On a peculiar variety of Hornblende from Mynydd Mawr, Carnarvonshire.

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MYNYDD MAWR is a conspicuous hill with a craggy face towards the north, and a well-marked corrie (Cwm Du) on that side. It lies to the south-east of Moel Tryfan and the west of Llyn Cwellyn (Carnarvonshire). On the Geological Survey map it is represented as a somewhat rounded oblong patch of felstone, about $1\frac{3}{8}$ mile from east to west, and a mile, or a little more, from north to south, intrusive in Lower Silurian (Ordovician) rocks, which are probably Arenig. I passed some years since to the north of the above-named face, and collected specimens from erratics which were plentifully strewn over the lower land. On microscopic examination I found them to contain a very puzzling and remarkable mineral which I have long intended to describe, but kept deferring this in hope of being able to revisit the place to obtain more specimens for examination, and by taking these from rock *in situ*, to prevent any question arising as to the true source of the rock.

But, as Mr. G. A. J. Cole,[2] who visited the locality last spring, has kindly allowed me to examine his specimens and use his notes, I need no longer delay, though the former happen not to be quite so coarse in grain as my own. He collected from a hollow in the eastern end of the mass, between the "dome-shaped" summit and Llyn Cwellyn. He states that so far as he could see, the material of the hill is uniform in character, without intersecting dykes. His specimens are: (1.) A darkish indurated slaty rock, weathering to a buff colour, in contact with the south-east margin of the igneous mass. This has the usual appearance of a "baked" shale or slate, proving, were it necessary, that the felstone is intrusive, but not indicative of very considerable alteration. (2.) Felstone, a contact specimen from the same locality: this is a dull olive-grey flinty rock, which in weathering assumes a tint similar to the last-named specimen. (3.) "From

[1] After this paper was written, but a few days before it was read, an interesting article, by Mr. A. Harker, appeared in the *Geol. Mag.* for May 1888. As, however, the two papers treat the subject from somewhat different aspects, I have left unaltered that part of my own which is common with his.

[2] The unusual quantity of snow impeded him in his work, and, unfortunately, a letter which I had written to him failed to reach him till too late.

near the eastern margin" : a more granular slightly greyer rock, showing a few small quartz grains, but without dark specks. (4.) "Felstone above waterfall" (*i.e.* higher up the hill) : a grey rock with numerous very dark specks, some little flakes of white mica, a few grains of quartz, and crystals of felspar (approaching the character of my specimens). A joint face is "glazed" with very minute films of silvery mica (see below). (5.) A similar but perhaps a shade more granular rock from "near the summit."

As my own specimens have a slightly more coarsely crystalline character than any of these, I presume they came from the lower part of the northern escarpment, and so represent the character of the mass at a greater distance from the original surface. They are of a light-grey colour, with a faintly mottled aspect; the tints varying from a brownish to a bluish-grey —but in both cases pale. The rock in weathering becomes a very little browner. In the matrix are numerous small spots of a bluish-black colour, rounded or slightly irregular in outline; these have occasionally a fairly distinct linear arrangement. The largest are about ·08″ in diameter, but this is an exceptional size,[1] about ·05″ diameter being much more common. Small grains of quartz and crystals of felspar are occasionally visible.

The rock, as one would expect from its appearance, is in good preservation. On examination with crossed nicols it exhibits a devitrified structure of a common type; rounded or slightly irregularly outlined granules of quartz being separated out from a felspathic mineral, which only shows incipient decomposition. In this ground-mass are numerous belonites, often about ·002″ long, almost colourless, but perhaps of a slight yellowish tint. It is difficult to make sure of their extinction angle, but it is certainly small, though sometimes appreciable. As the slide is rotated the mineral becomes of a rather bright golden colour. Probably it is a variety of hornblende.[2] Occasional grains of quartz occur and crystalline grains of felspar, often from about ·03″ to ·05″ in diameter, the edges being commonly ragged: both of early consolidation. As the oscillatory twinning characteristic of plagioclase is very rare, if present at all in the felspar, and two or three distinctly show twinning on the Carlsbad type, I regard the mineral as orthoclase. It contains not uncommonly hair-like microlites. There are a few well-defined oblong flakes of white mica,[3] about ·08″ or ·04″ long, also belonging to an early stage of consolidation. The mineral of chief interest is that occurring in dark patches. In external

[1] Mr. Harker speaks of larger specimens, about a quarter of an inch long.

[2] I do not think it can be tourmaline, as suggested by Mr. Harker.

[3] The acicular mineral described above is also included, so it must belong to a very early stage of consolidation.

orm these are very irregular, often being groups of aggregated granules rather than single crystals; still these granules usually exhibit a fairly defined crystalline continuity, and we occasionally find a tolerably distinct crystalline grain; the granules are separated, and the more crystalline grains to some extent intercepted by small granules apparently of quartz. The mineral, in short, presents an appearance which is common in cases of contact metamorphism, where some mineral, such as andalusite, garnet or ottrelite, has been developed in a matrix, where some of the constituents have still retained their individuality. Thus the mineral commonly appears as a ragged looking patch, sometimes a little elongated, sometimes roundish.

With transmitted light the colour varies from a dull yellowish or brownish green to a deep indigo-blue, sometimes almost a blue-black.[1] The mode of occurrence makes it difficult to ascertain the position of the crystals, but occasionally the external angles of a hornblende prism or the characteristic cleavages parallel with ∞P may be observed in a grain, though less frequently than the lines of cleavage indicating a section in the zone ∞P. This is a little singular, for two of my sections were intentionally cut at right angles one to another. The colour seems to depend not wholly on position; recognisable transverse sections indeed are usually, if not always, of the greenish tint; the longitudinal sometimes brownish-green, but more commonly indigo-blue, not seldom so deep that a grain is practically opaque. With polarised light transverse sections give a yellowish-green with a tinge of brown with vibrations parallel with a, a deep indigo-blue with vibrations parallel with b. In longitudinal sections indigo-blue for vibrations parallel with c, pale yellow-green or straw colour when perpendicular to it. With crossed nicols the colours are, if visible, rich but not brilliant. The extinction angle, owing to the peculiar habit of the mineral, is difficult to observe, but is not large, usually I think with a smaller range than for normal hornblende. In its general appearance and optical character this mineral exactly agrees with one which I observed some years since in a granitoid rock from Socotra, which is briefly described and is figured in *Phil. Trans.* 1888, p. 283, Plate VII. One section in the slide from that rock was transverse, one or two others longitudinal. The former showed a distinct hornblende cleavage, but the others seem to give a straight extinction. Obviously the mineral exactly resembled hornblende, but I had never seen such an

[1] The two, the green and the blue-black (commoner), are so closely associated and similar in all but colour that I feel sure they must be nearly related. Mr. Harker describes the latter as tourmaline. Formerly I held the same opinion, but am now convinced that the rock does not contain this mineral, but two varieties of hornblende.

extraordinary dichroism and was further perplexed by the apparently straight extinction, so that I suggested that the mineral might be a pseudomorph of tourmaline after hornblende, though I had my doubts as to whether the cleavages would then remain so distinct. But about a year since, Prof. Sauer kindly wrote to me that he had met with a similar mineral which he had been able to isolate and analyse, and had proved to be arfvedsonite; and I am now convinced, after again examining the slide, that the mineral is really a very singular variety of hornblende. This mineral exactly corresponds with that in the Mynydd Mawr rock, so that the latter must also be arfvedsonite.[1]

It would be desirable to have this identification confirmed by a chemical analysis, but to obtain satisfactory materials for one more than qualitative will be a difficult matter, owing to the minute inclusions mentioned above, which will not be easily eliminated. I have therefore drawn attention to the occurrence of this interesting mineral so that any one who visits the spot may search carefully for the most coarse grained specimens, for I much doubt whether my own would yield satisfactory results.

The felstone at the contact (No. 2 of Mr. Cole's specimens) contains numerous minute microliths, apparently of hornblende, sometimes aggregated, and these exhibit a rather strong dichroism, considering their size; the ground-mass has a minute devitrified structure, but there is else nothing calling for special remark. It is like many other specimens of very compact chert-like felstones in my collection. Specimen (4) agrees with my own in all important respects, except that the belonites, the patches of "arfvedsonite," and the devitrification structure are all on a slightly smaller scale; a few grains of epidote are present occasionally, associated with arfvedsonite. It is therefore certain that the blocks from which I collected came from the same *massif*—a point, however, on which I never had the slightest doubt in my own mind. A grain in this specimen shows characteristic hornblende cleavage and the "blue-black" dichroism.

The published analyses of arfvedsonite show it to be a hornblende with some alumina and a considerable percentage of soda, poor in magnesia but rich in iron. From the account given above it is almost certain that the mineral is of secondary origin, and was formed subsequently to the devitrification of the rock. I think it probable that there was originally an augite or hornblende present, rich in iron, or perhaps including, as is often the case, granules of iron-oxide—that this obtained some soda and alumina

[1] See also Rosenbusch, *Mikros. Physiog. Massig. Gestein.* p. 312. A slide, however, cut from a crystal of Norwegian arfvedsonite, shown me by Prof Judd, does not show this intense blue colour.

from adjacent felspathic granules, and thus the present mineral was produced. It might be urged that the porphyritic felspars are orthoclase, but there are occasionally instances where this is the case, and yet the matrix contains chiefly microliths of a soda-felspar or is a soda-glass, so that I do not think this a serious difficulty. It is, however, quite possible that (as the rock is so well preserved and the devitrified structure is much more marked in the inner part of the mass) the rock devitrified in cooling, and then the formation of the arfvedsonite, though in a certain sense secondary, may have taken place at a very early period of its history, after partial differentiation but anterior to perfect solidification.

The increase of coarseness in the devitrification structure seems to favour the idea that it was set up in cooling, while the abundance of belonites throughout suggests that the rock had once been a true glass; possibly, however, both these stages in structure may have been assumed before the mass finally cooled. The occurrence of the belonites in the crystals of felspar shows that they were formed at a very early period. Considering the size of the intrusive mass, one would have expected its structure to have been rather coarser.