A CHART FOR MEASUREMENT OF OPTIC AXIAL ANGLES

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Introduction

The simple petrographic microscope is the most widely used instrument for the study of the optical properties of minerals. Therefore any method to measure these properties in this way should receive careful attention.

In the interference figure normal to the acute bisectrix the optic (axial) angle (2V) can be determined by measuring the distance (2D) between the melatopes (points of emergence of the optic axes). 2V can now be calculated with the aid of the equation of Mallard:

$$D = K \sin E = KN_Y \sin V = KN \sin H; \tag{1}$$

where

D = half the distance defined above, measured in scale units of the eyepiece;
K = a constant dependent on the system of lenses used and on the scale of the micrometer eyepiece;
V = half the true optic angle;
E = half the optic angle as measured in air;
H = half the optic angle as measured in a medium with refractive index N;
N_Y = intermediate refractive index of the crystal;
N = refractive index of another medium (e.g. oil below immersion objective).

For further details of this relationship the reader is referred to a textbook on optical crystallography.

The constant K must be calculated or found by measurement of a mineral of known optic angle.

H. Winchell has published a chart[1] based on this equation. Each combination of lenses used (i.e. each value of K) can be plotted on the chart as a straight line. When this is done 2E (or 2V, when N_Y is known) is read directly for any distance 2D (measured in scale units of the eyepiece, using the Bertrand lens).

Especially in cases where several sets of lenses are used in routine work for the measurements of optic angles, the new chart gives a practical solution. Further details are given below.

The chart here suggested

In the construction of this chart the constant K is eliminated by plotting not 2D, but $d = 2D/2R$:

$$d = \frac{2D}{2R} = \frac{2KN_Y \sin V}{2KN \sin a} = \frac{N_Y \sin V}{A}; \tag{2}$$

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[1] Winchell, H., A chart for measurement of interference figures: *Am. Mineral.*, **31,** 43 (1946).

where

$2R$ = diameter of interference figure;
N = refractive index of medium below objective (immersion oil or air);
a = angular aperture of the objective;
A = numerical aperture of the objective;
other symbols as in equation (1).

When this is written in another way

$$\frac{d}{N_Y} = \frac{\sin V}{A} \tag{3}$$

the function is derived on which the chart is based. It is constructed in the same way as the well-known birefringence chart of Michel Lévy. The ordinate is divided from $N_Y = 1.00$ to 2.00, the abscissa from $d = 0.00$ to 1.00. Each value of (sin V)/A, for which 2V is a whole number is represented by a line which intersects the horizontal lines $N_Y = 1.00$ and $N_Y = 2.00$ at $d = (\sin V)/A$ and $d = (2 \sin V)/A$ respectively, and the ordinate at $N_Y = 0.00$. In place of the (sin V)/A values the chart gives directly those of 2V.

The use of the chart

The chart is designed for use when one objective with known numerical aperture (A) is used in routine work.

The chart given here is constructed for objectives with $A = 0.85$, which are widely used for the measurement of optic angles. When an objective of another aperture (A') is used, the chart can be consulted after multiplication of the measured d-value by $A'/0.85$ (which is easily done with a slide rule). When, however, such an objective is used in routine work, it will be worth while to make another chart to meet this special case.

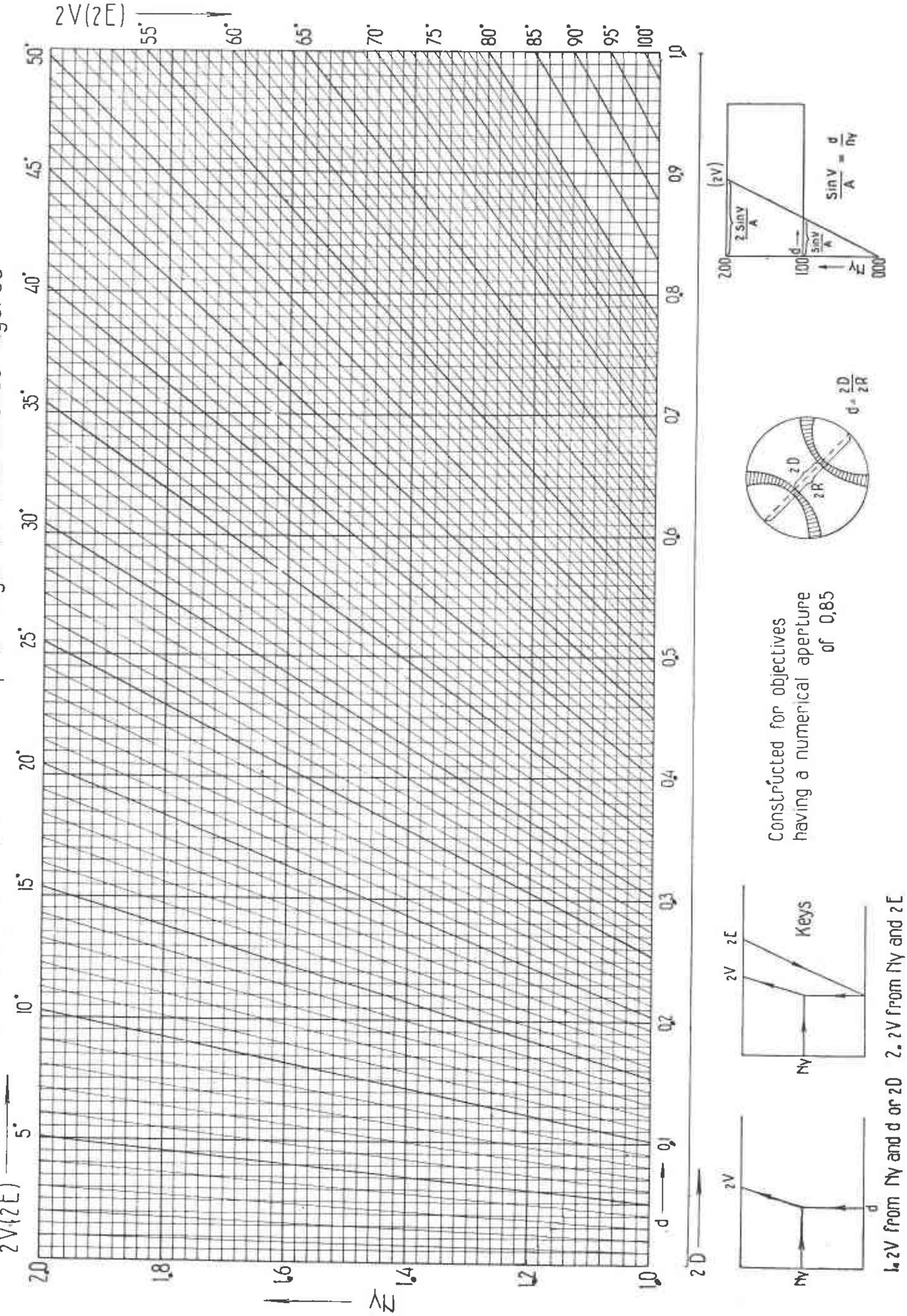
When a definite set of lenses is frequently used for the measurement of optic angles a $2D$-scale can be plotted along the base of the chart for this particular combination. This is done by measuring the diameter of the interference figure in scale units of the micrometer eyepiece. Should this e.g. be 31.5 scale units, then the distance in the chart between $d = 0.00$ and $d = 1.00$ should be divided in 31.5 equal parts. Along this scale $2D$ can now be used in the chart directly.

The chart can also be used with a simple petrographical microscope without a Bertrand lens; d is then directly estimated in the interference figure as seen without an eyepice. For the determination of a mineral this will suffice in most cases.

The reading of the chart

To obtain 2V from d or 2D the chart is used as indicated by Key 1. As the value $N_Y = 1.00$ is included, the chart can be used also to obtain

Chart for measurement of optic angle in interference figures



1. 2V from Nγ and d or 2D 2. 2V from Nγ and 2E

Constructed for objectives having a numerical aperture of 0,85

2V from 2E and N_Y, in so far as those values are covered by the graph (Key 2).

As higher and lower values of d (or 2D) are measured with the same degree of accuracy, linear scales are better adapted to the problem than are logarithmic ones.

It will be seen that the reading is of high accuracy, each degree of 2V being represented by a line. Any error made will thus be caused chiefly by the fact that the Mallard equation is an approximation.

The use of oblique interference figures

It is equally possible to measure optic angles in interference figures, in which the acute bisectrix is not well centered. Strictly speaking, the distance between the melatopes should now be measured in two parts, *i.e.* from the center of the interference figure to each of the melatopes. From these two distances $2D'$ and $2D''$ the values 2V′ and 2V″ should then be read separately from the chart and computed afterwards: $2V'+2V''=2V$.

It is seen from the chart however that 2V is almost proportional to d; therefore in practice $2D$ can be measured and used in the chart directly, just as in sections normal to the acute bisectrix. The error will be of the order of 1° or less. The optic plane, however, should be perpendicular or nearly so.

AN EASY METHOD TO OBTAIN *X*-RAY DIFFRACTION PATTERNS OF SMALL AMOUNTS OF MATERIAL

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It is often desirable to prepare *x*-ray powder diffraction patterns of very small amounts of material. Collodion may be used to work the mineral powder to a small ball between the fingers. It requires much practice to achieve success. The resulting ball may be too large, and some material is often lost.

An easy method to prepare balls which yield good powder diffraction photographs, is as follows: Transfer the small grain, which may weigh less than 0.005 mg., or measure less than 0.1 mm. in diameter, to a clean glass slide. Cover it with a small drop of thin rubber solution (such as can be obtained in a bicycle repair kit) which has previously been placed on another glass slide. The grain can now be ground in the solution between the glass plates without losing any material. Short strokes will prevent the powder from spreading out too much. By inspection under a binocular microscope one can ascertain when the material is fine enough.