1. The Gabbro Bombs at Lake Graenavatn

By

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In his paper of 1943, M.F. Kuthan mentions briefly (footnote on page 24) volcanic bombs with cores of diallagic gabbro, which he found on the shores of the maar lake Graenavatn in the valley of Krisuvik on the Reykjanes Peninsula. Three years later Prof. S. Thorarinsson and the present author observed these bombs in the same locality without knowing of Kuthan's discovery (Fig. 1).

This gabbro is mentioned by Thorarinsson in 1953, and was briefly described by the present author in a footnote following that paper, where other xenoliths of major interest found in Iceland up to that date are also listed.

On the suggestion of Prof. E. Norin the following microscopic study was made on one of the bombs at the Geological Institution of the University of Uppsala. The author wishes to thank Prof. Norin for the suggestion, and also for the chemical analyses of the plagioclase.

The Mafic Minerals

The bombs represent a light gray, medium-grained olivine-gabbro, rich in plagioclase. The bombs differ somewhat texturally as well as in their grain size. The piece investigated is of typical poikilitic-poikilophitic texture. The plagioclase crystals are relatively large, their average size being about 1.0×0.3 mm. They are exceptionally pure and homogeneous, foreign inclusions are rare, and zoning is rarely observed.

The plagioclase laths are enclosed in large pyroxene crystals. These attain, in some cases, a size of several cm. The optic axial angle, $2\,V_\gamma$, is in most cases about 50°. The extinction angles on (010), $c:\gamma$, average 42° when measured in a thin section on the universal stage, but 44° when measured in a powder preparate. The refractive index, determined by the immersion method on a crystal fragment, proved to be $n_\gamma{}' = 1.710 \pm 0.003$ and $n_\alpha = 1.691 \pm 0.003$, in sodium light.

Like the pyroxene, the olivine too is of normal basaltic type. The optic axial angle, $2\,V_\alpha$, is 80 – 86°. The refractive indices, measured on an oriented crystal fragment, were $n_\gamma = 1.735 \pm 0.003$ $n_\alpha = 1.696 \pm 0.003$. Accordingly, the olivine is a crysotile with about 30 mol-% fayalite.

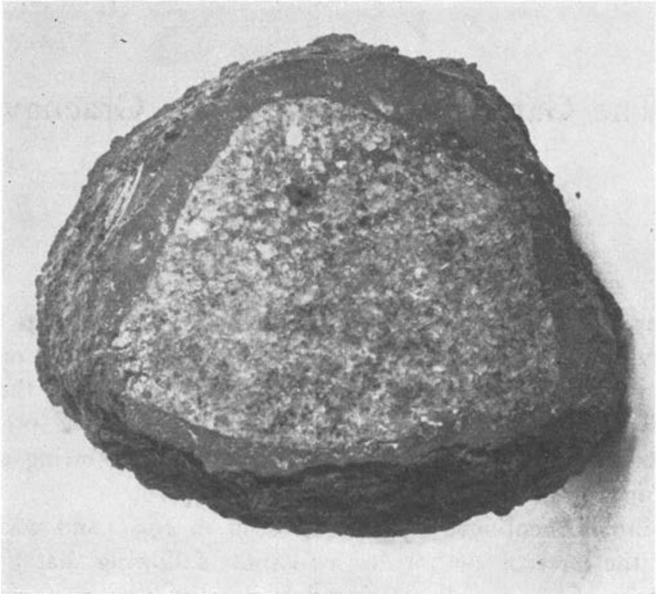

Fig. 1.

One large olivine crystal was found as a host to the plagioclase. As this has extremely seldom been reported before, the optic axial angle of the host crystal was measured repeatedly, and always with indentical results.

Both the augite and the olivine are for the most part quite fresh. However, on their border some of the crystals have been altered into a mineral resembling hornblende. The optical character of the secondary mineral is negative, with $2\,V_{\alpha} = 62 - 66°$. The extinction angle is far less than that of the augite, and the birefringence is low.

Optical Determination of the Plagioclase

On account both of their size and homogeneity, the plagioclase crystals are well suited to optical determinations, and also for separation for a chemical analysis. Furthermore, the rock is already disintegrated due to internal blasting effect. Through the sudden change in pressure caused by the eruption on the rock pieces ejected, the crystal boundaries in the gabbro became weakened. This facilitates the mechanical separation of the crystals.

The optical measurements were carried out on a four axes universal stage according to Berek's methods. The results are listed in a table with average values of the anorthite content in accordance with the migration curves given by Tertsch 1942 for the $\alpha - \beta - \gamma$ coordinates of the twin axes, and the angles between the corresponding directions of α, β and γ in both twins.

Table 1. An-content in per cent, average values, as measured on migration curves of Tertsch (1942).

		Twin axes	$\alpha \wedge \alpha$	$\beta \wedge \beta$	$\gamma \wedge \gamma$
Albite twins,	Low temp.	83	83	—	80.5
6 determinations	High temp.	78	80	—	75
Carlsbader twins,	Low temp.	79	85	80	82
5 detn.	High temp.	70	82	70	81
Albite-Carlsb.	Low temp.	81	80.5	81	83
twins, 15 detn.	High temp.	71	74	81	66.5
Pericline twins,	Low temp.		84	89	74
3 detn.	High temp.		86	100	67

Composition planes and cleavage planes are omitted in the table, as their determination along the N–S axis was not very exact. They have been used for auxiliary purposes in order to determine the twinning laws.

The coordinates of the optic axes were determined if they could be read directly on rotating the control axis in the 45° position. Much value should not be attributed to the 2 V-determination. Firstly, the 2 V-diagram is rather flat, and secondly, the errors in the measurements get doubled with the exception of the rare cases, when both axes can be read on the same individual crystal. The values obtained on the optic angles are therefore omitted from the results.

The $\beta \wedge \beta$ curve for albite twins is rather flat, and therefore of little value for the determination of the an-content. In this case the mean value of the angle was 61,1°, or some 5° higher than the very top of the low temperature curve.

The average points of coordination for the twin axes lie within 3 mm from the (010) curve, respectively 1 mm from the [001] and ⊥ [001] in (010) curves for low temperature orientation.

The tables show that the average results obtained from the measurements of albite, carlsbad and albite-carlsbad twins lie between 79 and 85% anorthite on the Tertsch curves for low temperature orientation. Considering that the determinations, on which these average values are based, are relatively few, the results agree satisfactorily both internally and with the curves. The average values for the pericline twins are far more divergent and unreliable. This might partially be caused by the fact that the averages are on only 3 determinations, and that the lamellae measured are relatively thin and difficult to work on. Furthermore, the curves for the pericline twinning might be based on relatively few measurements, since in basic plagioclases this twinning is not very common.

The Chemical Properties

In order to obtain crystals pure enough for the chemical analysis, the rock was pulverized and then separated in bromoform. The first analysis contained more femic components than permissible. Therefore a new separation was carried out with greater care. The fraction with the density between 2.718 and 2.766 was selected for the analyses. A microscopic examination showed that the crystal powder selected for the second analysis consisted of practically pure plagioclase, and that pyroxene grains were rarely found in the sample. The femic components in analysis No. 2 are due to minute inclusions in the plagioclase crystals, and some reddish-brown spots on their surfaces.

The normative anorthite content of the plagioclase is practically the same in both analyses, 80.2 Wt-% in No. 1 and 80.0 Wt-% in No. 2. This fact indicates that the impurities present in the samples analysed do not affect the calculations of the normative plagioclase to any noticeable degree. In other words: the calculated and actual anorthite content of the plagioclase analyzed is identical, and is not influenced by the impurities present in the samples.

The content of normative quartz depends on how the femic components are calculated in the norm. If FeO is calculated as ilmenite and all Fe_2O_3 as hematite, the Q obtained in both analyses is 2.14 resp. 2.2. If all FeO is used as magnetite, nothing is left over for ferrosilite, and Q becomes as high as

Analysis No. 1. Bytownite, Graenavatn in Krisuvik. Analyst: R. Blix.

	Weight %	Mol. prop.	Norm
SiO_2	48.63	8097	
TiO_2	0.07	9	
Al_2O_3	30.44	2986	or = 1.22
Fe_2O_3	1.40	88	ab = 16.93
FeO	0.52	72	an = 73.45
MnO	0.02	3	Q = 2.14 – 2.55
MgO	0.69	171	
BaO	0.01	1	or : ab : an = 1.3 : 18.5 : 80.2
SrO	0.012*	1	
CaO	15.68	2796	
Na_2O	2.00	323	
K_2O	0.21	22	
H_2O^+	0.28		
H_2O^-	0.13		
CO_2	0.02		
Total	100.11		

* Spectral analytic determination by St. Landergren.

Analysis No. 2. Bytownite, Graenavatn in Krisuvik. Analyst: R. Blix.

	Weight %	Mol. prop.	Norm
SiO_2	49.12	8179	
TiO_2	0.07	9	or = 1.22
Al_2O_3	31.61	3100	ab = 17.83
Fe_2O_3	1.01	63	an = 76.29
MgO	0.11	27	Q = 2.2 – 2.9
CaO	15.43	2751	
Na_2O	2.11	340	or:ab:an = 1.3:18.7:80.0
K_2O	0.21	22	
H_2O^+	0.30		
H_2O^-	0.14		
Total	100.04		

2.55 resp. 2.9. The actual content of excess silica is somewhere between the extreme values in both analyses.

As the gabbro seems to be quite fresh, and the thin sections do not reveal any sign of hydrothermal precipitation under the microscope, this excess of silica is a remarkable fact.

On calculating the norm of former analyses on plagioclase crystals gathered in Iceland by Bréon (1884), Damour (1850), Forchhammer (1842 and 43), Genth (1848), Rath (1871) and Sartorius von Waltershausen (1853), it turned out that from twelve analyses only one is definitely negative in the Q-value. The other analyses all contain more or less excess silica in their norms.

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