On the large Porphyritic Crystals of Felspar in certain Basalts of the Isle of Mull.

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(Communicated by Prof. JOHN W. JUDD, F.R.S.)

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IN the basaltic lavas of Iceland certain porphyritic crystals of unusually large dimensions, occur embedded in the matrix of the rock, and from an early date have received the notice of writers on the geology of that island. Amongst these authors might be mentioned :—Professor Forchhammer,[1] Dr. F. A. Genth,[2] M. A. Damour,[3] Prof. Zirkel,[4] M. P. Schirlitz,[5] and M. R. Bréon.[6]

In 1885, Professor Judd,[7] in a paper on the Tertiary Basic Rocks of Scotland and Ireland, called attention to the porphyritic basalts on the north-east side of Mull, between Tobermory and Ardnacroish, in which he noticed these large crystals of felspar—" in some cases no less than two inches across."[8]

In consequence of the striking analogies which have been shown to exist between the basalts of Iceland and Mull, I have thought an examination of the porphyritic felspars occurring in the lavas of Mull would, for the sake of comparison with the Icelandic examples, be of some considerable interest.[9]

The specimens I have examined exhibit crystals measuring, in some cases, an inch or more across, varying from colourless to yellowish-green

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[1] *Journal für praktische Chemie.* Band III. 1843. p. 385.

[2] *Annalen der Chemie und Pharmacie.* B. LXVI. 1848. p. 13.

[3] *Bulletin de la Société Géologique de France.* Tome VII. s. II. 1850. p. 83.

[4] *Reise nach Island.* Appendix, p. 295.

[5] *Mineralogische und petrographische Mittheilungen.* B. IV. 1882. p. 414.

[6] *Notes pour servir à l'étude de la Géologie de l'Islande et des Iles Foeroe.* 1884. p. 17.

[7] The specimens employed for the purposes of the present paper have been kindly put into my hands by Professor Judd, to whom also for advice and direction I am most deeply indebted.

[8] Quart. Journ. Geol. Soc. Vol. XLII. (1886) p. 71.

[9] Dr. Geikie mentions, on the authority of Mr. Clough, of the Geological Survey of Scotland, the existence of very large crystals of felspar in some of the basic dykes of Argyllshire. *Trans. Royal Soc. Edin.* Vol. XXXV. Pt. 2. p. 37 (1888).

in colour, and, for the most part, transparent to translucent. They are frequently corroded by the magma, the basaltic material penetrating into the crystals being totally different in character to the general matrix of the rock; whilst the rock is a beautiful example of ophitic structure on a minute scale, the minerals entering into the composition of the filling material are most distinctly granulated, and, moreover, are accompanied by a larger amount of vitreous magma.

The size and easy cleavage of the crystals have facilitated their detachment in sufficient quantities for the investigation of both their physical and their chemical nature.

The specific gravity has been determined both in water and in absolute alcohol, giving 2·720 as the mean of results varying from 2·716 to 2·725. The angle between the two principal cleavages—parallel to the basal plane 001 (oP) and to the brachy-pinacoid 010 ($\infty \breve{P} \infty$) respectively—have been determined by the reflecting goniometer and found to be 93° 38′.[1] Sections parallel to the brachy-pinacoid have been examined, in the manner proposed by Max Schuster, between crossed nicols, and show an extinction angle of —30° 11′ as a mean of eight experiments, measured from the lines of basal cleavage. Similar sections made parallel to the basal plane were optically extinguished in the negative direction also, at an angle of 18° with the traces of cleavage planes parallel to 010 ($\infty \breve{P} \infty$). The plagio-clastic twinning invariably follows the albite type and is very plainly exhibited, the crystal splitting with great facility along the *Gleitflächen*, exposing faces possessing a perfect vitreous lustre. The crystals frequently exhibit the phenomena of schillerization, the inclusions being arranged along parallel planes, the traces of which, on the face 010 ($\infty \breve{P} \infty$) included, in every case I have examined, an angle of 42° with the cracks of basal cleavage and 12° from the direction of optical extinction.

The chemical examination of these crystals has been made by the method of flame reactions, devised by Prof. J. Szabó, and by the ordinary methods of chemical analysis.

By Szabó's method I have obtained the following results :—

In the first experiment—heated for one minute in a Bunsen flame 5 millimetres above the burner—the coloration of the flame due to soda corresponded to degree 2 or from 2 to 3 in different trials, whilst there was no evidence whatever of the presence of potash. The angles

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[1] This result is an average of six experiments which varied between 93° 30′ and 9ᴜ° 40′, the wide difference being accounted for by the imperfect lustre of some of the faces of the cleavage plates, giving, thereby, only an imperfect reflection of the object employed.

and edges of the grain employed were each time slightly rounded.   In the second experiment—heated in the *Schmelzraum* for one minute—the degree of soda was again slightly over 2, potash still being absent, whilst not only the points and edges but the faces of the grain began to fuse.   By the addition of powdered gypsum and further heating in the *Schmelzraum* for two minutes—Experiment III. of Szabó—there was still no evidence exhibited of the presence of potash.   The mineral, digested for 24 hours in hydrochloric acid, gave abundant evidence of the presence of calcium by the distinctly red coloration produced in the Bunsen flame.   These results place the mineral, in these respects at least, somewhere near Bytownite, one of the types employed by Prof. Szabó, and in the scale of fusibility adopted by the same author it would take the degree 2 corresponding to about 5·5 on von Kobell's scale.

The chemical analysis has been performed by the ordinary method of decomposition with a mixture of the carbonates of soda and potash, a special decomposition for the alkalies being obtained by the method devised by Professor J. Lawrence Smith.

The following percentage composition has been obtained in this manner :—

Silica ..	...	...	50·80
Alumina } Ferric Oxide }	···	...	31.54
Lime ...	..	...	12·83
Magnesia	...	...	tr.
Soda ...	...	...	3·96
Potash ...	...	...	tr.
Loss on ignition		...	0·52
			99·65

These results give an oxygen ratio for the Silica, Alumina, and the Oxides of Calcium and Alkalies of about 6 : 3 : 1.

M. R. Bréon,[1] working in the laboratory of M. Fouqué, has examined the properties of a felspar, occurring in a similar manner as large porphyritic crystals embedded in basalt on the cliffs of Stigahlid, and on the plateaux between Kerkjubol and Djupidalr in Iceland.   These crystals, he says, sometimes reach a thickness of one centimetre, and a chemical analysis yielded him the following results :—

Loc. cit. p. 18 and Pl. II. fig. 2.

Silica ...	...	...	46·80
Alumina	...	...	33·50
Ferric Oxide ...		...	1·60
Lime ...	...	...	18·00
Magnesia	...	...	0·40
Soda ...	...	...	0·70
Potash	...	...	0·30
			101·30

These results give an oxygen ratio of 4·54 : 2·93 : 1, thus confirming the optical properties, which he found to agree with those of Anorthite. M. Bréon noticed the regular arrangement of inclusions[1] evidently the same as those to which I have already alluded—the phenomena to which the name of schillerization has been given.

Other authors, like Forchhammer, Genth, Damour, von Waltershausen, Zirkel and Schirlitz, have proved the existence, in the Icelandic basalts of felspars whose analyses undoubtedly refer them to Anorthite. Dr. Genth, for example, describes[2] what he thought to be a new mineral species under the name of Thjorsauite, occurring in the Hekla lavas near the banks of the Thjorsá.

He gives the following as the result of his analysis[3] :—

Silica ...	...	...	48·36
Alumina	...	...	30·59
Ferric Oxide ...		...	1·37
Magnesia	...	...	0·97
Manganese Oxide		...	tr.
Lime ...	...	...	17·16
Soda ...	...	...	1·13
Potash...	...	...	0·62
			100·20

Although Genth places this mineral as a form occupying a position in chemical nature between Scapolite, on the one hand, and Bytownite and

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[1] " On peut cependant remarquer dans les feldspaths des petites cavités rectangulaires alignées suivant les lignes de clivage et remplies de produits opaques dus à l'altération." *Loc. cit.* p. 18.

[2] *Untersuchung des Eruptionsproducte des Hekla. Loc. cit.* p. 18.

[3] This author gives a second analysis, in which he lost the alumina and neglected to estimate the soda and potash; but the results calculated differ but slightly from those quoted above.

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Barsowite on the other, there is no doubt as to its position amongst the basic members of the plagioclastic series of felspars.

In the tables below I quote the analyses, which have justified the authors mentioned for referring the mineral to Anorthite :—

	I.	II.		III.	IV.
SiO$_2$ ...	45·65	45·14		45·97	47·63
Al$_2$O$_3$ ...	35·90	32·10		33·28	32·52
Fe$_2$O$_3$ ...	0·36	2·03		1·12	2·01
CaO ...	17·75	18·32		17·21	17·05
MgO ...	—	—		—	1·30
Na$_2$O ...	1·16	1·06		1·85	1·09
K$_2$O ...	—	0·22		—	0·29
Water ...	—	0·31	Pyroxene impurity }	0·69	—
Mn$_2$O$_3$ ...	—	0·78		—	—
	100·82	99·96		100·12	101·89

    I. Felspar in basalt from Priesterhof Halldorstadtr.[1]
    II. Felspar in basalt from Hecla.[2]
    III. Felspar in basalt from Thjorsá.[3]
    IV. Felspar from Seljafjall.[4]

Although these analyses indicate a felspar far more basic in composition than that which I have examined, some of these authors have found similar large crystals, the chemical nature of which seem to be in close agreement with those from Mull. I quote these results below.

	I.	II.	III.	IV.
SiO$_2$ ...	51·61	52·52	52·17	50·80
Al$_2$O$_3$ ...	31·09	30·03	29·22	{ 31·54
Fe$_2$O$_3$ ...	0·24	1·72	1·90	
CaO ..	13·01	12·58	13·11	12·83
MgO ...	—	0·19	—	tr.
Na$_2$O ...	4·11	4·51	3·40	3·96
K$_2$O ...	tr.	—	—	tr.
Loss on ignition	—	—	—	0·52
	100·06	101·55	99·80	99·65

[1] Shirlitz, *loc. cit.* p. 435.
[2] von Waltershausen. " Ueber die vulkanischen Gesteine in Sicilien und Island." Göttingen, 1853, p. 22.
[3] Damour, *loc. cit.* p. 87.
[4] Forchhammer, *loc. cit.* p. 388.

I. Felspar in dolerite from Hafnarfjördr.[1]

II.   ,,   in basalt from Faroe Isles.[2]

III.   ,,   in altered basalt from near Berufjord on the east Icelandic coast.[3]

IV.   ,,   from Mull (T.H.H.).

So far as the physical characters are given by these authors, they agree with the Mull specimens with a fair amount of constancy.

According to Tschermak's theory, that the forms included in the felspathic series of which Albite and Anorthite are limiting members, are isomorphous mixtures of these two species, the results I have obtained by the examination both of the chemical and physical properties of this felspar would give it a formula of $Ab_1 An_3$, a compound which theoretically gives an optical extinction angle of $-17° 40'$ and $-29° 38'$ on the basal plane and brachy-pinacoid respectively, closely agreeing, it will be seen, with the measurements above cited.

The similarity between this felspar and the theoretical compound $Ab_1 An_3$ in physical properties is again confirmed in the chemical composition.

Taking the formula of Albite as Na_2O, Al_2O_3, $6 SiO_2$, we have an Oxygen ratio of $1 : 3 : 12$. Similarly considering Anorthite to be represented by CaO, Al_2O_3, $2 SiO_2$, we obtain a ratio of $1 : 3 : 4$. If then, we have a mixture of three parts of Anorthite (An_3) and one part of Albite (Ab_1) we should have $(1 + 3 + 12) + (3 + 9 + 12) = (4 + 12 + 24)$ parts of Oxygen present, giving a ratio of $1 : 3 : 6$, which result, is precisely identical with that calculated from actual analysis.

[The work in connection with this paper has been carried out in the Geological Research Laboratory of the Normal School of Science, South Kensington.]

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[1] Schirlitz, loc. cit. p. 435.

[2] Forchhammer, loc. cit. p. 387.

[3] Damour, loc. cit. p. 88.