On Occurrences of Riebeckite in Britain.

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IN the summer of 1890, in the company of Mr. L. W. Fulcher, I again visited Mynydd Mawr, on the west of the Snowdon area, in the hope of obtaining specimens of Riebeckite larger than those on which Mr. Harker[1] and Professor Bonney[2] based their observations in 1888, when they independently pointed out the occurrence of this mineral for the first time in the British Isles. Previous traverses of the dome-shaped mass had shown how uniform in structure and how minutely crystalline the rock of Mynydd Mawr was over all its surface; we accordingly examined the columnar cliffs on the north and west, paying especial attention to the great western hollow, where denudation allows one to stand almost in the centre of the intrusive neck. But even here we were somewhat disappointed, and our specimens are only slightly coarser in grain than those studied with such striking results by Professor Bonney.

In section, however, the blue colour of the amphibole is seen in these new specimens with greater clearness than heretofore. The streaky patches formed by the mineral are two to three millimetres across, and in one case, taken from a loose block fallen from the cliff, we have the remains of a single crystal at least two millimetres in length. The axis-colours, changing from the characteristic intense black-blue to a rich yellow-brown, are particularly striking in these large examples.

Though the groundmass of the "felsite" of Mynydd Mawr has undergone secondary devitrification, and at one time must have approached the glassy condition so prevalent in Wales among rocks of Bala age, yet abundant porphyritic crystals occur in these central masses. Orthoclase is predominant, with some quartz, which has in part developed with its proper outlines, as happens in so many rocks intermediate between granite and

[1] "On the Blue Hornblende of Mynydd Mawr." *Geol. Mag.*, 1888, p. 455.

[2] *Mineralogical Magazine*, Vol. VIII., pp. 103 and 169. For analysis of Riebeckite see *ibid.* p. 167.

the glassy rhyolites. The quartz granules of the groundmass, in their association with the duller felspathic areas, suggest the commencement of a micro-pegmatitic structure. Throughout this groundwork of material imperfectly differentiated and developed, the patches of soda-amphibole seem an appropriate and original constituent. Their mode of occurrence recalls the groups of streaky biotite characteristic of the spherulitic and micro-pegmatitic soda-eurites.

The development of all the minerals seems, however, to have been hurried, doubtless owing to the comparatively short time during which highly silicated lavas remain fluid. Hence the amphibole, while surrounding in places well formed crystals of felspar, and tending to produce an ophitic structure, has been interfered with by the development of quartz and felspar in the glassy groundmass round it, and has thus only rarely arrived at any recognisable crystalline form. But for the inclusions of idiomorphic orthoclase, which run into the amphibole from the surrounding groundmass, it might have been urged that these ophitic areas were relics of large crystals which had been eaten into on all sides by the glass.

In a prior consolidation, however, when the porphyritic crystals were produced, similar amphibole arose under conditions that would have rendered the rock granitic. For we find in one of the thin sections an interesting "glomeroporphyritic"[1] group, consisting of quartz, orthoclase, and the richly coloured riebeckite. The material is unfortunately insufficient to afford evidence of the order of succession of these minerals in the granitic consolidation. The quartz of this group has been corroded by the groundmass, and the riebeckite seems also to have suffered.

The evidence of these central specimens, if I read it rightly, is that the rock of Mynydd Mawr reached its present position, in what seems to be a volcanic neck more than a mile in diameter, as a soda-glass containing porphyritic crystals and groups of crystals; these were attacked as long as the mass remained fluid, but they suffered less than is common in actual lava flows. While consolidating as a pitchstone on its margins, where it abuts against the altered slates, the mass in its more central parts tended to become micro-pegmatitic, after the manner of the eurite of Cader Idris, but without spherulitic aggregation. At this stage the riebeckite developed, filling up interstices and forming in many places continuous ophitic crystals. The cause of its crystallisation at so late a stage is probably to be found in its easy fusibility, to which attention has

[1] Judd, *Quart. Journ. Geol. Soc.* Vol. XLII. (1886), p. 71.

been called by Mr. Harker.[1] With 35 per cent. or so of iron oxides, 10 per cent. of alkalies, and a striking deficiency of magnesia, riebeckite would remain far longer than ordinary amphiboles in the condition of a molten glass.

That Prof. Bonney has foreseen some of these conclusions, despite his view that the mineral is of secondary origin in the great mass of the rock, is clear from the concluding passages of his paper.[2]

While I was considering these specimens from Mynydd Mawr, I received from Mr. P. F. Kendall, F.G.S., of Stockport, a pebble of eurite from the drift of the North of England. Both Prof. Sollas, who kindly examined it, and myself were satisfied that the broad dark patches in the yellow groundmass of this rock represented a blue amphibole, and hence probably a variety rich in soda. Mr. Kendall had been independently struck with the same idea, and had consequently compared his specimens with the rock of Mynydd Mawr. He has allowed me to have sections prepared of two pebbles, one collected in the Isle of Man, the other, curiously enough, from Moel-y-Tryfan, close to the western face of Mynydd Mawr. But, apart from the presence of the interesting slate-blue amphibole, the rock has no close resemblance to any now exposed at Mynydd Mawr. Mr. Harker[3] has referred, however, to pebbles of the Mynydd Mawr rock in the drift of the neighbourhood; and it is quite possible that both these soda-eurites, from different sources, may have been brought together during the formation of the glacial beds. Suffice it that Mr. Kendall's specimens, as he himself points out, have more in common with one another, though from such different localities, than they have with the rock of Mynydd Mawr.

Thus in the specimen from the drift on Moel-y-Tryfan the structure is that of the coarser types of eurite. We have a beautifully developed micro-pegmatitic, but not spherulitic, groundmass; and, intimately associated with this, ophitic crystals of blue-green amphibole. At times the amphibole has developed soon after the separation of idiomorphic felspar, and has thus produced a patch in the rock from which quartz is locally excluded. In other places micro-pegmatitic growths of quartz and orthoclase have been filled in, and in part surrounded, by ophitic amphibole. This micro-pegmatite occurs in straggling patches, as in much of the well-known enstatite-diorite of Penmaenmawr; if we may regard these as

[1] *Geol. Mag.* 1888, p. 455.
[2] *Min. Mag.* Vol. VIII. p. 107.
[3] *Geol. Mag.* 1888, p. 224.

original products of consolidation, as I am inclined to do, areas remained between them in which less stable felspars were afterwards developed. These have decomposed to a dusky brown tint, leaving the micro-pegmatitic patches, together with the amphibole, remarkably fresh and clear. It would appear, indeed, as if the micro-pegmatite, and also the porphyritic crystals of quartz and orthoclase, represented a previous attempt at crystallisation during quiet conditions of consolidation; the material was, however, broken up and set in motion, and the subsequent devitrification of the interstitial glass has given us the dusky areas. The characteristic amphibole appears also in the latter, but in the form of minute rods and granules.

The porphyritic crystals of quartz contain brown glass-enclosures, often with bubbles, and bear very little resemblance to the quartz of old granitic rocks. The amphibole occurs here and there in fair-sized crystals, but still with a tendency to ophitic inclusion of felspar at the edges, and with a consequent lack of idiomorphic outline. But such sections are much more easily studied than those of the same mineral at Mynydd Mawr, and the agreement of the optical characters of this amphibole with Sauer's riebeckite can be satisfactorily demonstrated. The approximate coincidence of the direction of greatest elasticity with that of the principal axis of the crystal would remove the amphiboles of Mr. Kendall's specimens from the ordinary well-known types; the intensity of the pleochroism, and the fact that indigo-blue rather than blue-violet axis-colours appear, show, moreover, at once that we are dealing with a mineral less familiar even than glaucophane.

I need say nothing of the pebble from the Isle of Man, beyond that it repeats in a remarkable degree the characters of that from Moel-y-Tryfan. In this respect the microscopic evidence only bears out Mr. Kendall's accurate judgment in the field; and geologists will be glad to learn to what locality he may be able to trace these interesting erratics.

The nature of the riebeckite crystals in the specimens from the drift has not permitted me to make very exact determinations of their extinctions; the sponge-like structure of so many, owing to the multitude of ophitic enclosures, renders the observer cautious in judging of their orientation. But in those examples where I have felt more secure, I have read off a larger angle between c and a than is recorded for typical riebeckite. I have thus obtained 6°0′, 8°5′, 9°45′ and 8°0′. It is, however, reasonable to suppose that variations towards normal amphibole will be found in this peculiar group of forms, just as among soda-pyroxenes the extinctions depart widely from the small angle of strictly defined ægirine and acmite.

It will be interesting to learn, as our knowledge of soda-amphiboles increases, whether riebeckite is typical of rocks of igneous origin, while glaucophane arises in regions of pressure-metamorphism; or whether the peculiar relation of the axes of elasticity to those of form depends, as at present appears, purely on chemical constitution, viz. on the presence or absence of iron oxide.