The dispersion images of epididymite from Ilímaussaq and epididymite from Narssârssuk (Flink's material) are completely identical.

The acute bisectrix is perpendicular to (100). The axial angle $2V_\alpha$ varies from $26° \pm \frac{1}{2}°$ in red light where the axial plane is parallel to (001), over 0° in bluish violet (4400 Å) to $16° \pm \frac{1}{2}°$ in the deepest violet, the axial plane now being parallel to (010).

$$\begin{aligned} \text{For } \lambda &= 589 \text{ m}\mu \\ 2V_\alpha \text{ calculated} &= 26° \\ 2V_\alpha \text{ measured} &= 25° \pm \tfrac{1}{2}° \\ (n\gamma - n\alpha) &= 0.00350 \pm 0.00003 \end{aligned}$$

The results are presented in Fig. 1.

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DETERMINATION OF INDICATRIX ORIENTATION AND 2V WITH THE SPINDLE STAGE: A CAUTION AND A TEST

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Introduction

A series of recent papers has highlighted the potentialities of the spindle stage in the determination of the optical constants of small crystal fragments: a short bibliography of the most recent and accessible papers on this topic is given at the end of this contribution, but it is not intended to review these here. The principal advantage of the spindle stage is that, as with the Panoramic Stage of Vincent (1954), no "refractive index corrections" have to be made to the measured angles (Vincent, 1958), and 2V and all refractive indices can be determined on the same fragment, but unlike the Panoramic Stage, the manipulation is fairly simple.

Methods for the determination of 2V depend on several extinction directions being located by rotation of the mounted fragment on its two axes (microscope stage and spindle) and the treatment of this data, either graphically or by direct calculation, to yield a value for the 2V of a grain, usually with the assistance of the Biot-Fresnel theorem. The schemes of working can be roughly grouped as—

1) the plotting, in projection, of the locus of the extinction directions when the grain is roated on the spindle axis to give two "extinction curves," followed by a variety of calculation techniques making use of the properties of these curves: the key contribution of this method is that of Garaycochea and Wittke (1964);

2) the construction, in projection, of an "equivibration curve" (n_0 curve), which is closely related to the extinction curves, and measurement of its major and minor diameters followed by direct calculation of 2V (Joel, 1963a);

3a) plotting a limited number of extinction directions and following this with an elaborate group of geometrical constructions to locate the position of the optic axes in projection (Joel, 1964);

3b) measuring a limited number of extinction positions and treating these by computer to produce a value for 2V (Joel, 1965);

4) a bracketing technique by which sections of the stereographic projection of the crystal which do not contain an optic axis are eliminated, this method uses a number of individual extinction positions which can be selected as the experiment proceeds (Tocher, 1964); and

5) use of the spindle to rotate the crystal into a convenient position for the use of Mallard's formula, if the conoscopic field of view contains an optic axis (Noble, 1965).

It may be said that increasingly complex calculation techniques are now being evolved without improvement in the accuracy of results: for the mineralogist and petrographer the fountain has run dry.

DISCUSSION

It would seem obvious that methods involving the locus of points, in this case extinction directions, will more probably give satisfactory results than those using a restricted number of points. The value of method 5) is very limited, for although it depends less directly on the Biot-Fresnel theorem than the other methods and results can be obtained by using it when other techniques fail, one will rarely wish to vitiate the care required in mounting a selected grain by applying the crudities of the Mallard method. The most attractive method is 2), for it involves the construction of the locus of points on an equivibration curve and this, along with that of the associated extinction curves, will give the complete orientation of the fragment so that the refractive indices can be measured immediately. The relationship derived by Joel (1963a) is that the cosine of the optic angle V is given by the division of the sine of the semi-minor diameter of the equivibration curve by the sine of its semi-major diameter.

Figure 1 presents some of the family of curves representing 2V plotted with the semi-major and semi-minor diameters of the n_o (equivibration) curve as coordinates: in its more complete form it can be used as a determinative diagram to eliminate calculation, but it is not proposed to present the more complete diagram here. The diagram demonstrates that the separation of the 2V curves is greatest when the semi-major diameter has a value of 90°; this occurs when an optic axis lies 90° from the spindle axis (the n_o curve is coincident with the circular sections of the indicatrix). Near this most favorable portion of the diagram an error in the measurement of the semi-major axis is relatively uncritical, particularly if the

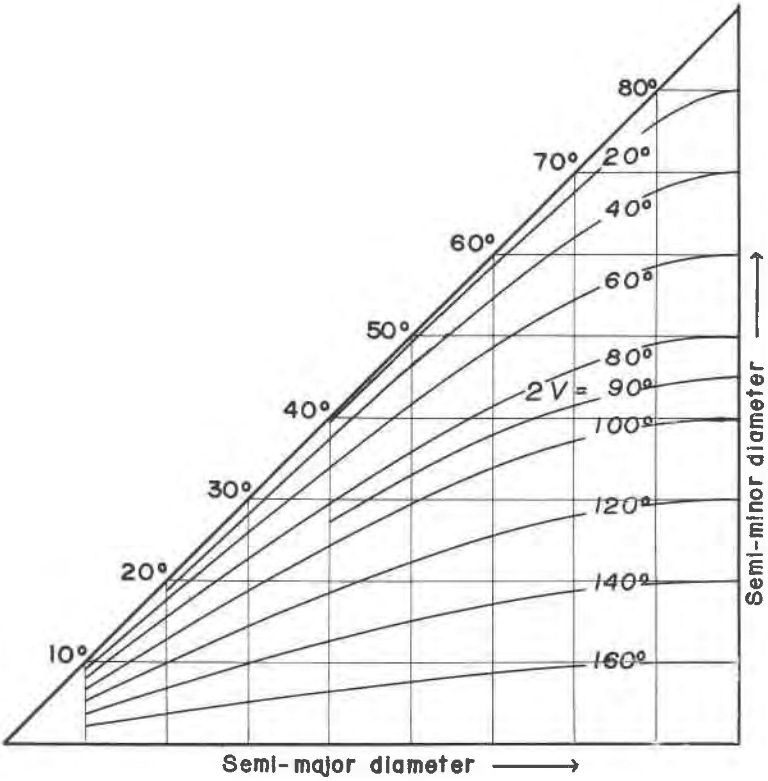

FIG. 1

obtuse bisectrix lies on the polar extinction curve, *i.e.* at the center of the n_o curve, but, whatever the value of 2V, an error in the measurement of the semi-minor diameter will result in an inaccuracy of twice that size in 2V. In other portions of the diagram variations in the semi-major diameter become important and errors in the semi-minor diameter are alarmingly more critical; the utility of the portions of the diagram in which the semi-major diameter has a value less than 40° is doubted. Joel's equivibration curve method fails with some crystal/spindle orientations because it is impossible to obtain sufficiently accurate readings from the spindle and microscope verniers to make the results meaningful; these same physical limitations apply to the other methods for 2V determination on the spindle stage (except Noble's) and it must not be expected that fragments mounted on the spindle in an orientation unsuitable for the application of the n_o curve method will yield up an accurate value for 2V by another mathematical process.

It will be found that fragments mounted unfavorably for the determination of 2V will also be unsuitable for the precise location of β and the other principal vibration direction situated on the equatorial extinction curve, since the great circles that pass through the points of intersection of the equatorial curve with the great circle 90° from the spindle direction (P_o) become too nearly coincident with the equatorial curve for points of tangency with it to be located with certainty (Garaycochea and Wittke, 1964, fig. 2), and the locus of the mid-points on the groups of great circles intersecting the equivibration curve (Joel, 1963a, fig. 2) does not cut the equatorial curve at a high enough angle to be helpful; also the arc subtending 90° with the principal vibration direction on the polar curve cuts the equatorial curve at inconveniently low angles.

It is however fortunate that some of the properties of the polar extinction curve enable a rapid check on the suitability of crystal/spindle orientation to be made before undertaking any plotting. Both the polar extinction curve and the n_o curve pass through the projection point of the spindle axis (P_o) and, measured from P_o the n_o curve intersects great circles at twice the intercept of the polar extinction curve. Thus for any crystal/spindle orientation it is certain that the angular distance from P_o to the remotest part of the polar extinction curve cannot exceed the semi-major diameter of the n_o curve, also it cannot be less than the semi-minor diameter: it will normally lie between the two. If it is decided that no measurements shall be conducted on a crystal that has an orientation relative to the spindle such that the semi-major diameter of the n_o curve is less than 40°, this can be ensured by eliminating mountings in which the polar extinction curve does not meet or cut a small circle of radius 40° about P_o.

Mountings in which an optic axis coincides with the spindle axis will have the remotest part of the polar extinction curve at an angle equal to the semi-minor diameter of the n_o curve, thus the test will eliminate suchlike mountings of crystals with a 2V of less than 80°, whereas the simple restriction that the semi-major axis of the n_o curve may not be less than 40° should permit crystals with a 2V as small as 66° to be accepted for measurement in this orientation. Consequently the test will reject a few reasonably favorable mountings, but it is probably better to reject these few than to waste time plotting for unsuitably mounted crystals.

Practical Procedure

The "40° test," which has been stated before but without any explanation or justification (Wright, 1965), is applied as follows: rotate the spindle stage (or synchronous polars) so that the spindle direction is 40° from the direction of one of the crossed polars: if the crystal can be brought into extinction at any position by rotation of the spindle alone, continue with detailed measurements, but if the crystal retains birefringence at all times during rotation, remount it in a different orientation on the spindle.

It may be noted here that grains that are mounted in orientations that are marginally favorable will extinguish once on rotation of the spindle through 360° (small circle 40° from P_o is tangential to the polar extinction curve); in reasonably favorable mountings there will be two extinctions per rotation (40° circle cuts the polar extinction curve), and in the most favorable mountings there will be four extinctions (40° circle cuts both polar and equatorial extinction curves).

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UPPER STABILITY OF MUSCOVITE

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Introduction

Muscovite is an important constituent of metamorphic rocks and is common in acidic igneous rocks. It is one of the first minerals to form in the metamorphism of pelitic sediments, and its disappearance marks higher grade metamorphic assemblages. A knowledge of its upper thermal stability, therefore, is useful to the petrologist.

Determinations of the stability of muscovite have been made previously by Yoder and Eugster (1955) and Crowley and Roy (1964) and of muscovite+quartz by Segnit and Kennedy (1961). All three studies reported the observed breakdown of muscovite but not the formation of muscovite from its anhydrous breakdown products, sanidine and corundum, near the breakdown temperature. Thus the establishment of equilibrium was not demonstrated. The recent work of Evans (1965) gives a determination of the upper stability of muscovite at 2 and 3 kb. These results (Evans, 1965) agree closely with those of the present study. It is interesting to note that Evans' experimental method was based upon reaction reversal.

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