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II.—NOTE ON A HYPERSTHENE ANDESITE FROM PITCULLO, FIFESHIRE.

By D. BALSILLIE, F.G.S., Chemistry Department, University of Edinburgh.

TWENTY-ONE years ago Dr. Flett in a valuable paper (*Trans. Edin. Geol. Soc.*, vol. vii, 1897) described an exceedingly beautiful hypersthene andesite from the volcanic series of the Lower Old Red Sandstone at Dumyat in the Western Ochils. In the following brief communication I propose to give a short petrographic account of a strikingly similar rock that has occurred to me in the field in a more easterly portion of the same range of hills and which is of the same geological age.

In East Fife the volcanic rocks of the Lower Old Red Sandstone rise abruptly above the southern shores of the Firth of Tay. They consist here as elsewhere of lavas, tuffs, volcanic breccias, and agglomerates, with intervening belts of sediment that no doubt

marked intervals of quiescence more or less prolonged in the course of their volcanic history. The prevailing dip of the rocks is towards south-east, so that as we proceed in that direction progressively higher members of the sequence are encountered. As usual among the igneous products of this geological period, the most abundant extrusive types are andesites. More acid rocks, such as felsites, also occur, but there is no evidence to prove conclusively that in the area in question these are ever true lavas. (Reference may here be made to the salmon-pink felsite of Lucklaw Hill, which has hitherto been regarded as a lava. The enormous extension of this mass at right angles to the general strike of the rocks and the manner in which it sends ramifications into the andesites that surround it, especially on its northern boundaries, point only to one conclusion, viz. an intrusive origin.) The andesites vary greatly in their physical characters. Some are slaggy, having abundant mineral-filled vesicles, others being thoroughly compact with a platy system of joints and an occasional development of brecciation along their lower portions. These latter compact rocks afford excellent material for microscopic investigation, and as in many cases they have been laid bare in quarries for the provision of material to macadamize the public roads it is not difficult to collect representative examples of the fresher types of the district. It is in reference to a fortunate exposure in one of these artificial openings that this note has been written, and the remarks that follow are based entirely on the examination of rock specimens collected from one locality, viz. near Pitcullo in East Fife.

Inspection of a 1 inch to the mile topographic map of Fifeshire will show that on the main road between the county town of Cupar and Dundee there is, about 1 mile to the north-east of the little village of Dairsie, a farm steading named Muirhead, from which point a road runs west across the hills towards Craigsanquhar. Less than half a mile along this road from the junction just mentioned, and immediately on its right-hand side, a quarry has been opened among the lavas. The main rock of the quarry, which is situated at no great distance from the mansion house of Pitcullo, and is consequently designated the Pitcullo Quarry, is not of such character as to attract any special attention, but high on the worked face, on the side remote from the road, a rock of remarkable freshness and with a pitchstone-like resinous lustre occurs. It is coated externally with a light-brown crust, perhaps as much as a quarter of an inch in thickness, but beneath this weathered zone is very black and compact, and shows on a freshly broken surface abundant porphyritic crystals of a glassy felspar. There is no line of demarcation between this fresh rock and that lower in the quarry face, and the probability is that it is merely a modification of the rock occurring there.

Under the microscope confirmation of the fresh nature of the rock is immediately to be obtained. It consists of a remarkably homogeneous, brown in colour, isotropic groundmass, in which are disposed numerous porphyritic crystals of glassy felspar, orthorhombic and monoclinic pyroxenes, as well as irregular grains and granules of magnetite.

The porphyritic feldspars, which in many cases are beautifully zoned, belong to the albite-anorthite series and exhibit albite, carlsbad, and pericline twinning. They are often elongated along the crystal axis *a*, but are sometimes also equidimensional on the second pinacoid. Examination by Fouqué's method shows that in sections normal to the bisectrix there is an angular divergence between the trace of the optic axial plane and (010) of 64° , the corresponding extinction angle on slices perpendicular to γ , measurement being made to the (001) cleavages, amounting to from 20° to 24° , these values agreeing well with an acid labradorite. Confirmation of this identification can be readily obtained from sections that exhibit both carlsbad and albite twinning by the well-known method of Michel Lévy, as also from slices cut normally to (010) and (001). The feldspar phenocrysts are much more abundant than in the Dumyat rock, are equally fresh and unaltered, and as in its western counterpart the feldspars here often contain glass inclusions and show evidence of resorption, though this phenomenon is not nearly so marked as in the rock described by Dr. Flett. Neither is there here the same indication of flow structure, the phenocrysts in the field of the microscope not showing the rough parallelism that immediately strikes one in the Dumyat rock. As noted, the feldspar crystals are often elongated along the crystal axis *a*, and a single Baveno twin was observed cut almost normally to the bisectrices *a*, the two halves giving angles of 60° and 61° respectively between the optic axial plane and (010). Each half was in addition twinned on the albite law, and an albite lamella in the one half was seen to be continued across the composition face and be prolonged in the other individual on the pericline law. This optical distinction could easily be made out under high magnification and making use of a thin gypsum plate.

The pyroxenes include, as has been said, both orthorhombic and monoclinic varieties. The former mineral, which predominates, is optically negative, markedly pleochroic, and may safely, I think, be taken as hypersthene. The crystal outlines are well-marked sections transverse to the crystal axis *c*, being rectangular in form, with the prism faces occurring as mere truncations of the corners. Such sections are invariably traversed by a set of irregular cracks, in addition to which there is a well-developed prismatic cleavage. A pinacoidal cleavage I did not observe. The hypersthene is usually quite fresh and have a tendency to occur as little coterries of small crystals, sometimes in association with the monoclinic pyroxene or in other places along with the feldspars. The pleochroism is as follows: *X* pale reddish-brown, *Y* pale yellow, *Z* green.

The monoclinic pyroxene is at once to be distinguished from the hypersthene by its oblique extinctions and higher interference colours. The dark borders that were noted by Dr. Flett to surround the augites in the Dumyat rock do not occur here. The crystal outlines are but ill defined, and twinning occurs on one or more laws that I did not determine. The mineral is not pleochroic, and on the prismatic zone of faces exhibits very often roughly parallel cleavage traces. The angle between the bisectrix *Z* ($=\gamma$) and (100) was

found to amount from 40° to 45° , this corresponding with augite, which I therefore take to be the monoclinic pyroxene present.

Magnetite occurs disseminated as quadrangular and irregular grains throughout the rock, and is frequently enclosed in the pyroxenes. Apatite such as occurs in the Dumyat and Cheviot andesites I did not observe.

The groundmass of the Pitcullo rock examined under low powers appears remarkably isotropic, but is resolvable under higher magnification to a mass of little felspar crystals that lie in an ultimate base of pale-brown or colourless glass with globulites. In addition to the felspars, which are twinned on the albite law and have only a small extinction angle, a second generation of pyroxenes also occurs. Magnetite, too, is an abundant constituent.

In sections of the Dumyat rock a number of lighter areas made up of minute microlites and having a darker periphery were observed by Dr. Flett. In their most perfect form these occur "as rounded bodies which have some resemblance to spherulites". Such circular aggregations of microlites I have not noted in the Pitcullo rock, though irregular areas of a similar kind, and often with a darker border, not uncommonly occur. Comparison, however, with hand-specimens of the typical kugel andesite from Bath, Hungary, convinces me that it would be quite unwise to describe kugel structure as occurring in the Pitcullo rock. The Hungarian rocks have had a sort of pseudo-amygdaloidal structure conferred upon them by the physically separable character of their kugels. This certainly is not the case in the rock from East Fife.

The rock that has now shortly been described is by far the freshest typical andesite that I know in the district in which it occurs. It is not, be it at once said, quite so glassy as the exceptionally fresh rock from Dumyat, but in the best specimens is only a little less so.

The bulk of the material in the quarry consists, as has been indicated, of hypersthene andesite, but is really a rock quite different in appearance from that described in the foregoing notes. It is grey in colour, is obviously in a much less fresh condition, and suggests in no way, macroscopically at all events, relationship with the fresh "pitchstone" that comes on top of it. Notwithstanding this physical distinction, both appear to have belonged to the same parent mass. Under the microscope the felspars can be seen to be equally clear and glassy and to have an identical composition. Both orthorhombic and monoclinic pyroxenes occur, as in the unaltered rock, the former, however, now only represented by pseudomorphs made up of strongly absorbing fibres. Impregnations and veins of iron oxide are frequent, obscuring totally in some slices the real nature of the rock that carries them. The base is much less glassy, and the felspars of the second generation are larger. It will therefore be seen that any distinction that occurs may only be due to differences in the cooling history of the two portions of the rock and to the fact that the glassy rock by virtue of its compactness has had conferred upon it a higher degree of resistance to the agencies of secondary change.

Being interested as to the chemical nature of the unaltered andesite, Mr. R. K. S. Mitchell, one of the senior workers in this laboratory, kindly undertook to carry out for me a determination of the silica and bases present, which he did under the supervision of an exceedingly skilled analyst, my friend Dr. Sidney A. Kay. Mr. Mitchell's figures are as follows:—

Si O ₂		61.37
Al ₂ O ₃		18.80
Fe ₂ O ₃		5.46
Mn O		—
Ca O		5.62
Mg O		1.88
Na ₂ O		3.83
K ₂ O		2.05
		<hr/>
		99.01

Comparison of these results with the analyses given by Sir Jethro Teall in his valuable papers on the Cheviot andesites (GEOLOGICAL MAGAZINE, 1883) will at once show in what striking fashion there is chemical similarity between the Old Red "pitchstone porphyrites" of the borders and the example described above from East Fife.

In conclusion, it is my duty to express very cordial thanks to Professor James Walker, F.R.S., for having added to the equipment of this Department several items of optical apparatus which have enabled me to carry out the foregoing mineral determinations.

III.—THE THICKNESS OF THE ZONE OF *BELEMNITELLA MUCRONATA* IN THE ISLE OF WIGHT.

By R. M. BRYDONE, F.G.S.

IN 1908 Dr. Rowe published an account of the Chalk of the Isle of Wight¹ with a zonal map in which the zone of *Belemnitella mucronata* was shown as entirely absent at some points but generally present in substantial thickness. At the two ends of the island actual measurements were made, of 150 feet at Culver Down and 475 feet at the Needles. How much of the latter thickness was measured in the cliffs and how much is made up of somewhat less satisfactory measurements at low tide on weed-covered reefs is not clear, but at any rate there must be well over 300 feet in the cliffs. This figure is sufficient to show how great a ravining of the pre-Tertiary surface of the chalk would be required for the repeated disappearances of the zone as mapped. It seems justifiable to pay some critical attention to the evidence on which such a state of things is alleged.

It will be found on reference to the map in question that there are five points at which the zone of *Belemnitella mucronata* is represented as disappearing completely, while in between them it swells out each time to a very substantial thickness. (I do not include the

¹ "The Zones of the White Chalk of the English Coast. V. The Isle of Wight": Proc. Geol. Assoc., vol. xx, pt. iv, p. 209.