A NEW METHOD OF DETERMINING THE EXTINCTION ANGLE OF MONOCLINIC MINERALS, ESPECIALLY OF PYROXENES AND AMPHIBOLES, BY MEANS OF RANDOM SECTIONS

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With 3 Text-figures

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I. INTRODUCTION

The extinction angle in random thin sections of monoclinic minerals, especially of pyroxenes and amphiboles, has been approximately measured by finding the maximum value of the extinction angle of numerous crystals which were cut nearly parallel to the zone of [001]. The extinction angle $(Z' \wedge c')$ obtained by the above method is near to the true value $(Z \wedge c)$, but it is not absolutely exact unless a crystal parallel to (010) is found. Recently, C. BURRI(1) and H. NIELAND(2) separately have devised two procedures by which the extinction angle in random thin sections of monoclinic pyroxenes and amphiboles are determined with the aid of the universal stage. In this paper a new method is proposed which is an improvement on the forgoing procedure in that it increases the accuracy of the determination.

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(1) C. BURRI: Bestimmung der Auslöschungsschiefe monokliner Augite und Hornblenden auf (010) mittels beliebiger Schnitte. Schweiz. Min. Petrog. Mitt., Bd. 11, 1931, SS. 285–289.

(2) H. NIELAND: Zur Bestimmung von Auslöschungsschiefe und Kristallformen mittelst des Drehtisches nach Fedorow. Cbl. Min. Geol. Paläont., A, 1932, SS. 215–218.

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II. PROCEDURE

Principle :—

Most of the monoclinic minerals, especially of the pyroxenes and the amphiboles, have an optic axial plane parallel to (010) and are twinned on (100). Taking advantage of these properties, the present method is designed to measure the extinction angle ($Z \wedge c$) by means of locating three axes of elasticity ($X, Y, Z,$) and three planes of the axes of elasticity (XY, XZ, YZ) of two twinned individuals with the aid of the universal stage and, finally, by finding the position of the crystallographic axis c on the net.

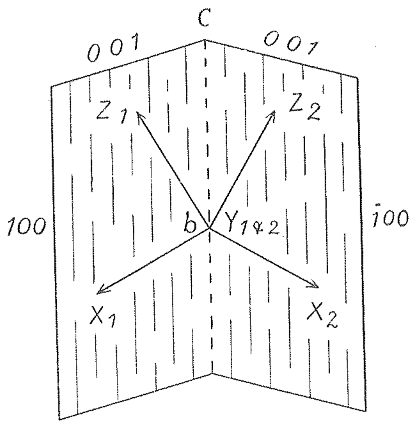

Fig. 1. Crystallographic and optic orientations of monoclinic twinned crystal on (010).

In monoclinic minerals, the crystallographic and optic orientations of the twinned crystal on (010), that is the optic axial plane, is as shown in Fig. 1. In twinned individuals, both XZ planes are parallel owing to the fact that Y_1 and Y_2 are parallel, and therefore, Z and X, respectively, intersect with axis c at an equal angle.

$$Z_1 \wedge c = Z_2 \wedge c \qquad X_1 \wedge c = X_2 \wedge c$$

Consequently, the point of axis c is settled by locating the middle point of arc Z_1Z_2 or arc X_1X_2 after projecting X, Y, and Z of two twinned individuals. Then the value of $Z \wedge c$ is directly obtained on the net.

Treatment :—

(1) Select a twinned crystal of which it is intended to measure the extinction angle. Although any random thin section will do, it is better to select a section in which the three planes of the axes of elasticity are actually observed in order to obtain an accurate result.

The suitable section as above stated is in actual fact very rare. In most crystals, it is common that only two planes of the axes of elasticity are observed while the other is settled graphically on net. In these cases, it is better to select a crystal which is so cut that the angle between the plane of section and the optic axial plane is smaller than 50°–60°, not larger. This holds true, in the latter case, one of two planes of the axes of elasticity actually projected is the optic axial plane the position of which is not accurately settled on account of the incomplete extinction resulting from the dispersion of the optic axis. In the former case, however, owing to the fact that two planes of the axes of elasticity actually located are XY and YZ, the extinction of which is complete, these two planes and their poles, X and Z, are exactly plotted. That the random crystal is cut nearly parallel with either the former or the latter is easily understood from its outline, cleavage, birefringence and the direction of the twinning plane.

(2) With the universal stage, project the axes of elasticity and their planes of two twinned individuals. From the fact that Y and XZ of two individuals should coincide respectively, it is possible to judge whether the projection is accurately made or not. In the crystal the extinction angle ($Z \wedge c$) of which is near to 45° as in augite, the projection must be so located that X and Z of two individuals do not lie one upon another. In other words, the projection is performed through accurately settling two planes of axes of elasticity, XY and YZ.

(3) On the net, locate the center point c of arc Z_1Z_2 or arc X_1X_2 which lie together upon the same great circle. The point c is the projection of the crystallographic axis c.

(4) Next, on the net, measure the angle between c and Z. This is the extinction angle which we intend to obtain.

(5) Lastly, in order to determine the kind of twin which is under observation, project the actual twinning plane. If the crystal is twinned on (100), the projection has to coincide with the great circle upon which c and $Y(b)$ lie.

III. EXAMPLE

By the present method, the writer measured the extinction angles of augite and hornblende which are phenocrysts of andesite from various localities in Japan. As a specific example, there is described below the procedure of determination of the extinction angle of augite in Daizaki lava, olivine-hypersthene-augite-andesite, from Daizaki, Island of Urup, Tisima (Kurile) Islands.

The outline of the crystal selected and the stereographic projection of its optical elements are as shown in Figs. 2 and 3. In order to make easy to understand the plane of the section of augite and the arrangement of its optical elements, in Fig. 3, the plane of projection is taken to be parallel to that of the section, and Figs. 2 and 3 are placed in the same direction. As shown in Fig. 3, the crystal is

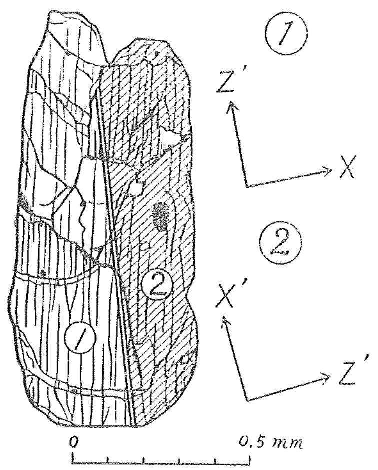

Fig. 2. Twinned crystal of augite and its optic orientation.

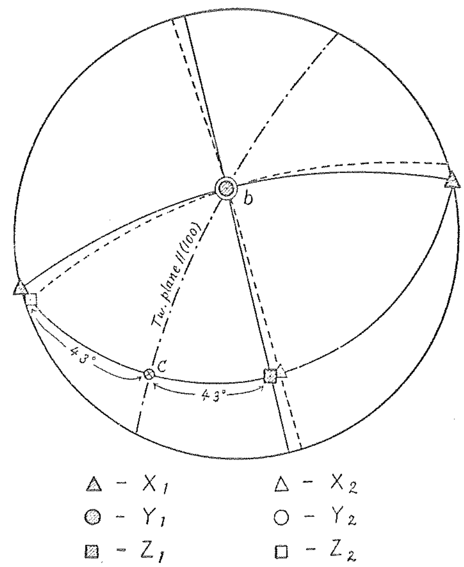

Fig. 3. Stereographic projection of optical elements of two twinned individuals.

so cut that the thin section intersects with the optic axial plane at an angle of 24° and accidentally contains X of the twinned individuals (1). Though Y and XZ of two individuals are not actually observed, X, Z, XY and YZ are so accurately located that Y and XZ are projected with complete coincidence. After finding the crystallographic axis c, the center point between arc Z_1Z_2 or arc X_1X_2, the extinction angle, that is the angle between c and Z, is obtained on the net. Thus the value 43° is determined.

For comparison, the writer measured the extinction angle ($Z' \wedge c'$) of the same crystal which is so cut that the section inclines at 24° with the optic axial plane and is parallel to X of the twinned individuals (1), obtaining the following results;

Twinned individuals	(1)	$Z' \wedge c' = 48°$
,, ,,	(2)	$Z' \wedge c' = 37°$.

It is interesting that the value determined by the present method is nearly the same as the mean value of the above results which are obtained from a random thin section and individually show a remarkable difference from the value.

VI. ACCURACY

The present method, projecting merely the axes of elasticity and the planes of the axes of elasticity of two twinned individuals, may be almost free from error if careful treatment is accorded. It is necessary, however, to select a twinned crystal cut adequately, as stated above, since the accuracy of the present method depends upon the direction of the plane of a thin section. Moreover, that Y and planes XZ of two individuals coincide respectively, and that the angle of arc X_1Z_2 is equal to that of arc Z_1X_2, both of which result from the exact projection, serve to decrease the error. Therefore, if an accurate projection is made it is possible to expect a sufficient accuracy in the present method.

V. SUMMARY

The writer has devised a procedure by means of which the extinction angle in random thin sections of monoclinic minerals, especially of pyroxenes and amphiboles both which prevail in igneous and metamorphic rocks, is accurately determined. The principle and the treatment of the present method is, briefly, as follows:

1. Making use of the general property of monoclinic pyroxenes and amphiboles which are twinned on (100), project the optic elements of two twinned individuals with the aid of the universal stage.

2. Locate the point of axis c through settling the middle point of arc Z_1Z_2 or arc X_1X_2 on the great circle which corresponds to the optic axial planes of two individuals.

3. Lastly, obtain the value of $Z \wedge c$ on the net.

Though the present method is more complex and requires more time than BURRI's and NIELAND's methods, it, being free from error when carefully carried out, gives a more accurate result than those methods. Consequently, it is reasonable to consider that the present method is more suitable than the above two methods in determining the extinction angle in random thin sections of monoclinic pyroxenes and amphiboles, although it has the defect that one must select a thin section cut in a favourable direction.