Fig. I

× 8.

Fig. II.

× 16

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ORIGINAL ARTICLES.

I.—NOTES ON THE CHEVIOT ANDESITES AND PORPHYRITES.

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[PLATE IV.]

(Continued from p. 108.)

BEFORE proceeding to describe the more common porphyrites, I wish to return to the subject of the true andesites, referred to in my last paper, and their relation to Tertiary and recent rocks of a similar chemical and mineralogical composition. On referring to the note appended to that paper, it will be seen that my description of the pyroxenic constituents of these rocks was very imperfect, not to say inaccurate. The number of elongated sections which extinguished parallel with the vibration-planes of the crossed Nicols attracted my attention when first I examined the rock, but seeing that the same feature occurred in the so-called augite-andesites of Hungary and Santorin, and seeing further that as regards cleavage and crystalline form the pyroxenic constituents of the Cheviot rock resembled those of the augite-andesites above mentioned, I came to the conclusion that the prevailing pyroxene in both cases was the same, and also that it was augite. In the former conclusion I still think I was right, but in the latter I was unquestionably wrong.

A flood of light, as far as I am concerned, has been thrown on this question by an article in the February number of the American Journal of Science, by Mr. Whitman Cross, to which my attention was called by Prof. Judd. The article is an abstract of a paper to be published as a Bulletin by the U. S. Geological Survey, and is entitled "On Hypersthene-Andesite." It commences as follows: "In the course of the investigation of some apparently normal augite-andesites of the most typical variety, occurring at the Buffalo Peaks in South Park, Colorado, the writer found that a large part of the pyroxenic constituent possessed the crystalline form and chemical constitution of hypersthene rather than of augite. The comparative study of similar andesites from this country and from well-known European localities has forced him to the conclusion that in very many, if not in all of them, augite is decidedly subordinate to a rhombic pyroxene, which is presumably hypersthene." After giving a description of the general macroscopic and microscopic characters of the Buffalo Peaks rock which would answer very well for the Cheviot andesite, he states: "When the pyroxene crystals and grains . . . are examined in polarized light, it is clear that a large portion of them do not belong to the monoclinic augite. If, in the first place, all those individuals of which the vertical axis seems to lie in, or nearly in,

the plane of the section, be examined, it is seen that much more than half of them are distinctly dichroic, and that all of these extinguish light parallel to the vertical axis. The others are not visibly dichroic, and extinction takes place at a very decided angle, usually approaching 40° from the vertical axis. If, on the other hand, those crystals which are apparently cut at right angles to the principal axis (judging from cleavage and outline), are tested, more than half of them are found to extinguish light when the diagonals of the prism, as indicated by the best developed cleavage-planes, coincide with the principal sections of the crossed Nicols."

The author describes the pleochroism of the mineral, and remarks that it does not seem to differ from that often described for the "augite" of the andesites. The mineral in question was isolated by the method of M. Fouqué, and three separate analyses of different specimens were made. These agree very well with each other, and the following may be taken as representing its composition:— SiO_2 , 51.157, Al_2O_3 , 2.154, FeO , 18.360, MnO , 0.363, CaO , 3.812, MgO , 24.251, Total, 100.097. In conclusion, the author states that he does not claim all the augite-andesites as hypersthene-bearing rocks, but only those with which he is acquainted.

So far as my own observation has gone, I can confirm the opinions of Mr. Whitman Cross, and it will perhaps be as well if I describe the rhombic pyroxene as it is now known to me, and indicate the localities of the rocks in which I have observed it. Sections more or less parallel with the principal axis are usually long, and sometimes very long in proportion to their width. The ends of such a section are sometimes bounded by two definite crystalline faces, which meet at an obtuse angle. Irregular transverse cracks are usually present, and these evidently exercise an important influence on the alteration of the mineral. Longitudinal cleavage-lines may sometimes be observed, but as a rule they are not conspicuous. The dichroism of these sections is well marked in sufficiently thick preparations, and the colours vary from green to yellowish or reddish-brown; green when the axis lies parallel with the vibration-plane of the polarizer (short axis of the Nicol), yellowish or reddish-brown when the axis lies at right angles to the vibration-plane. Cross-sections of the prism show that the pinakoidal faces are largely developed at the expense of the faces of the prism. The prismatic cleavages are strongly marked, though somewhat irregular. The two sets of lines in the cross-section meet at an angle of about 90° . The dichroism in these sections is less marked than in the longitudinal sections; the colours being yellowish and reddish-brown. The pyroxene in the Cheviot and other andesites of a similar character occasionally shows twinning parallel with a pinakoidal face, as pointed out in my previous paper. I suspect, however, that this only occurs in the monoclinic¹ mineral, though I am not able to speak positively on this point.

¹ Mr. Whitman Cross expresses doubt as to the monoclinic character of the pyroxene associated with hypersthene in the American rocks. I have not examined a sufficient number of sections of the corresponding mineral in the Cheviot rocks to speak positively on this point, but I have seen nothing to suggest a doubt as to its being a true augite. I therefore speak of it as monoclinic in this paper.

Putting the above facts together, we may say that the rhombic pyroxene, when fully developed, occurs as columnar, doubly terminated crystals, which are made up mainly of the pinakoidal, and only to a slight extent of the prismatic faces. It is markedly pleochroic, the three axial tints being green, yellow, and reddish-brown. The prismatic cleavages are strongly marked. Prof. Rosenbusch speaks of a perfect pinakoidal cleavage, but this I have not been able to make out in my sections.

I will now enumerate the rocks in which I have observed this mineral, and it must be remembered that in each case there is a striking general resemblance to the Cheviot type. In short, there is not the slightest doubt that, unless we are prepared to make geological age, *per se*, a point of classificatory value in petrology,¹ the same name must be applied to each and all of the rocks about to be referred to, with the exception of the one from Dorf Hladomer.

The anorthit-trachyte of Szabó² from Lörinczi, West-Mátra and South Servia, contains this mineral in abundance, and this rock also resembles the prevalent Cheviot type in the most striking manner in other respects. A hand-specimen from Lörinczi in the British Museum may be described as a compact rock with semi-resinous lustre and conchoidal fracture.

It also occurs as the characteristic bisilicate in specimens of andesite from Kohlbach, Bagonya near Schemnitz, Dorf Nevolut near Kremnitz, and Dubnik near Eperies. An andesite-lava from a point near the summit of Ararat contains it along with a twinned monoclinic and non-dichroic pyroxene, and a similar association occurs in the rock which forms the summit of Stromboli. The above statements are based on the examination of specimens kindly shown to me by Prof. Judd, to whom I am also indebted for the loan of Prof. Szabó's communications.

As already stated, all the Cheviot andesites contain the mineral in a comparatively unaltered condition, while many of the porphyrites contain it in an altered form. It occurs also in the so-called augite-andesites from Tokaj, Hungary, and in those from Santorin, including the lava of 1866.

A rock from Dorf Hladomer, Hungary, which in other respects resembles the hypersthene-bearing andesites, contains as the pre-

¹ I do not wish to be understood as holding the view that there is no difference between igneous rocks of different geological epochs. I do hold, however, that a petrologist should be able to name a rock without reference to its geological age, just as a palæontologist should be able to name a well-preserved fossil without reference to its age. If geological age, *per se*, is to be accepted as a point of classificatory value in petrology, then there are, as every field geologist knows, many intrusive rocks that we can never name, for we can never determine their geological age. Such, for instance, are the rocks forming many of the dykes in the North of England.

² Trachyte eingetheilt nach den natürlichen System. Exposition Universelle, Vienne, 1873.

Classification macrographique des trachytes par J. Szabó.

Sur la classification et la chronologie des roches éruptives tertiaire de la Hongrie, Paris, 1880. Extrait du compte rendu sténographique du Congrès international de Géologie tenu à Paris du 29 au 31 août et du 2 au 4 Sept. 1878.

dominating bisilicate, if we may judge from a single microscopic section, a twinned monoclinic and slightly pleochroic pyroxene. This rock looks then as if it might be a true augite-andesite.

It thus appears that many of the rocks hitherto known as augite-andesites ought rather to be called hypersthene-andesites, and the question arises what rock are we to regard as typical augite-andesite? In connexion with this, I should like to point out, as indeed is well known, that there are undoubtedly non-olivine bearing plagioclase-augite rocks of a porphyritic character, with a silica per-centage varying from 55 to 59, and a specific gravity of from 2·7 to 2·8; such, for instance, as the rock forming the Cleveland dyke, which is, be it remembered, certainly Post-Jurassic, and almost certainly Miocene. These can scarcely be called basalts, and it becomes a question therefore whether the term augite-andesite may not with propriety be applied to them. If so, we should then have as the generic term *pyroxene-andesite*, and as specific terms, *hornblende-andesite*, *hypersthene-andesite*, and *augite-andesite*. In a short time I hope to publish a detailed description of the rock of the Cleveland dyke, and it can then be decided whether such a rock has any claim to the now somewhat discredited term augite-andesite.

MICROSCOPIC ANALYSIS OF THE CHEVIOT PORPHYRITES.

These rocks are for the most part only altered andesites, and it becomes a question, therefore, whether the term porphyrite should be applied to them at all. There is no doubt that in this country we have included under the general term porphyrite rocks of extremely diverse character; and a considerable difficulty therefore arises when we attempt to give the term a precise petrological signification. Considerable work will have to be done on the porphyrites before it becomes advisable to remodel the terminology; meanwhile, it is important to note that a large number of the Cheviot porphyrites are merely altered andesites, and therefore quite different from the felspar-magnetite rocks, which are described as porphyrites by Prof. Geikie in his paper on the Carboniferous Volcanic Rocks of the Firth of Forth.¹

For the purpose of description the Cheviot porphyrites not belonging to the type described in my previous paper, in which the distinguishing macroscopic feature is a resinous lustre, may be divided into two groups according to the presence or absence of mica, and it is worthy of note that Szabó divides the Hungarian trachytes, under which term he includes the andesites, in a similar way. Whether the mica porphyrites of the Cheviots occur as true lavas, I am not able to state definitely; but they certainly occur as dykes, and in this respect, as well as in others, they are related to the mica-bearing quartz porphyries or porphyrites which occur in the same district. To these latter rocks, however, I do not propose to refer in the present paper. The porphyrites without mica are by far the most

¹ Trans. Royal Soc. Edin., vol. xxix. part 1.

abundant, and they undoubtedly occur as lavas in association with tuffs of a similar andesitic character. The vesicular and scoriaceous portions of the original flows are now amygdaloidal, owing to the deposition of chalcedony, jasper, and quartz, together with certain green minerals in the original cavities. A cursory examination of the thin sections of the porphyrites shows at once that they are closely related to the andesites; that some of them in fact are andesites, whilst others are merely altered andesites. The altered forms very largely predominate, and the question arises, why is it that certain andesites have been preserved from alteration, whereas others have been so profoundly modified as to have lost almost all traces of their original character? No doubt the original rocks varied in character as do the Tertiary andesites of Hungary; some were vitreous, others semi-vitreous, and others compact and crystalline. It is these latter types which appear to have suffered most during the lapse of time; the former, in which the constituents were imbedded in a highly acid glassy base, having retained their original characters to a surprising extent. As the rocks now to be described vary in character much more than those referred to in the previous paper, I propose to select a few of the more characteristic specimens and describe them individually.

Thompson's Walls, near Yetholm.—My attention was called to this rock by Prof. Lebour, who kindly gave me a specimen. I have since visited the locality. The rock is exposed in an old quarry on the hill-slope behind the houses at Thompson's Walls, and a similar but more altered rock occurs at Goldsmith Hill, about two miles S.S.W. of Thomson's Walls. Macroscopically it consists of a dark purple or black compact matrix, throughout which porphyritic feldspars of triclinic species are abundantly scattered. The pyroxenic constituent cannot be easily recognized with a hand lens. The specific gravity of the rock is 2.67. The microscopic appearance of a thin section is represented in the Plate, Figure 1. The rock from which the section was prepared is very fresh, and thoroughly entitled to the term andesite. I will now give a description of that portion of the section which is represented in the Figure. Nearly in the centre of the field of view is a somewhat rounded grain of feldspar, evidently a fragment of one of the larger porphyritic feldspars. Many other similar grains may be recognized in the section. To the south-east of this grain, supposing the figure to represent a map, is a section of a feldspar crystal with definite crystalline boundaries; inclusions of the ground-mass are abundant and their characters are well represented in the Plate. Under crossed Nicols the section is seen to be striated, so to speak, from E.N.E. to W.S.W.; but the striations are somewhat ill-defined, owing to the fact that the section is cut very oblique to the twinning plane.

On the west side, and with its longer edge parallel with a diameter of the figure, is an elongated rectangular section taken out of the zone of the macrodiagonal axis. In this case the twin striation is sharply defined. If we use the letters *a* and *b* to indicate the two sets of lamellæ, then the character of the twinning may be described

as follows. The right-hand portion of the section is divided into three tolerably equal bands. The lower third consists of very broad bands of the *a* set, with two or three narrow bands of the *b* set; the middle third consists of broad bands of the *b* set, traversed by extremely narrow bands of the *a* set; the upper third is divided into two halves, the lower half consisting of broad bands of the *a* set, divided by fine lines of the *b* set, and the upper half having this condition of things reversed. The bands here referred to are not continuous along the whole length of the section. So far as my very limited observation has gone, I have found this type of twinning characteristic of feldspars, which give the extinction angles of labradorite in cleavage flakes parallel with the basal plane.

Immediately to the north of the feldspar section just described there occurs another containing inclusions of the ground-mass arranged in a zonal manner round the edge of the crystal section; and to the south there occurs a feldspar reduced to the condition of a skeleton by the number of inclusions which it contains. In this case the bulk of the foreign matter must be greater than that of the feldspar substance, and yet the feldspar has impressed its character on the compound mass. One is reminded of the masses of Fontainebleau sandstone, on which calcite has impressed its characteristic crystalline form. This portion of the Plate should be examined through a lens.

Rather more than half-way between the central feldspar grain first referred to and the top of the Plate there occurs a somewhat elongated rectangular section lying with its longer axis inclined a little north of east and south of west. It shows a fibrous structure. This is a longitudinal section of a somewhat altered crystal of the rhombic pyroxene. The fibrous structure is due to the fact that the altered and unaltered portions lie side by side in bands which run, roughly speaking, parallel with the longer edge of the section. The altered portions give aggregate polarization which may be best seen when the unaltered portions are dark. The black patch below, and slightly to the right of the section just described, is a more highly altered crystal of the same mineral. Another similar section may be seen a little above the largest porphyritic feldspar. At the bottom of the figure and intersected by the margin is a fragment of an altered pyroxene, surrounded by a dark ring due to the segregation of iron oxides. Magnetite occurs, mostly as opaque grains, and may be recognized in the Plate. The ground-mass of the slide is composed of small feldspars together with numerous specks and grains of opacite (? magnetite) and ferrite (? hematite) imbedded in a tolerably clear crypto-crystalline base. I doubt whether any true isotropic glass occurs in this rock. Apatite occurs in comparative abundance.

Roadside, half a mile above Shillmoor Farm, Coquet.—At the point in question the road makes a slight turn to the right, and on the north side there occurs an exposure of dark purple porphyrite. The ground-mass is compact, and throughout it are scattered crystals of plagioclase and ill-defined greenish patches resulting from the alteration of pyroxene. Sp. Gr. 2.56. The following is an analysis of this rock by Mr. Waller, of Birmingham :—

Silica	...	...	...	...	...	...	...	...	...	64.2
Alumina	..	...	...	...	...	...	...	...	...	16.0
Iron oxide ¹	...	...	...	...	...	...	...	...	...	4.3
Lime	...	...	...	...	...	...	...	...	...	1.7
Magnesia	...	...	...	...	...	...	...	...	...	2.5
Soda	...	...	...	...	...	...	...	...	...	2.9
Potash	...	...	...	...	...	...	...	...	...	5.9
Loss	...	...	...	...	...	...	...	...	...	3.3
										100.8

On comparing this analysis with the one given in the last paper, it will be seen that the lime is replaced by alkalies, and that the proportion of soda to potash is reversed. Notwithstanding this, the porphyritic feldspars appear to be entirely plagioclase.

Microscopically the rock is a very interesting one. The large feldspars are fresh and of the usual character, so that a special description of them is unnecessary. The pyroxene is in the condition of a green slightly dichroic mineral, sometimes showing definite optical characters and at others passing into the condition of serpentine. A fibrous structure may sometimes be observed in it. Alteration appears to have proceeded along the cracks, as in the case of olivine, and sometimes iron oxides have been formed along these cracks. These characters connect this mineral with bastite, the well-known alteration product of enstatite. Magnetite occurs as large crystals and grains and also as minute grains abundantly scattered throughout the ground-mass together with ferrite. Apatite prisms are not uncommon. The iron oxides also have segregated in places in a patchy manner. The ground-mass itself is mainly composed of minute feldspar microlites intimately interwoven with each other (mikrolithenfilz), and I do not think, though on this point it is difficult to be positive, that any portion of it remains persistently dark between crossed Nicols.

Coquet, one mile below Windy Haugh.—A dark purplish-grey compact ground-mass containing porphyritic feldspars and a few elongated amygdaloids all lying with their longer axes parallel to one another. The form of these amygdaloids is probably due to the flow of the semi-fluid magma in which the original vesicles were produced. The amygdulæ consist of quartz and calcite. Specific gravity of the rock, 2.63. Under the microscope the ground-mass is resolved into a felted aggregate of extremely minute and somewhat ill-defined feldspar microlites and specks of opacite (? magnetite). It is difficult to say whether any true isotropic substance remains. The porphyritic feldspars contain the usual inclusions and exhibit the characteristic twin striation. There is no pyroxene at present existing in the single section of this rock which I have examined, but there are numerous patches of calcite and quartz, and some of the outlines of these patches suggest the form of pyroxene. Pseudomorphs after pyroxene of this kind are not however seen in other specimens of the Cheviot rock which I have examined.

Coquet, quarter of a mile above Windy Haugh.—This rock is exposed only a short distance from the glassy andesites described in the previous paper. It consists of a dull compact ground-mass,

¹ Estimated as Fe₂O₃.

containing altered feldspars and a dark greenish mineral derived from the pyroxene.

Under the microscope it is at once seen to be most closely allied to the pitchstone-porphyrity which occurs in the immediate neighbourhood. It is a rock of essentially the same composition and structure; the same constituents may be recognized down even to the minute reddish-brown mineral which occurs in thin hexagonal plates (? hematite) in the ground-mass. There was doubtless some slight physical difference in the condition of the ultimate base of this rock which led to its being more easily attacked by the ordinary agents of weathering than its glassy relative; such a difference, however, may have been produced by slight differences in the conditions under which the rock consolidated, so that after all this porphyrite and the andesite with a glassy base may have originally been portions of one and the same molten mass. As there is such a marked macroscopic difference in the two kinds of rock I did not suspect their close relationship in the field, and consequently did not look closely for evidence as to their connexion with each other.

In the thin section the feldspars are seen to have been slightly attacked and in the usual way; iron oxides are scattered pretty abundantly throughout the rock, and some of these appear to be of secondary origin. The most interesting mineral, however, is the one which exhibits the characteristic form of the rhombic pyroxene. It is now green in all sections, but still pleochroic in various shades of green. Cross-sections have lost their prismatic cleavages, and so also have the longitudinal sections; these latter, however, sometimes contain numerous rigidly parallel interpositions of perfectly straight hair-like rods, which were probably present in the original mineral. When examined under a high power, the substance is seen to be not perfectly homogeneous, and longitudinal sections show a somewhat indistinct parallel fibrous structure. At times very minute fibres may be seen to proceed from a central axis, exactly like the barbs of a feather. Under crossed Nicols the mineral approximates in character to an orthorhombic crystal, but owing to the want of uniformity above referred to, the sections do not give perfectly definite extinctions. We have here, doubtless, a mineral closely allied to hastite, and like bastite¹ occasionally passing, by almost imperceptible gradations, into serpentine.

EXPLANATION OF PLATE IV.

Figure I. is described in the text.

Figure II. represents a thin section of the prevailing type of Cheviot andesite, described in the last number of the *GEOLOGICAL MAGAZINE*. The two kinds of feldspar are well shown; the earlier and larger crystals with inclusions, and the later and smaller ones for the most part without inclusions. A longitudinal section of the rhombic pyroxene occurs immediately above the large porphyritic feldspar. The microscopic ground-mass is not well represented in the Figure; it consists of black opaque grains (? magnetite), a minute hexagonal mineral occurring in thin plates (? hematite), and a considerable amount of nearly colourless isotropic glass.

¹ Levy and Fouqué, *Min. Micro.* p. 383.

(*To be continued.*)

ERRATA IN PREVIOUS PAPER.—Page 103, line 47, for 0' to 44' read 0° to 44°; page 108, line 4, omit the word *not*; page 108, line 23, for *Nape* read *Nahe*.