Optical properties of olivines from Ubekendt Island, west Greenland.

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THE olivines, which are the subject of this note, were obtained from a series of basaltic lavas and dikes on Ubekendt island, which lies off the west coast of Greenland in latitude 71° N., longitude 54° W.

The optical properties of the olivines were investigated in order to determine any range in composition; such variations might have been expected in the very thick lava series. From this aspect, however, the results are disappointing, the composition range being small. However, it is thought that the results may have a certain interest in showing the relative accuracy obtainable in the measurement of refractive indices and optic axial angles. The usual determinative methods have been slightly varied. It is the purpose of this note to describe these variations and to compare the relative speed and scope of the method used with those obtained by other methods.

The lavas form a series at least 30,000 feet thick. The base is nowhere exposed. The olivines here described were obtained from only the lowest 4000 feet of this series. The dikes, with sills and small transgressive sheets, cut the lavas. They are well exposed in the steep cliffs for about 15 miles along the east coast, where they were collected. About sixty dikes outcrop in the 16 mile stretch of this coast, south of Ingia—the northernmost point of the island. Nearly all were sampled.

The rocks were crushed and sieved, those crystals being retained which had a diameter of approximately $\frac{1}{3}$ to $\frac{1}{4}$ mm. These crystals were then hand-picked under the microscope and a first selection made of olivines with clean-cut, straight, and moderately thin edges. After some trial it was decided to determine the index β, for the following reasons.

Crystals lying in such a position that one optic axis emerges almost vertically (thus giving β as refractive index) are easily recognized by their low interference-colours, which do not change on rotation. Such crystals can be easily and rapidly segregated, when confirmation of their

orientation is obtained by examination of their interference-figures. Sections yielding α or γ as indices cannot be recognized by their behaviour between crossed nicols, but only by determining their interference-figures. The necessity for this procedure makes their segregation a very much slower operation than in the former case, in which a large number of crystals can immediately be discarded during examination with nicols crossed. An alternative method consists in the manipulation of the crystals until the required orientation is produced. This is a difficult and tedious operation—especially so with olivine, which has no good cleavages. The 'statistical' method is also lengthy. In this instance γ and α are derived from the highest and lowest refractive index values, obtained by measuring a large number of random sections. It is, perhaps, not generally realized that this method can be applied to the determination of β. Thus, if γ' and α' be the higher and lower refractive index values obtained for each random section, γ' (max.) $= \gamma$, and α' (min.) $= \alpha$ (given a sufficient number of determinations). Also the mean of the lowest value obtained for γ' and the highest value obtained for $\alpha' = \beta$.

These 'statistical' methods, however, can properly be applied only to a set of crystals which possess exactly the same refractive indices. The results obtained give a mean value from a large number of measurements, whereas the method used in this determination shows small differences in refractive index occurring in olivines from the same rock.

The single dispersion method was used. Monochromatic light was obtained from a Tutton monochromator which had previously been calibrated by the spectra obtained from sodium, mercury, and cadmium lamps. This part of the method is precisely the same as that used by Deer and Wager [M.A. 7-447] for refractive index determinations on the olivines of east Greenland.

Since the refractive indices of these olivines were not higher than 1·74 it was possible to use a refractometer (Abbe-Pulfrich) in place of prism and goniometer for measuring the refractive indices of the liquids, which consisted of methylene iodide and α-monobromo-naphthalene in varying proportions.

Because of the comparative speed and simplicity of the refractometer method compared with the prism method, it was decided not to draw a large number of dispersion curves for mixtures covering the required refractive index range, but to plot four only. Special 'dispersion' paper (Hartmannsches Dispersionsnetz) was used for the plot. On this the curves closely approximated to parallel straight lines. The curve for any other mixture in this refractive index range was then rapidly obtainable,

by determining the refractive index of the mixture using the sodium lamp and then drawing a curve through the point so obtained on the Na[D] ordinate, parallel to the adjacent curve of the four already plotted.

A few drops of the mixture were placed on an ordinary microscope slide and small additions made of one or other of the component liquids until a match was obtained between the refractive index of the crystal and liquid at some point of the visible spectrum. A small portion of the drop was transferred in a capillary to the refractometer and its refractive index determined for the Na[D] wave-length. The dispersion curve for this mixture was then drawn as indicated above. On this curve was plotted the point which corresponded to the wave-length at which the match had been obtained (i.e. the wave-length at which refractive index of mixture = refractive index of crystal). The procedure was repeated for other mixtures and more points thus obtained on the dispersion curves of these mixtures.

The curve obtained by joining these several points is the dispersion curve for the olivine crystal. The point of its intersection with the Na[D] ordinate gives the refractive index [β] of the crystal for sodium-light.

Only those crystals were measured which showed the emergence of an optic axis close to the centre of the field—in no instance farther from the centre than half the radius. After a 'match' had been obtained between the refractive index of liquid and crystal it was found necessary to re-check the orientation of the latter to ensure that it had not moved during examination.

It is maintained that the procedure outlined above obviates, to a large extent, the difficult business of temperature control. Refracto-meter, slides, capillaries, and liquids are kept in the same room for at least twelve hours prior to the determinations, and the room-temperature is kept uniform as far as is possible. Immediately the refractive indices of liquid and crystal have been matched on the slide, a drop or two of the liquid is transferred to the glass hemisphere of the refractometer, and the refractive index at once determined. It seems reasonable to assume that any temperature variations which occur during this process must be very small. It is essential that the dispersion curve for the mixture should be obtained at the same time and at sensibly the same tempera-ture as the refractive index 'match' between crystal and mixture.

The determinations of the optic axial angles were made on the uni-versal stage, using rock sections. Monochromatic illumination—sodium lamp—was used. Owing to the large value of 2V, this angle could seldom

be measured direct, but was obtained from the position of one of the optic axes and a bisectrix.

Only those crystals were measured in which neither an optic axis nor the two measured optic planes made large angles—greater than 35° approximately—with the vertical. An exception to this was made, of course, in those rare instances where the crystal was so oriented that a bisectrix emerged nearly vertically, thus permitting a direct measurement of 2V. Five readings were taken of the position of an optic axis or optic plane, and the mean of these was used for plotting.

In order to obtain a reliable mean value for 2V, it was also found necessary to make the same number of measurements about γ as about α. A set of values obtained about one bisectrix usually showed fair mutual agreement, but differed by as much as 7° or 8° from another set obtained about the other bisectrix; whereas the mean of the two sets always showed good agreement with the value inferred from the measurement of β. In nearly every instance the mean of a set of angles, obtained about one bisectrix only, was found to depart farther from 90° than did the true value of 2V. No explanation can be suggested for this, but it is certainly not accidental, since it was of almost universal occurrence.

The results obtained are given in table I. The first column gives the number of the rock and indicates the field occurrence. The second shows the range in β for each set of crystals, which were measured in each rock. The number in parenthesis is the number of crystals in each set. In the third column is the value of 2V corresponding to the mean value obtained for β (from data by Winchell). The fourth gives the mean value of 2V, obtained by direct measurement from each set of crystals. The number in parenthesis shows the number of crystals in each set. The last column indicates the percentage range of Fe_2SiO_4 corresponding to the range obtained for β (column 2; from data by Winchell). β was determined for 63 crystals and 2V for 65, these totals being divided, as table I shows, between 10 rocks.

It has been stated that as great a reliance cannot be placed on 2V as on α or γ (and therefore, presumably, β also) for the determination of chemical composition of olivines. The results indicate the truth of this statement, if only a few crystals are measured, but show that the mean of a considerable number of determinations of 2V is as reliable a guide to composition (Fe_2SiO_4 percentage) as the mean value obtained for β— always provided, as stated above, that the same number of measurements are made about one bisectrix as about the other.

By reference to table I it will be seen that the mean value of 2V by

measurement (65 crystals) is $89.7°$ (+); whereas the value obtained by inference from β (63 crystals) is $89.8°$ (+). Although the mean values of a large number of measurements of β and 2V show excellent mutual agreement, individual coincidence is often not so good, and in these instances β is always more closely in accord than 2V with the composition (as determined from a considerable number of crystals). An illustration of this is furnished by dike no. D 14 (1) in which the variation in β is from 1·669 to 1·676 (corresponding to a range in composition from 9 to 12·1 mol. % Fe_2SiO_4). The variation in 2V, however, is from $83\frac{1}{2}°$ (+) to $87\frac{3}{4}°$ (−), corresponding to a composition range from 0 to 19 mol. % Fe_2SiO_4, which is probably considerably too great.

The refractive index variation (β) in some rocks (for different olivine crystals) is as large as 0·015—a composition difference of about 9 %—while in others the range is less than 0·003, i.e. within the limits of experimental error. Broadly the variation is greater in the olivines from the lavas than in those from the dikes. The former also contain a slightly higher Fe_2SiO_4 content (14·2 %) than the latter (11·8 %).

The highest value obtained for β in any crystal was 1·690 (19 % Fe_2SiO_4) and the lowest 1·666 (8·5 % Fe_2SiO_4). The data for 2V were $83°$ (+) and $84°$ (−), (0 % and 28 % Fe_2SiO_4) respectively.

TABLE I. Optical data of olivines.

Rock.	Refractive index variations (β).	2V, calculated from mean value of β.	2V, direct measurement on universal stage.	Molecular % Fe_2SiO_4 deduced from β.
Flow, no. 2	1·672–1·683 [6]	90·0° (±)	—	—
,, 22	1·675–1·690 [5]	89·2 (−)	89·0° (−) [8]	11·75–19·0
,, 25	1·676–1·684 [7]	89·75 (−)	89·3 (−) [6]	12·0 –15·25
,, 29	1·675–1·685 [5]	89·6 (−)	89·2 (−) [6]	11·5 –16·5
Dike, no. 2	1·671–1·683 [7]	90·0 (±)	89·75 (+) [10]	9·75–15·25
,, 14 (1)	1·669–1·676 [6]	89·0 (+)	88·8 (+) [6]	9·0 –12·1
,, 14 (2)	1·671–1·682 [7]	89·0 (+)	89·3 (+) [6]	9·75–15·0
,, 18 (1)	1·676–1·679 [7]	90·0 (±)	89·5 (−) [8]	12·75 (mean)[1]
,, 18 (2)	1·666–1·670 [5]	88·2 (+)	87·5 (+) [7]	8·5 (mean)[1]
Sill, no. 021	1·677–1·681 [8]	89·8 (−)	88·6 (+) [8]	13·9 (mean)[1]
		[63] crystals	[65] crystals	

[1] Range in value of β here too small to indicate any composition differences.

Mean value of β in olivines from flows = 1·681
,,   ,,   ,,   dikes = 1·675

Difference ... ... = 0·006 corresponding to a composition difference (mol. % Fe_2SiO_4) of 2·4 %.