites and gabbros of the district are certainly later than the serpentine, but these do not show the abnormal appearances of the Littleton Hill rocks. Rocks having the same characters have been recorded at several other localities in this district,[10] and it is permissible to assume that they have had a similar origin.

EXPLANATION OF PLATE.

Fig. 1.—Granulitic hornblende-mica diorite, Crags near shooting-butts, S. side of Littleton Hill. Ord. light, × 24.

A granulitic aggregate of brown hornblende and biotite, with water-clear plagioclase. The coloured minerals are not distinguishable from each other in the photograph. The field shows the separation of hornblende and biotite into long narrow streaks, alternating with similar streaks of plagioclase. This is the beginning of true schistose structure.

Fig. 2.—Granulitic hornblende-mica diorite, porphyritic variety, S.W. flank of Littleton Hill. Ord. light, × 24.

Shows phenocrysts of diallagic pyroxene and plagioclase in groundmass consisting of brown hornblende and biotite, with water-clear plagioclase. The pyroxene shows very close lamellation parallel to one of the pinacoids, and is surrounded by a zone of brown hornblende, by which it is also penetrated in streaks and patches. The porphyritic felspar is broken up into a granular aggregate, and is also penetrated by strings and patches of hornblende.

[9] Tert. Ign. Rocks of Skye (1904), pp. 52, 115, 116.

[10] *Mem.* on Silurian Rocks of Scotland (1899), pp. 477-479; 482.

Fig. 3.—Same slide as Fig. 2, but different field. Polarised light, × 24.
Shows a broken crystal of plagioclase in a granulitic groundmass of hornblende, mica, and plagioclase.

Fig. 4.—Hornblende-mica picrite, N. side of Littleton Hill. Ord. light, × 24.
The field shown consists almost entirely of brown hornblende and mica. One or two of the larger plates of pale bleached hornblende are seen in the top left-hand corner of the field. Olivine, represented by serpentinous alteration products, is seen as clouded areas at the bottom left-hand and top right-hand corners. Decomposed felspar occurs on the extreme left of the field.

Fig. 1.

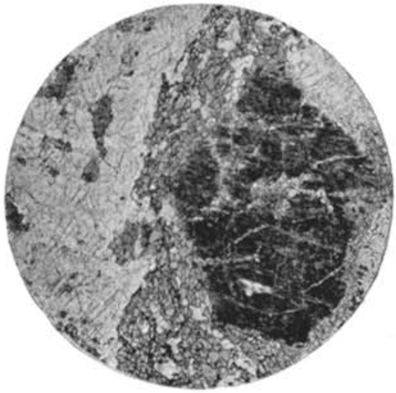

Fig. 2.

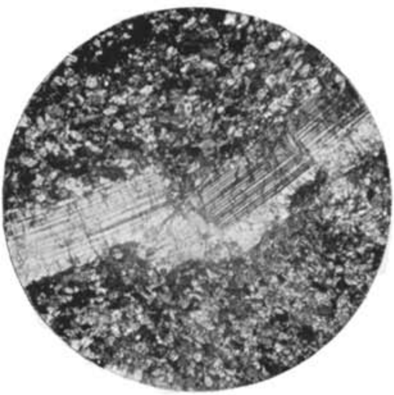

Fig. 3.

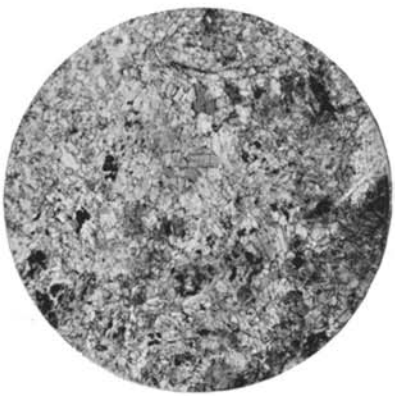

Fig. 4.

Micro-photographs of Rocks from the Ballantrae District.