for the case of the reciprocal lattice; corresponding letters without the asterisk may be used for the direct lattice should occasion arise.

It will be noted that these are much the same symbols as used on pp. 1049–1051, except that the capitals are marked with an asterisk, and the $t^*$ is replaced by $i^*$. The use of the "meaningless" capitals is much simpler for the printer.

Professor M. J. Buerger informs me[7] that nearly all of his precession orientation work is done using a "layer-line" screen with a *circular* (not annular) opening of 12 mm. diameter (ideal $r=5$ mm. with an extra mm. for tolerance) with $s=28.4$ mm. and $\bar{\mu}=10°$. If my 7 mm. radius screen (fn. 6*a*, p. 1041) is used with a circular opening (actual diameter 17 mm.) at $\bar{\mu}=10°$, then it will not cut off the ends of the longer radiating Laue streaks if the orientation error is not greater than 1° with $s$ at 39.7 mm. With a larger error in orientation, the screen should be moved closer to the crystal; thus with the screen at $s=31.7$ mm., the orientation error may be as much as 3° without decapitating the longer Laue streaks. This method of taking orientation pictures is very rapid and yields "clean" negatives that lack the sometimes-confusing $n$-level Laue streaks.

*Erratum*

Assuming the negative ends of the $a$ and $b$ axes are where indicated in Fig. 36 (p. 1049), then $+c^*$ must extend *up* normal to the paper (fn. 8 on p. 1048 should be corrected). This means that $+c^*$ must extend to the *left* in Fig. 37*b*, hence the signs for all the digits of the node indices in this figure must be reversed. Also $+c^*$ should be changed to read $-c^*$ on p. 1051 (line 8 from base) and p. 1054 (line. 2).

[7] Personal communication, Dec. 24, 1952 and Jan. 13, 1953.

## TWO DEFINITIONS OF POSITIVE AND NEGATIVE EXTINCTION ANGLES IN THE PLAGIOCLASE FELDSPARS: ONE LEADING TO CONSISTENCY AND CLARITY, THE OTHER TO INCONSISTENCY AND CONFUSION

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An extinction angle has been defined as positive by Duparc and Reinhard,[1] by Rosenbusch and Mügge,[2] and by Chudoba,[3] if the rotation of

[1] Duparc, L., and Reinhard, M., La détermination des plagioclases dans les coupes minces: *Mémoires de la Société de Physique et d'Histoire Naturelle de Genève*, **40**, 14, 22 (1924). (It is to be noted that the statement of the definition of a positive extinction angle by Duparc and Reinhard was not accompanied by any qualification limiting the application of the definition to the upper half of the crystal.)

the line generating the angle proceeds clockwise from the reference direction (cleavage trace, trace of composition plane of twins, trace of crystal face) to the $X'$-vibration direction. (Under the microscope one actually turns the stage and crystal with respect to the line, the North-South crosshair, which remains stationary. Thus, if one first sets the trace of the 010-cleavage to coincide with the North-South crosshair and then rotates the stage counterclockwise through an angle less than 90° to a position of extinction, and if the vibration direction which then coincides with the North-South crosshair is the $X'$-vibration direction, the sign of the extinction angle is positive.) Stereographic projections of the extinction angles of the plagioclase feldspars with the trace of the 010–cleavage (or composition plane) as the reference direction have been published in several books.[4] Each of these projections gives the extinction angles for the upper half of the crystal. Of course, the numerical value of the extinction angle of any section of a crystal will be the same if the section is turned over. Hence from the numerical values of the extinction angles for the end of the crystal represented in the projection, one can obtain the numerical values of the extinction angles for the other end. The convention that an extinction angle is considered positive if the line generating the angle is turned clockwise from the reference direction to the $X'$-vibration direction necessitates that the sign of the extinction angle is reversed when the section is turned over. In conformity with this requirement, in the published stereographic projections the extinction angles at points on the circumference of the projection at opposite ends of a diameter have opposite signs (cf. Fig. 1); these two extinction angles, numerically equal, but opposite in sign, of course apply to the same section; the first extinction angle applies with one side of the section up, the second, numerically equal, but opposite in sign, applies when the section is turned over.

The statement was made by Duparc and Reinhard and by Rosenbusch and Mügge in the publications cited that in sections perpendicular to the $a$-axis the sign of the extinction angle is positive if the $X'$-vibration direction lies in the acute angle between the traces of the two perfect cleavages; to this these authors added the statement that in the case of sections perpendicular to the $a$-axis the sign of the extinction angle

[2] Rosenbusch, H.-Mügge, O., Mikroskopische Physiographie der petrographisch wichtigen Mineralien, Bd. I, 2te Hälfte, 5te Aufl., S. 745, Schweizerbart'sche Verlagsbuchhandlung, Stuttgart (1927).

[3] Chudoba, K., Die Feldspäte und ihre praktische Bestimmung, S. 13, Schweizerbart'sche Verlagsbuchhandlung, Stuttgart (1932).

[4] Cf. Duparc and Reinhard, *op. cit.*, Plates 1–8, and Rosenbusch-Mügge, *op. cit.*, Plates 30–35.

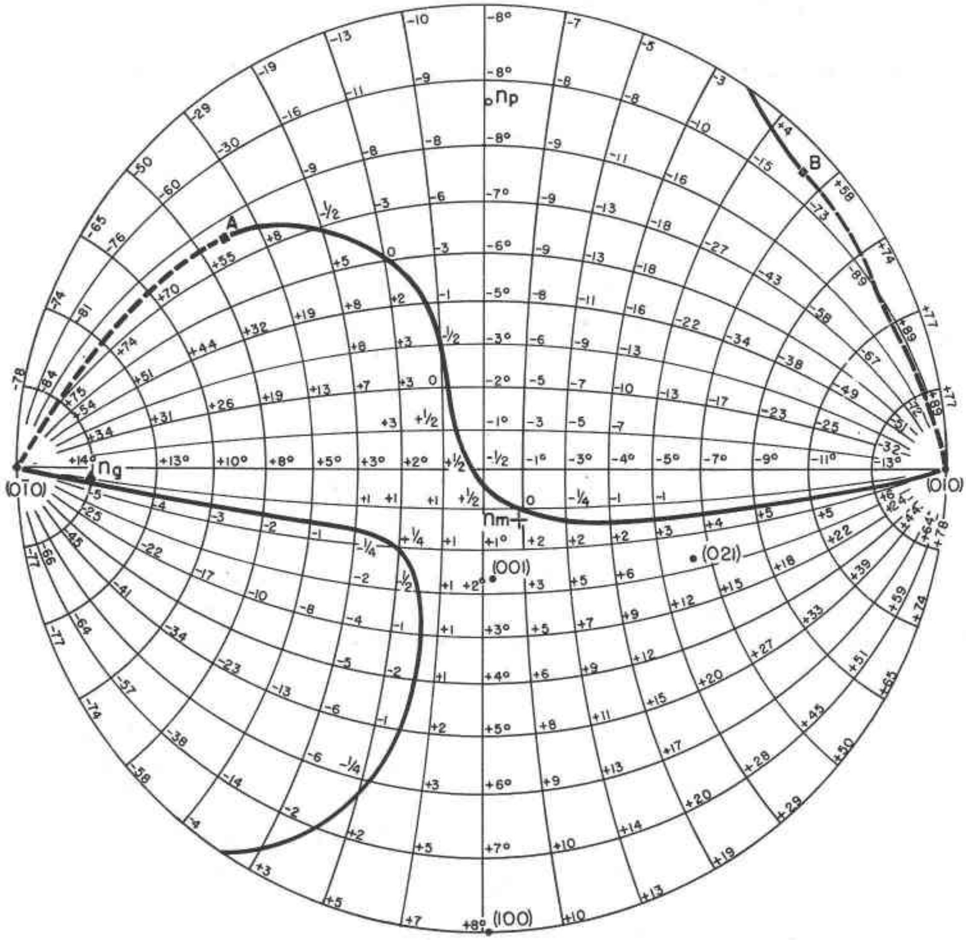


FIG. 1. Stereographic projection of the extinction angles of oligoclase from Duparc and Reinhard's "La Détermination des Plagioklases dans les Coupes Minces."

can practically always be determined, since the two perfect cleavages are practically always sufficiently developed so that their traces can be observed, but that in the cases of sections parallel to 001 or perpendicular to a bisectrix, the sign of the extinction angle usually cannot be determined.[5] Now the statement that the sign of the extinction angle of a section perpendicular to the *a*-axis is positive when the $X'$-vibration direction lies in the acute angle between the traces of the two perfect

[5] Chudoba made equivalent statements in the cases of sections perpendicular to 010 and sections perpendicular to the *a*-axis. *Op. cit.*, pp. 13, 23, 24.

cleavages conflicts with the original convention that an extinction angle is positive if the line generating the angle is turned clockwise from the reference direction to the $X'$-vibration direction. The acute angle forms the upper left corner of the section perpendicular to the $a$-axis when it is viewed from the positive end of the $a$-axis, and the upper right corner when it is viewed from the negative end of the $a$-axis. Thus with a section perpendicular to the $a$-axis, angles are turned counter-clockwise from the trace of the 010-cleavage (or composition plane) to a line lying in the acute angle between the traces of the perfect cleavages if one is looking at the section from the positive end of the $a$-axis, and clockwise if one is looking at the section from the negative end of the $a$-axis. The convention that with a particular section of a crystal the sign of the extinction angle is the same no matter which side of the section is toward the observer, requires that at a point on the projection sphere near some great circle, the sign of the extinction angle be the opposite of the sign of the extinction angle at a second point on the other side of and close to the same great circle, although the extinction angle does not pass through zero between these two points, a very unsatisfactory outcome. A convention that the sign of the extinction angle is the same no matter which side of the section is toward the observer requires that positive extinction angles be turned clockwise from the reference direction to the $X'$-vibration direction on one half of the crystal and counter-clockwise on the other half, a very unnatural and arbitrary rule. Moreover, with this convention along one half of the great circle arbitrarily chosen to divide the sphere of projection into two halves, positive extinction angles must be turned clockwise from the reference direction to the $X'$-vibration direction, and along the other half of this great circle, positive extinction angles must be turned counter-clockwise from the reference direction to the $X'$-vibration direction. In the stereographic projections of Duparc and Reinhard, and those of Rosenbusch and Mügge, however, the signs of the extinction angles at the opposite ends of any diameter of the great circle forming the circumference of the projection are not the same. Thus, Duparc and Reinhard, and Rosenbusch and Mügge did not adhere consistently to a convention that the sign of the extinction angle is the same no matter which side of the section is toward the observer. On the other hand, neither did they adhere consistently to the alternative convention that the sign of the extinction angle is positive if the line generating the angle is turned clockwise from the reference direction to the $X'$-vibration direction no matter which side of the section is toward the observer.

If the original convention that an extinction angle is positive when the line generating the angle is turned clockwise from the reference direction to the $X'$-vibration direction be applied to all sections of the crystal, then along any circle on the projection sphere the sign of the extinction angle will only change from positive to negative as the value of the extinction angle passes through zero. This convention is therefore a satisfactory one and does not lead to any inconsistency. It should be noted also that application of the original convention to both ends of a crystal enables one to determine the sign of every observed extinction angle even in those cases in which one cannot determine from which side he is viewing the section. With this definition of the sign of the extinction angle the published curves representing the extinction angles of the plagioclase feldspars for certain sections, or the maximum extinction angle in certain zones, presuppose that a particular side of each section is toward the observer. The curve for the other side is obtained by changing the sign of each value, or, in other words, by reflecting the original curve across the axis of abscissae. Thus, for example, the curve of the extinction angles in sections perpendicular to the *a*-axis viewed from the negative end of the *a*-axis is represented in Fig. 2*a*. The curve of the extinction angles in sections perpendicular to the *a*-axis viewed from the positive end of the *a*-axis is represented in Fig. 2*b*. With plagioclase feldspars there is no uncertainty as to which end of the *a*-axis this section is viewed from, because the angle between the traces of the two perfect cleavages in the plane of the section is perceptibly different from 90°. Therefore, one knows whether the value of the extinction angle that he measures is to be compared with the curve of Fig. 2*a* or with that of Fig. 2*b*. In the case of the maximum extinction angle in the zone perpendicular to 010 the curve given in numerous books is for the top half of the crystal; the curve for the bottom half is again obtained by changing the sign of each value, or, in other words, by reflecting the original curve across the axis of abscissae. In Fig. 3 the solid curve represents the maximal extinction angles for the zone perpendicular to 010 for the top half of the crystal and the dotted curve represents the maximal extinction angles for the same zone for the bottom half of the crystal. When an albite twin is found showing the maximum extinction angle of all the sections in the zone perpendicular to 010, the determination of the composition of the plagioclase by the use of these curves is unique, except in cases in which the maximum extinction angle is less than 17°. If the maximum extinction angle is less than 17°, and if the sign of the extinction angle is positive, the intersections of the horizontal line representing the observed positive maximum extinction angle with the two curves for the two ends of the crystal give two possible compositions of the plagioclase. Since it is not possible to prove from which side the section was viewed in this case, it is not possible to tell which of the

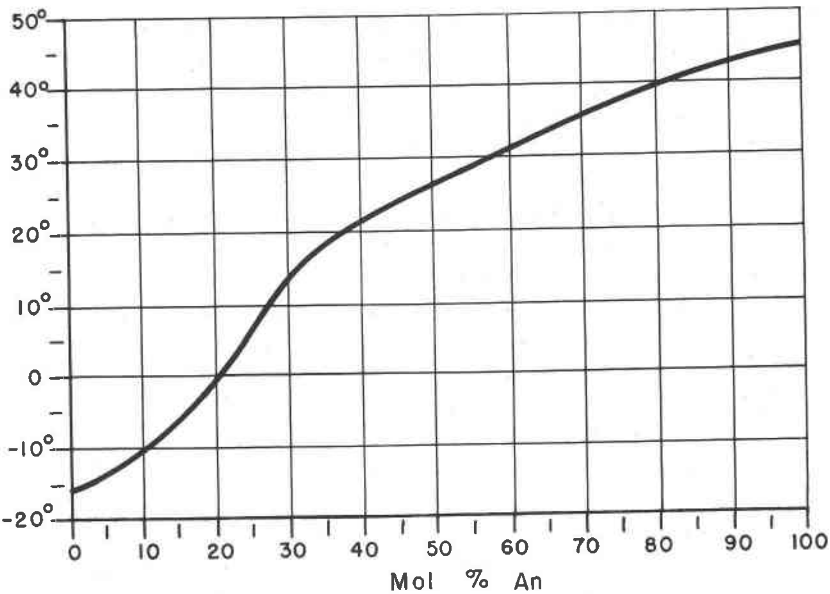


FIG. 2*a*. Extinction angles of the plagioclases in sections perpendicular to the *a*-axis viewed from the negative end of the *a*-axis.

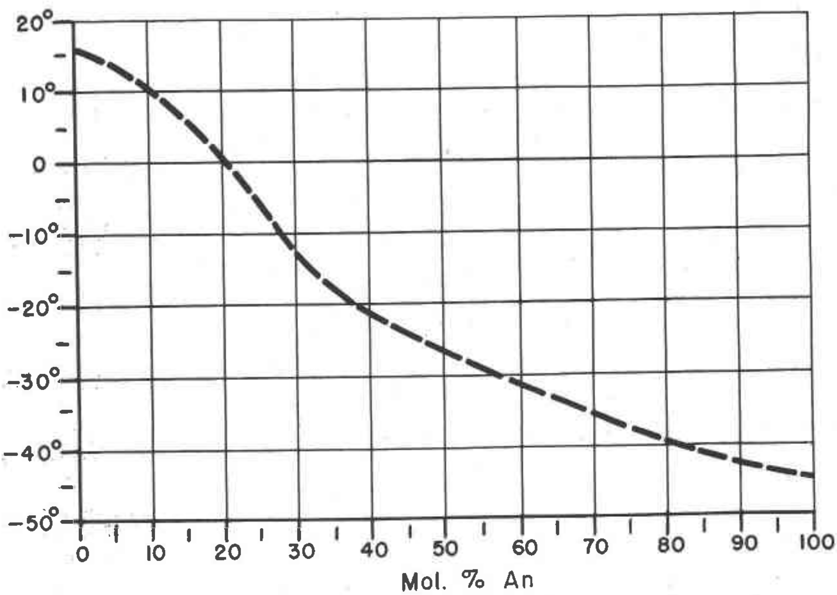


FIG. 2*b*. Extinction angles of the plagioclases in sections perpendicular to the *a*-axis viewed from the positive end of the *a*-axis.

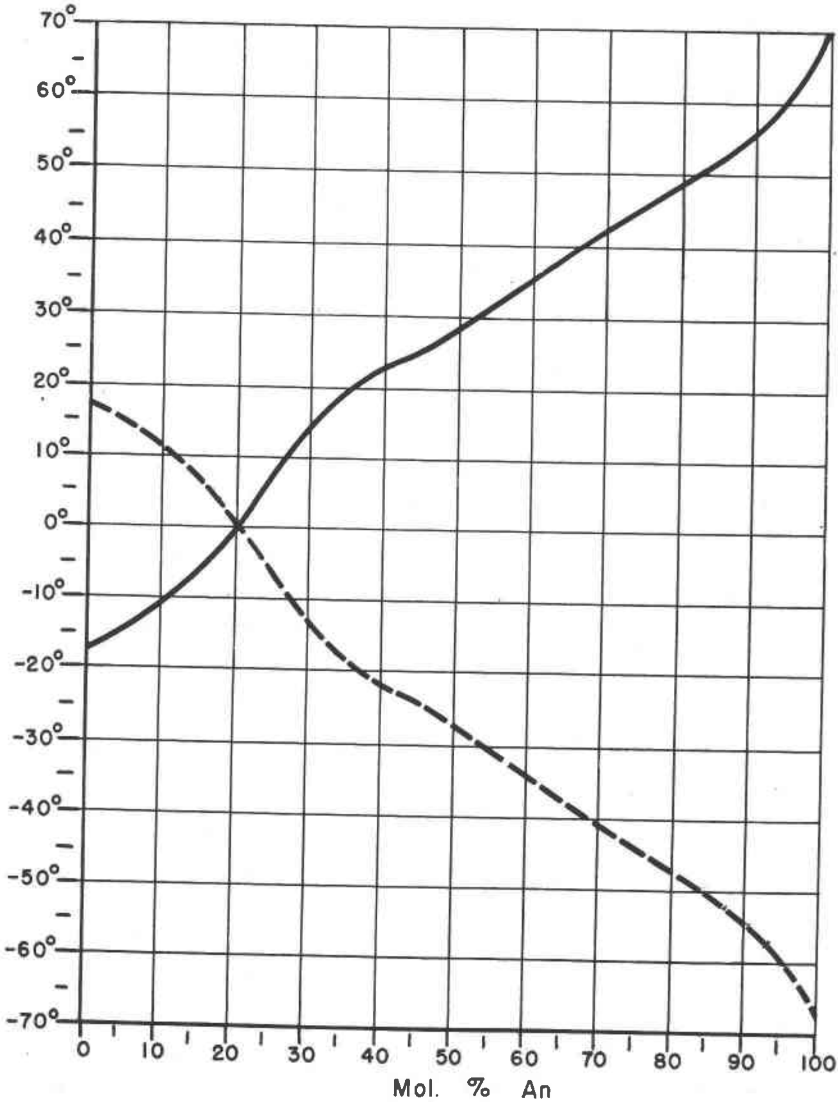


FIG. 3. Maximal extinction angles of the plagioclases in the zone perpendicular to the 010-pinacoid.

two alternative compositions is the correct one by the use of this method alone. If the sign of the maximum extinction angle were negative, the numerical value being the same as in the preceding case, the intersections of the horizontal line representing the observed negative maximum extinction angle with the two curves for the two ends of the crystal would again give two possible compositions, and these two possible compositions would be the same ones that were found in the preceding case.

## Conclusion

The confusion caused by the simultaneous use of two conflicting conventions for the sign of the extinction angle can and should be resolved by adherence to the one convention that the sign of the extinction angle is positive if the line generating the angle is turned clockwise from the reference direction to the $X'$-vibration direction no matter which end of the crystal is being viewed. (It must always be remembered, of course, that under the microscope one actually turns the stage and crystal with respect to the line, the North-South crosshair, which remains stationary. Thus if one first sets the trace of the 010–cleavage to coincide with the North-South crosshair and then rotates the stage counter-clockwise through an angle less than 90° to a position of extinction, and if the vibration direction which then coincides with the North-South crosshair is the $X'$-vibration direction, the sign of the extinction angle is positive.) This convention leads to simple, straightforward technique and to consistent statements of all the optical relations.

## STUDIES OF BORATE MINERALS: 1—*X*-RAY CRYSTALLOGRAPHY OF COLEMANITE[1]

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As part of a general *x*-ray study of borate minerals begun in the U. S. Geological Survey laboratories, the crystal structure of the most common calcium borate, colemanite, is being investigated. This investigation has begun with a redetermination of the space group and of precise lattice constants for colemanite. Powder patterns using Cu and Cr radiation have been measured and indexed.

The crystals of colemanite used came from Meyerhofferite Tunnel in Twenty Mule Team Canyon, Death Valley, Inyo County, Calif.; they were furnished by Waldemar T. Schaller, U. S. Geological Survey. The crystals used are small, colorless, transparent, prismatic elongated along [001], with large (110).

Weissenberg patterns, using Cu radiation, were prepared for the zero and upper levels around [001] and [010]. The systematic extinctions observed, namely that reflections $(0k0)$ with $k$ even only, and $(h0l)$

[1] Publication authorized by the Director, U. S. Geological Survey.