Optical determination of aegirine-augite with the universal stage.

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[Read 25 January 1962.]

Summary. The accurate determination of α:[001] and $2V$ in members of the aegirine-augite series often presents difficulties owing to strong absorption and dispersion, especially as high angles of tilt on the universal stage are often involved. Both of these angles depend on the location of α, and this operation is the one most subject to error.

An alternative procedure is the determination of A:[001], the angle between an optic axis and [001]. This angle is very easily and accurately determined and varies systematically with composition. It can be derived from the values for α:[001] and $2V$, while conversely values of α:[001] and $2V$ can be obtained from A:[001] by reference to standard curves.

OPTICAL data normally determined in members of the aegirine-augite series, as in all monoclinic pyroxenes, are α:[001] or γ:[001] and $2V$. Positions of extinction are, however, not always precisely determinable, owing to the strong absorption colour and frequently high dispersion, and with high angles of tilt of the stage considerable discrepancies are found. Moreover, in the experience of the writer, at high angles of tilt the discrepancies are irregular, and are not capable of systematic correction.

The method described by Haff (1941) for the determination of γ:[001] in sections showing a single cleavage depends on obtaining the direction of [001] as the perpendicular to the plane containing β and the pole to the cleavage. Since the angle between β and the cleavage pole is only about 45°, small errors in the determination of each are considerably exaggerated in the location of [001], although the fact that [001] must necessarily plot on the trace of the optic axial plane[1] gives an illusion of accuracy. Moreover, sections suitable for this method are not those in which an optic axis is generally or easily accessible for the determination of $2V$ (fig. 1); this is a serious objection where, as often happens in aegirine-augite, crystals show zoning or significant variations in composition from one crystal to another.

[1] The perpendicular to any plane containing β will fall on the optic axial plane.

More reliable estimation of [001] is commonly only possible in sections showing two prismatic cleavages by determining their line of intersection, although an alternative is provided by the intersection of the

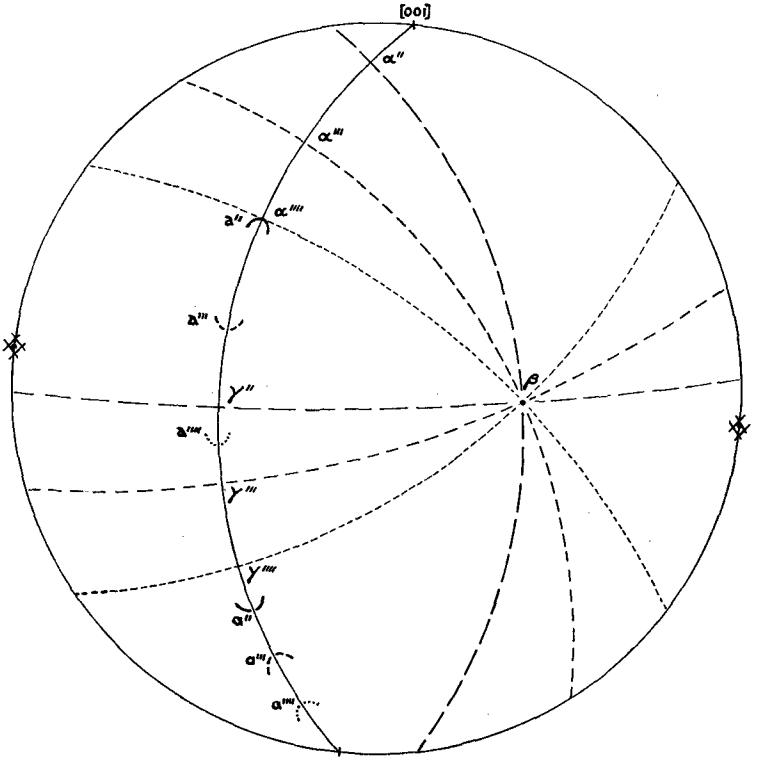

FIG. 1. Variations in the positions of α and γ and the optic axes in sections perpendicular to one cleavage for members of the aegirine-augite series.

	α:[001]	$2V_\alpha$
''	10	80
'''	30	100
''''	50	120

twin plane with the optic axial plane in crystals twinned on (100). Twinned crystals are, however, insufficiently common for this procedure to be normally possible. In using the intersection of the two cleavages the coincidence of [001] so determined with the optic axial plane provides at least a partial check on accuracy.

In sections approximately perpendicular to two cleavages the

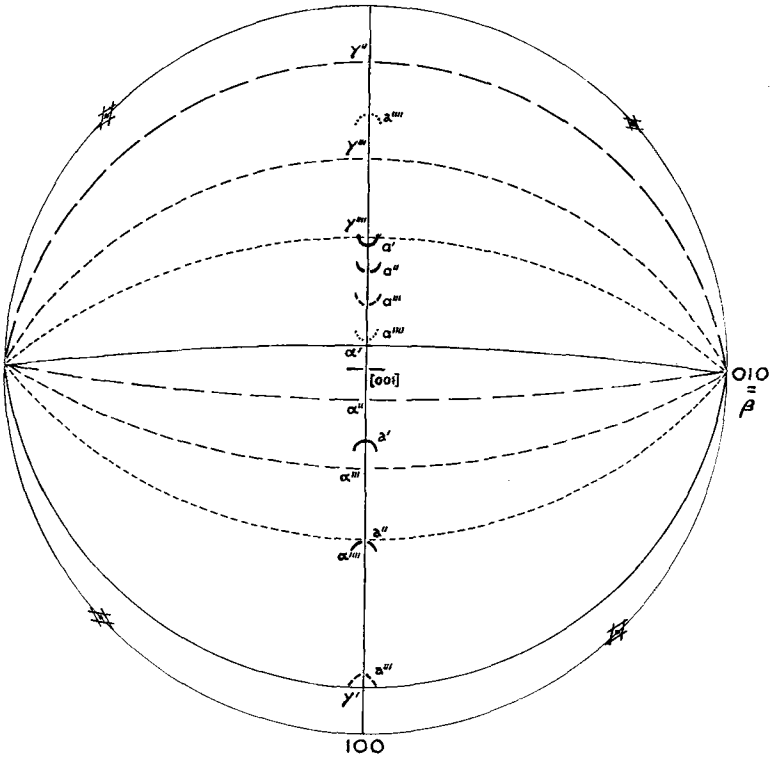

FIG. 2. The migration of α and γ and of the optic axes relative to c [001] in the aegirine-augite series.

	α:[001]	$2V_\alpha$	A^1:[001]
′	−8	60	38
″	10	80	30
‴	30	100	20
⁗	50	120	10

determination of the second symmetry plane, thereby locating α or γ, involves considerable angles of tilt over all but the more aegirine-rich range of the aegirine-augite series (fig. 2). This difficulty affects not only the accuracy of the determination of γ:[001] or α:[001][1] but also, since it is only in aegirine-rich pyroxenes that both optic axes are accessible in approximately transverse sections, the determination of $2V$, which depends upon the correct location of the acute bisectrix (γ or α).

Repeated determinations of α:[001] and $2V$ on pyroxenes in the same

[1] Hereafter only α:[001] will be referred to, since this angle is normally stated for aegirine-augite.

thin section made it evident that the chief source of error in both of these values is connected with the location of α. When the values obtained are plotted on standard curves (e.g. Tröger, 1956, p. 64), the aegirine content derived from α:[001] only exceptionally agrees with that derived from $2V$. The plots show, however, that the discrepancy in the inferred aegirine content increases systematically as the values for α:[001] and

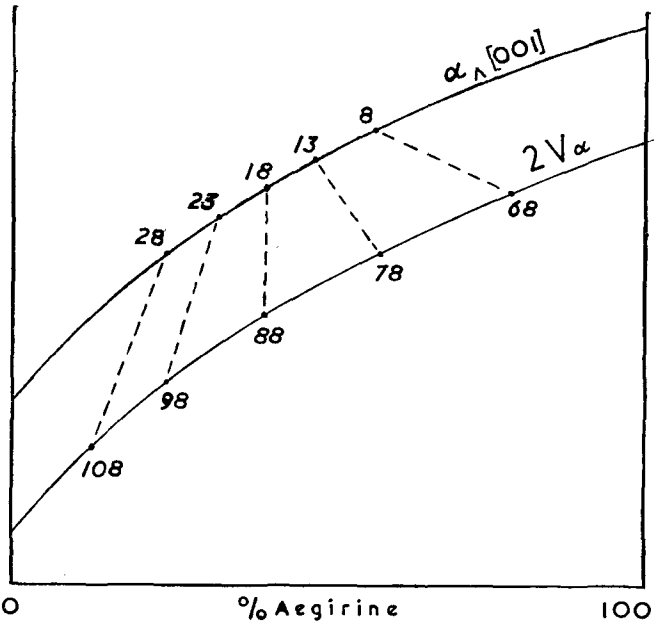

FIG. 3. The effect of errors in locating α on the values of α:[001] and $2V_\alpha$. Only the values joined by the vertical tie-line indicate the same content of aegirine. The errors are greatly exaggerated for the purpose of the diagram. The curves correspond to those for α:[001] and $2V_\alpha$ on fig. 4.

$2V$ depart from those values that do correspond to the same content of aegirine. Tie-lines on the graph joining α:[001] and $2V$ thus splay outwards from the vertical tie-line joining figures giving consistent values for aegirine content. This pattern clearly results from the fact that every degree of error in locating α corresponds to only one degree of error in α:[001], but to two degrees in $2V$. The effect is illustrated in fig. 3.

It is thus apparent that one method of eliminating error due to the difficulty of correctly locating the acute bisectrix is to repeat determinations until values for α:[001] and $2V$ are obtained that give consistent values for the aegirine content. This is, however, both tedious and

unnecessary for it is evident that if there exists a systematic relationship between composition and α:[001] and $2V$, there is equally a relationship between composition and the positions of [001] and an optic axis. The angle A:[001] is thus just as critical an optical character as the two angles that are normally determined; it can, moreover, be readily

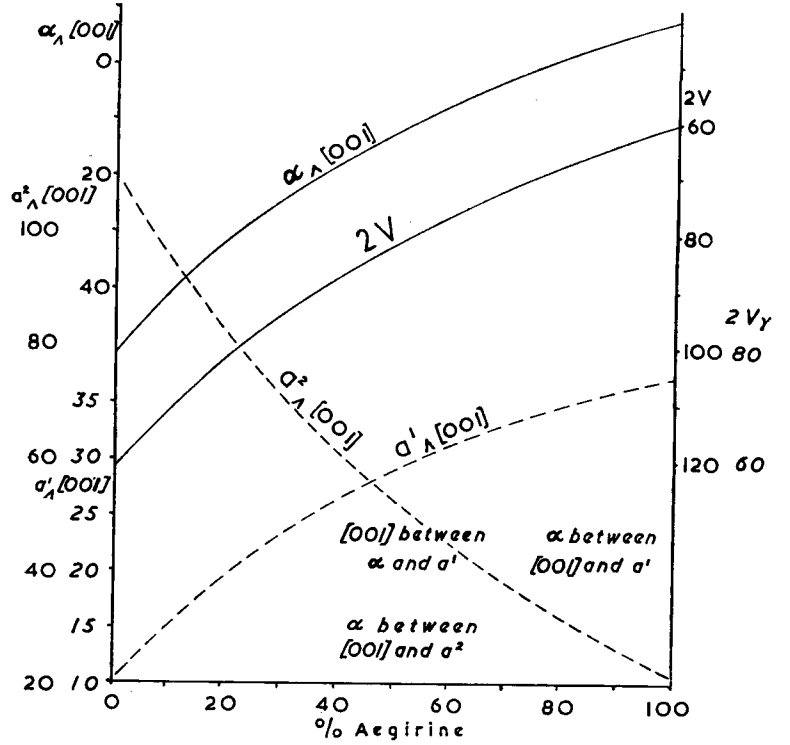

FIG. 4. Curves for A^1:[001] and A^2:[001] corresponding to the standard curves for α:[001] and $2V_\alpha$ in the aegirine-augite series. α:[001] and $2V_\alpha$ are from Tröger, 1956, p. 64.

calculated from determinations of α:[001] and $2V$ and the curve for variation of A:[001] with composition can be plotted from standard curves for α:[001] and $2V$ (fig. 4). Conversely, values of α:[001] and $2V$ corresponding to particular values of A:[001] can be read off from the graph. There is thus no difficulty in making comparisons with existing data on extinction and optic axial angles.

Fig. 2 shows the migration of the optic axes relative to the c [001] crystallographic axis for variations in composition according to Tröger.

There are obviously two A:[001] angles depending on which optic axis is located, but, as the figure shows, whereas one optic axis (A^1) migrates slowly relative to [001], the other (A^2) migrates very rapidly. The extreme range of A^1:[001] is from 10° for 100 % diopside to 38° for 100 % aegirine, which in general involves satisfactory angles of tilt for accurate determination on the stage, and it will be noted that unlike α:[001] angles, which may be positive or negative in the aegirine-rich range, no such ambiguity arises in A^1:[001] values. Beyond about 80 % aegirine the A^1:[001] angle involves fairly large angles of tilt and the alternative A^2:[001] angle may be more easily determinable, but in many such cases an additional check is provided by the accessibility of both optic axes.

Experience shows that the determination of A^1:[001] rather than α:[001] and $2V$ is not only more rapid, but yields very much more closely reproducible results. Such consistency reflects not only the greater precision with which A^1 and [001] can be located as compared with α or γ, but also the relatively small angles of tilt that are involved. It is suspected that much of the inconsistency shown between the α:[001] and $2V$ angles recorded in the literature for members of the aegirine-augite series is ascribable to these factors.

Finally, it should be observed that, while for the purpose of the present account and the construction of the diagrams the curves by Tröger relating optical properties to composition have been employed, the data on which they are based are extremely slender. The corresponding curves given by Winchell (1951, p. 414) indicate decidedly different values of α or γ:[001] and $2V$ for given compositions of aegirine-augite, although the derived A^1:[001] values would be closely similar for both sets of curves. The assumption has also been made for the present purpose that the aegirine-augite series ranges from diopside to aegirine. In fact as noted by Sabine (1950, p. 121) and as implied by the triangular diagram given by Winchell (op. cit., p. 415), hedenbergite is an almost equally important end-member. Work in progress under the direction of the writer is designed to provide additional data relating optical properties to composition in this series.

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