DETERMINATION OF EXTINCTION ANGLES IN AUGITE AND HORNBLENDE WITH THE UNIVERSAL STAGE ACCORDING TO THE METHOD OF CONRAD BURRI.

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ABSTRACT. An advantageous method for determination of extinction angles in hornblende and augite with the universal stage is described. The procedure, originated by Conrad Burri, is based on determination of the coördinates of two morphological reference planes in the vertical zone. The necessary data are obtained during routine mineral examination, and the method offers both a saving of time as well as greater inherent accuracy as compared with the usual statistical thin-section approach.

IN 1931 Conrad Burri, of the Mineralogisches-Petrographisches Institut, E.-T. Hochschule, Zürich, Switzerland, presented a rapid, practical universal-stage procedure for determining extinction angles in augite and hornblende.[1] It is felt that this advantageous method should be made more readily available to English-speaking students. Recognition of its simplicity and applicability to general petrographic study should further stimulate universal-stage work.

The method affords appreciably higher accuracy than that obtainable by ordinary thin-section techniques. Only one section of a crystal showing (110) cleavage is required. There is no need for repetitious measurement to secure the maximum extinction angle, and tedious searching for suitably oriented grains is virtually eliminated. Required manipulations are performed as part of routine mineral examination. The procedure is particularly well adapted to differentiation of the orthorhombic and monoclinic pyroxenes.

The method is based directly upon the relationships between the indicatrix and fixed crystalligraphic directions in minerals belonging to the normal class of the monoclinic system. In all such crystals there is but one plane of symmetry. In this plane lie crystallographic axes a and c, while b is the only symmetry axis. One of the three axes of optical elasticity always coin-

[1] "Bestimmung der Auslöschungsschiefe monokliner Augite und Hornblenden auf (010) mittels beliebiger Schnitte." Schweizerische Min. u. Petr. Mitt., Vol. 11, pp. 285-289, 1931.

cides with *b*. The other two, therefore, lie in the symmetry plane but are not coincident with either *a* or *c*. Since in augite and hornblende N_β coincides with *b*, the optic axial plane, containing N_α and N_γ lies in the symmetry plane (010). Conventionally, the extinction angle is given as that between N_γ (=Z) and the *c* axis, i.e., $Z \wedge c$ equals the extinction angle in degrees.

In universal stage determination of biaxial minerals, coördinates of the three optical symmetry planes are obtained and their respective poles and great circles plotted on a stereogram. With this procedure the pole of N_γ is available for reference. If now, the zone axis [001], which is also the *c* axis, were located, the extinction angle could be secured from the projection. In Burri's technique, the position of the zone axis [001] is determined by constructing the great circle of a plane normal to two morphological reference planes in the vertical zone. Construction of the pole of this plane then gives the location of [001].

The optical symmetry axis N_β is normal to the face b(010) in both hornblende and augite. Hence, the great circle of N_β is used as the first reference plane in the vertical zone. Since cleavage in both these minerals is parallel to (110) measurement of the position of one such plane provides a second reference plane in this zone.

Coördinates of two optical symmetry planes in the selected crystal are measured. Those of the third symmetry plane are later obtained by construction when the data are plotted. Thus, the location of the optic axial plane, which contains N_γ, is determinable whether or not its position is fixed by actual measurement. The coördinates of one cleavage plane in the crystal are now determined.

Directions for measurement of cleavage or twinning planes are here given briefly. Remove substage condensor and analyzer from the microscope system. Insert high magnification objective. Place a piece of frosted glass or sheet of oiled paper between mirror and lamp. Adjust substage diaphragm until the cleavage trace appears sharpest. Rotate on A_1 (vertical axis of universal stage coincident with microscope axis when stage is in rest position) bringing the cleavage line parallel to the N-S crosshair. Rotate on A_2 (N-S horizontal axis of stage) until the cleavage trace makes the finest and sharpest possible line. Check adjustment by observing the Becke line which should spread out evenly on both sides of the trace if the plane is vertical. Note down the A_1 and A_2 readings.

With the aid of a Wulff stereographic net the great circles and poles of the three optical symmetry planes, together with the pole of the measured cleavage plane, are plotted (Fig. 1). The great circle connecting the cleavage plane pole and that of N_β is drawn. The pole of this great circle is then constructed. This is the pole of the desired zone axis [001]. If

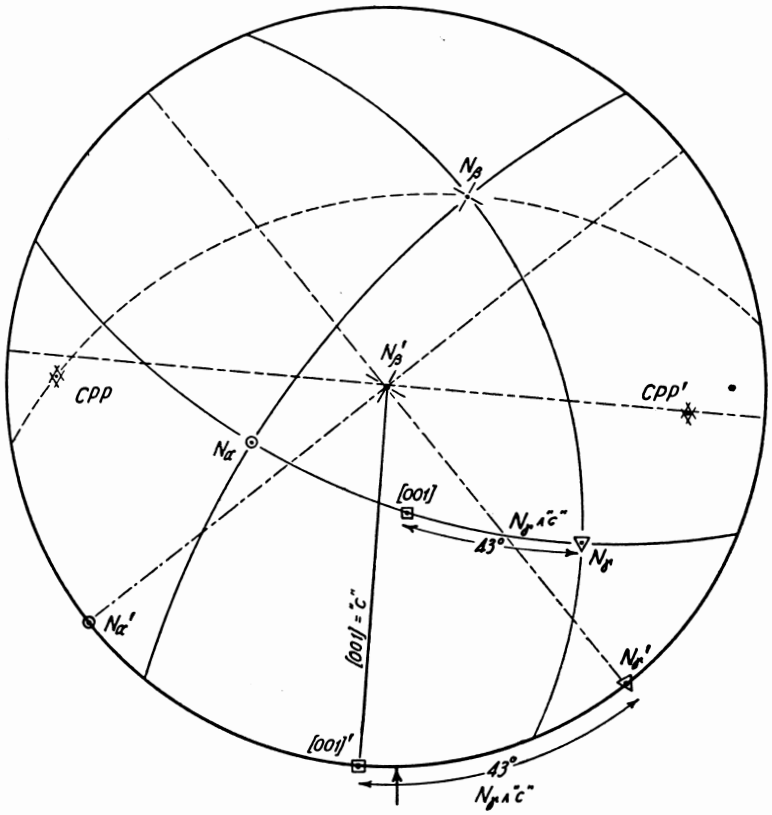

Fig. 1. Stereogram of measured augite crystal from gabbro near York, Maine, showing method of determining the extinction angle as herein described. Coördinates are represented in the stereograms as follows: N_α by a circle, N_β by a cross, N_γ by a triangle, and the pole of the cleavage plane by a lozenge. The following table gives the angular values of the coördinates.

	A_1	A_2	
N_α	201°	48°	L(eft) (constructed)
N_β	67°	33°	L
N_γ	139°	22°	R(ight)
cleavage pole	357°	8°	R = cleavage plane pole

both measurement and plotting are accurate, it will fall on the great circle containing N_α and N_γ.

To obtain the extinction angle, rotate the stereogram until poles N_γ and [001] lie on the same great circle of the net. Along the arc of this great circle read off the number of degrees between these two poles (Fig. 1).

Somewhat higher accuracy may often be obtained if the stereogram is rotated so that the optic axial plane becomes the projection plane. Poles N_α, N_γ, and [001] then fall on the projection circumference. The pole of N_β will lie at the center. The optical symmetry planes and that defined by the transposed N_β and cleavage plane pole are now represented by straight lines. The extinction angle is obtained as before, except that it is now measured along the net circumference.

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