On the biotite-bearing greenstones and on a rhyolitic pumice in the metamorphic aureole of the Falmouth granite.

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I. *Biotite-bearing Greenstones.*

IN the metamorphic aureole of the Falmouth granite, the greenstones which are largely referable to epidiorites form an important and interesting assemblage of rocks. These are lower Palaeozoic in age and are pre-granite and have suffered from metamorphism as an effect of the granite-intrusion in post-Carboniferous times.

The chief mineral constituents, viz. hornblende and plagioclase, are quite normal for a rock of this nature except that the former is clearly a derivative of augite, many relics of which are still preserved; among the most important accessory minerals are biotite, chlorite, epidote, iron-ores, quartz, augite, axinite, and garnet.[1] One may pass over some of the accessories as being quite usual, being partly primary and partly secondary in origin, but biotite is one of those the presence of which requires to be specially explained.

The Geological Survey hinted that its origin was probably due to contact-metamorphism by the granite.[2] On the other hand, a recent study of the exposures on the north-east side of the granite (near Burnt House) leads the writer to adopt a different view. There is no doubt that a certain amount of reconstruction of the structural and mineralogical features of the greenstones has been brought about by the granite-intrusion, but no evidence could be found that the mineral had originated from any other pre-existing constituent of the greenstone. The field evidence itself strongly suggested that the genesis of this mineral was due to the contamination of the basic magma by the pelitic suite (slates) into

[1] On the geology of Falmouth and Camborne. Mem. Geol. Survey of England and Wales, 1906, p. 41.
[2] Op. cit., p. 43.

which it was intruded and which was largely disrupted and assimilated by it, leaving behind certain altered residues (biotite-hornfelses) which are all that remain of the sedimentary inclusions. Where shattering and dispersal of the fragments have been complete the inclusions have disappeared as such, but stray crystals of biotite still remain in the normal mineral assemblage of the greenstones.

The evidences found in the field and under the microscope in favour of this view are given below.

Field characters.—In the quarry, just north of Cosawes Pascoe, there is a good exposure of epidiorite; its contact with the strongly altered slates is also observed in places. The rock is sheared and sometimes schistose; the colour is preponderatingly dark green. But what arrests attention in this general scheme of dark green colour is the occurrence of definite buff and bronze-coloured zones, streaks, and patches which are apparently composed chiefly of biotite; these are schistose, and their schistosity may not be parallel to that of the greenstone. Bridging these typically xenolithic aggregates of biotite on the one hand and the normal epidioritic rock on the other, there are gradations in which the proportion of biotite gradually falls; and it is not unusual to find specimens showing beautiful lit-par-lit injections of the greenstone material along the planes of schistosity of the biotitic patches grading on to specimens where only a few specks of biotite may be discernible.

Microscopical evidence.—Microscopical examination confirms the xenolithic nature of the biotitic patches. In the normal epidiorite, which is of a more or less intergranular texture and composed of augite and its decomposition products (actinolite, chlorite, &c.), plagioclase in large patches (mostly decomposed), sphene, iron-ores, &c., there are observed sheaf-like foliated aggregates of yellowish-brown crystals of biotite. These biotite clots are very often interspersed with small, clear and rounded grains of plagioclase and a little quartz. The texture of the biotitic patches (including biotite, plagioclase, quartz, and an abundant dark, opaque material, probably graphite), which recalls that of biotite-hornfelses in granites, at once marks them out as distinct from the rest of the rock; their boundaries are quite sharp and end against the usual minerals of the epidiorite. There may be little or none of the epidioritic or doleritic minerals in these patches; but when they are present, as is generally the case, crystals of augite or its derivative hornblende, and large decomposed felspars occur dispersed at all angles to the foliation planes of biotite, and it is evident that the whole assemblage is a complex mixture of two distinct types of rocks, viz. the doleritic magma on the one hand and the biotite-hornfels on the other. In addition to these types where both varieties of rocks may be distinguished by their distinct textural and mineral assemblages, there also occur types in which they are represented mainly by biotite on the one hand and pyroxene or amphibole on the other. In others, when the amount of biotite falls very low its xenolithic nature is entirely lost, the mineral having the aspect of a normal constituent of the rock; these cases are to be explained as due to the extreme shattering and dispersal of the constituents of the hornfelsed material.

The later crystallization of the doleritic material under a condition different from that of the biotite-hornfels is also brought out by the complete indifference of the behaviour of the augite or hornblende crystals of the epidiorite with respect to the planes of schistosity in the biotite patches. Thus the elongation of the ferromagnesian minerals may not only be at a different angle to that of the schistosity of the biotite but it is not unusual to find aggregates of the biotite heaped into an arch where they are in contact with augite or hornblende: individual crystals of the latter may be seen cutting through the biotitic zones; and, though rarely, veins of the epidioritic material may be seen intersecting the biotite folia. These observations alone raise a serious objection to the view of the derivation of the biotite from the greenstone material itself, presumably from its augite and hornblende; if that had been so, the textural relations would have revealed biotite to be younger than and unaffected by augite and hornblende crystals of the greenstone.

Regarding the genesis of the biotite-hornfels, it seems likely that the pressure and temperature conditions prevailing at the time of intrusion of the doleritic magma into the shale rock converted it into a hornfels in which biotite predominated. The fragments of the country-rock which were stoped by the magma were shattered and dispersed throughout its body, and on further shattering gave rise to the small patches and streaks and, finally, to the isolated crystals of biotite in the basic magma. For lack of chemical investigations it is as yet too early to say if the original sedimentary fragments were acted on in a way similar to the slate fragments in granite, or even if there was any interchange of material at all—issues that might be followed up subsequently.

II. *Rhyolitic pumice.*

The occurrence of rhyolite is interesting as being perhaps the first recorded example of acid hypocrystalline rocks in this region.[1] It

[1] Op. cit., p. 41.

occurs in the metamorphic aureole of the granite, to the south of the Burncoose greenstone mass on the north-eastern side of the granite. Unfortunately, its field-relations are extremely obscure. It shows evidences of metamorphism which may be ascribed to the granite-intrusion. But whether it represents the acid extrusive phase of igneous activity of which the adjacent mass of greenstones is the basic intrusive counterpart, it is difficult to say. It could be traced intermittently over an area of about $\frac{1}{8}$ by $\frac{1}{8}$ mile mixed up with slate and epidiorite fragments about one-sixth of a mile to the north-east of Gilly's farm-house.

Megascopic characters.—In hand-specimens the rock is greenish, purplish, and violet; when decomposed it is buff. It is composed of porphyritic crystals of much weathered felspars and quartz; the former is at times large; both are greatly fractured; these are embedded in an opaque, greenish, or purplish groundmass which is full of holes that impart a scoriaceous and slaggy character to the rock. Flow-structure is sometimes noticeable in the arrangement of the gas-holes and bands differing in colour.

Microscopical characters.—Porphyritic felspars, which are orthoclase, are thoroughly decomposed, fractured, and granulated. The quartz is full of inclusions; it is granulated and shows undulose extinction; sometimes the fractured parts of quartz are cemented by a glassy base. The phenocrysts are embedded in an abundant glassy base which is full of numerous gas-holes, generally empty. The groundmass is colourless in places, but is generally of a dark tone. Its transparency also varies, chiefly due to the inclusions of an opaque dust. Cubical crystals of pyrite, shreds of brown hornblende, and plumose or acicular crystallites are also present in the groundmass. There may also be present minute laths of felspar recalling the trachytic texture. Some dark, opaque bodies which are quite angular and irregularly notched occur in the groundmass—these perhaps represent some xenolithic material.

Some cordierite also occurs showing sector-twinning; the crystals are colourless, more or less rounded in appearance, and are very small. The gas-holes are generally empty, but a little chalcedony and tridymite (?) have also been noticed in them.

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