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Graphical Aids for the X-ray Determination of the Position of the Rhombic Section in Pericline-Twinned Feldspars

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With 8 figures in the text

Abstract

The X-ray methods for the determination of the position of the rhombic section in pericline twinned Feldspars, can be further simplified applying nomograms instead of calculating the results. The direct X-ray method, briefly described by LAVES and MICHAELIS DE SÁENZ (1973) is illustrated with some more detail.

Recently a direct method for the determination of the position of the rhombic section, by Buerger's precession method, was described by LAVES and MICHAELIS DE SÁENZ (1973). The aim of the present note is to furnish further helpful illustration as well as nomograms that avoid tedious calculations involved in both X-ray methods: the direct one and the calculative method, from the lattice constants.

Let us shortly repeat some main ideas:

Pericline twinning is said to occur in triclinic feldspars when two orientations exist, in a crystal, that can be turned into each other by an 180° rotation around the b-axis. In these twins the position of the interphase or composition plane, yields an additional information, although the twin law is sufficiently well defined by the symmetry operation. The composition plane in pericline twinning is called the *rhombic section.* It may be defined as a particular section of the triclinic "prism" {110}, {1$\bar{1}$0}, having the shape of a rhombus. Its diagonals named d_1 and d_2 are perpendicular, d_1 coinciding with the b-axis. The angle between d_2 and a is called σ. SCHUSTER (1881) defined the so called "*Schuster's rule*" that can be stated as follows: Looking upon (010), σ is measured as the deviation of d_2 from the a axis. If the rotation of a towards d_2 around b occurs in the same sense as the rotation of the trace of ($\bar{1}$01) (that

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is clockwise) the sign of σ is positive, if it is counterclockwise it is negative. It is recommended to give positive σ values to avoid confusions. (See Fig. 1 and 2.)

If this rule is followed the following formula applies:

$$\cot \sigma = \cos \alpha^* \operatorname{tg} \gamma . \tag{1}$$

Frequently, specially when applying the direct X-ray method it is useful to define the position of the rhombic section by the angle between this composition plane and the plane (001). This angle was already mentioned by v. RATH (1869) and was named s by TUNNELL (1952).

$$\operatorname{tg} s = \operatorname{tg} \alpha^* \cos \gamma . \tag{2}$$

The sign of s will also be taken conveniently as positive. Schuster's rule is applied. (Compare LAVES and MICHAELIS DE SÁENZ, 1973.)

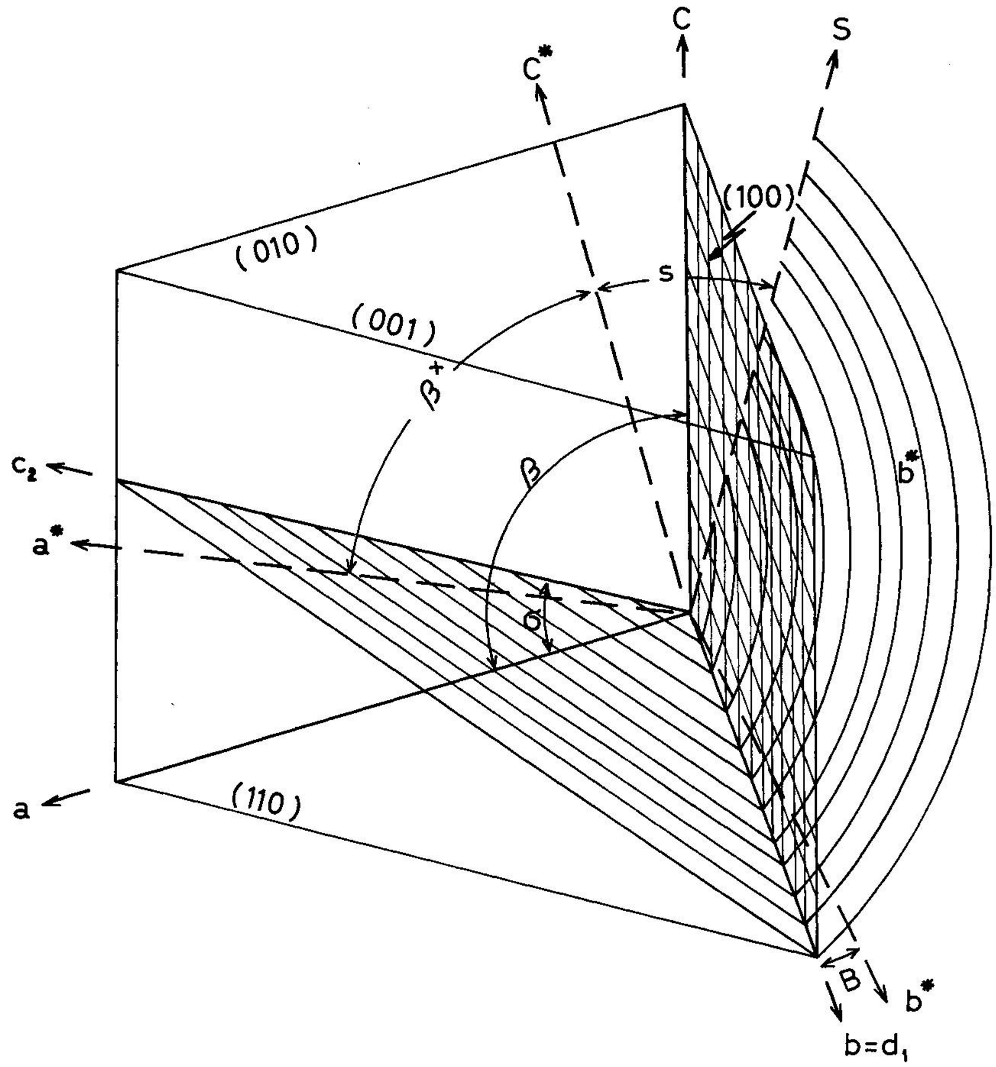


Fig. 1. Sketch illustrating the main crystallographic directions and angles of feldspars mentioned in this note as well as those elements used to determine the position of the rhombic section.

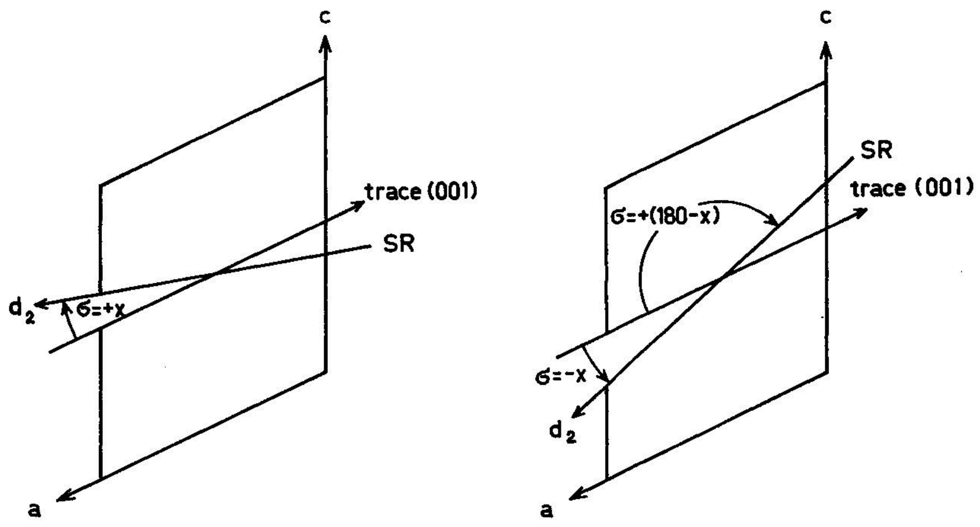


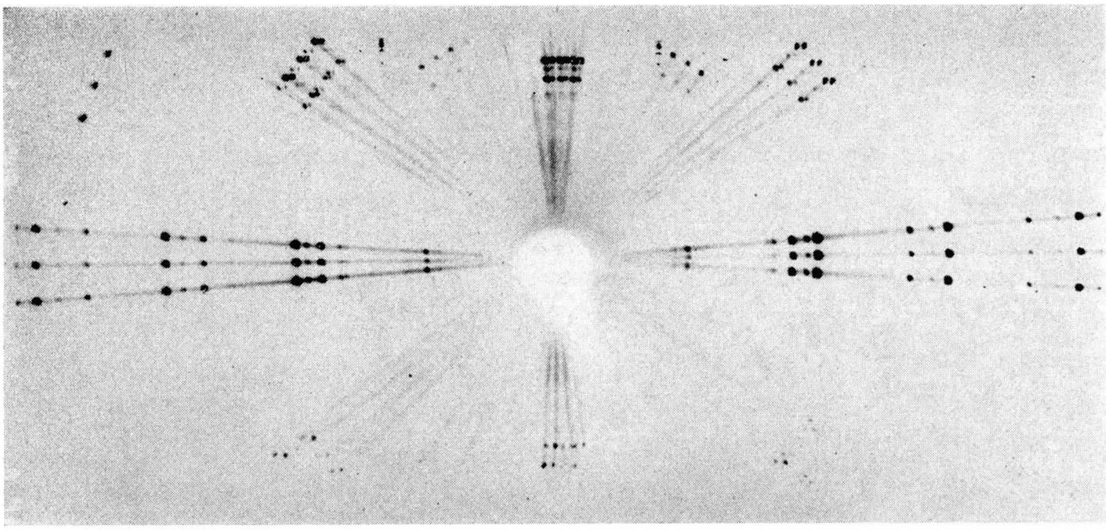
Fig. 2. Sign convention for the sign assigned to σ and s. In literature σ is usually given as an acute angle with a + or — sign. It seems to be convenient to give always positive σ and s values ranging from 0 to 180°. It is evident that $\sigma = -x \equiv \sigma = +(180-x)$.

A considerable confusion exists in the literature about the formulae and rules for the determination of the position of the rhombic section. For the sake of clarity some comments are made on mistakes found in the literature:

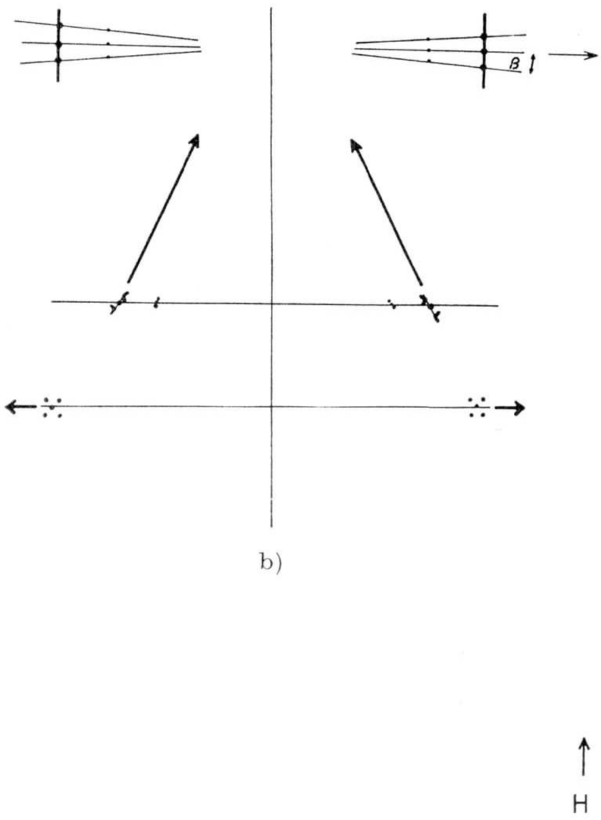
VOM RATH (1869, 1876) uses a formula to calculate s and σ but does not explain it in his papers. The formula is given correctly and explained by SCHMIDT (1919). Again MÜGGE (1930) publishes the correct formula which contains the signs. Other formulae published by MÜGGE (1927, 1930a) contain mistakes, partially corrected by the same author. After the confusion existing about 1930, as some authors employed MÜGGE's erroneous formulae SCHNAASE (1936) again publishes the correct formula (that also contains the signs). TUNNELL (1952) also observes these errors and again gives "the correct formula" omitting the signs. In addition now TUNNELL makes new mistakes, as he gives a wrong definition of Schuster's rule. TUNNELL's erroneous definition is also given by STARKEY (1967). Starkey introduces further errors referring to the angle b*/b that will not be commented here.

As described in the paper quoted above, the position of the rhombic section can be determined by a *direct X-ray* method. The Buerger's precession camera is used to locate the normal to the rhombic section (b*-plane). The b axis is chosen as rotation axis and zero-level precession photographs are taken of the b*-plane and (001)*. The rotation angle around the b-axis is called η. To obtain the exact position of the rhombic section the η values are plotted against the angle H (see fig. 3 and 4) and the value for $H=0$ is interpolated.

There is also a *calculative method* for the determination of σ or s. The position of the rhombic section is calculated from the lattice constants. This calculation can be carried out regardless whether the material is twinned or not. VOM RATH (1869, 1876) was the first who used such a procedure being at that time confined to optical goniometry as source of data of the lattice angles. MÜGGE (1927, 1930) and SCHNAASE (1936) also made very careful determina-



a)



b)

Fig. 3. a) Precession diagram of the b*-plane. Note that only the reflections along the b*-axes are sharp; being an irrational plane it is not surprising that no other reciprocal lattice points are contained in it. The remaining reflections appear aplitted as they belong to misadjusted planes. b) The upper part of the sketch illustrates a precession diagram of the b*-plane with d_2 as precession axis. The lines drawn through the (0k0) reflections form the angle H; here H = 0. Next underneath an intermediate position is shown the dial angle being inclined less than 90° with respect to d_2. Again H is measured between the lines joining the reflections or the diffuse streaks. Below, a scheme is given of a diagram taken along the direction S, normal to the rhombic section, as precession axis. The plane of the rhombic section can not be "seen". Here splitting is highest, four (0k0) reflections appear (H = 180°).

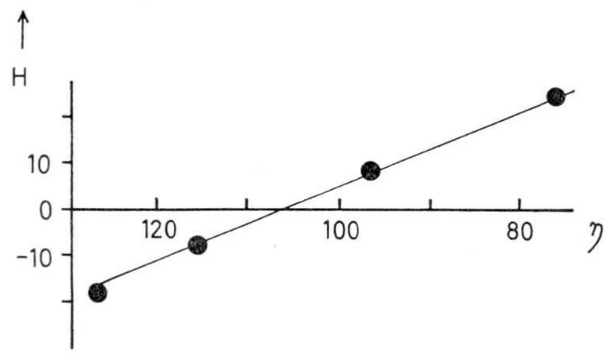


Fig. 4. The H-angles are plotted against the η angles and the position corresponding to $\eta = s$ is interpoleted. Here an adularia from Disentis was chosen as example (s = 107° ± 5°). The precision was lower as the measured streaks were very diffuse.

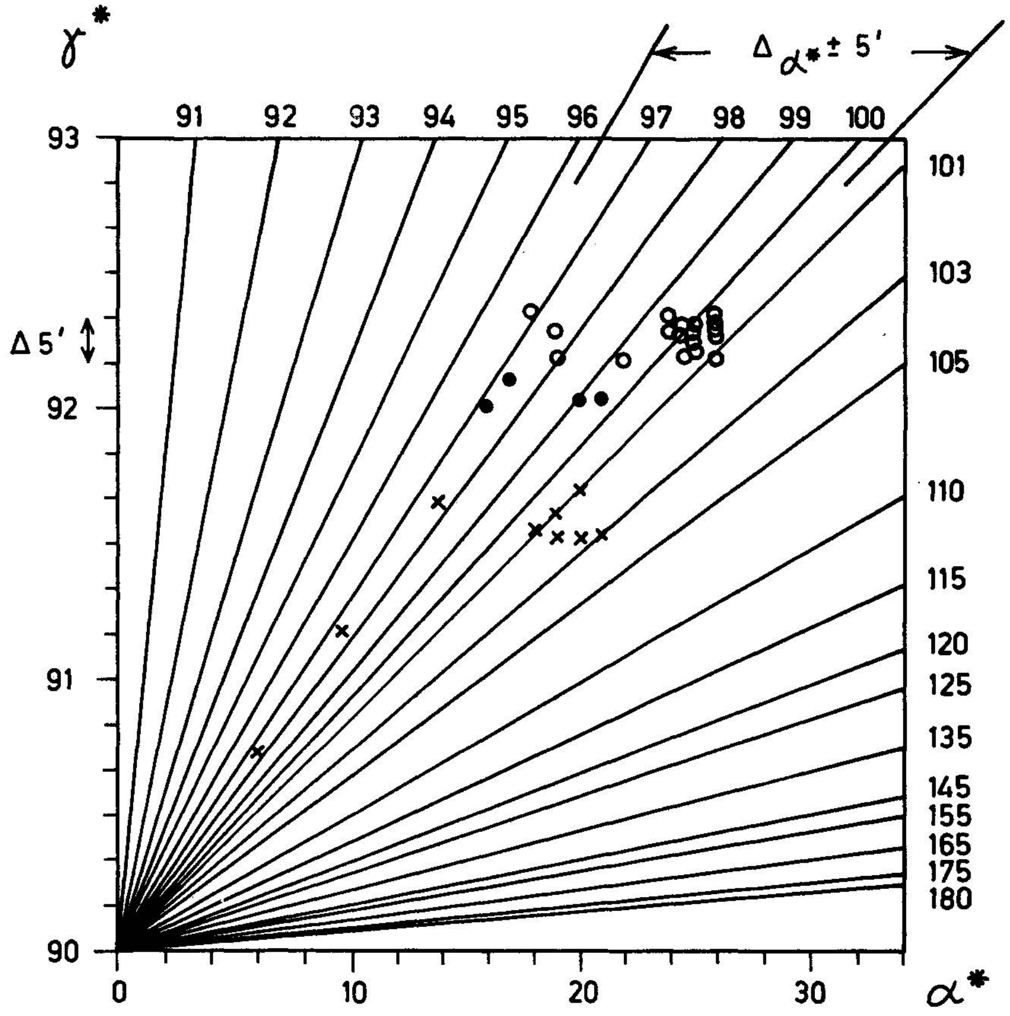


Fig. 5. Nomogram for the determination of α^* in microclines from the measurement of s and γ^*. The nomogram can also be used for the estimation of errors and for the determination of s from α^* and γ^*. Reliable values can be only obtained if the angles are not too near to 90°, compare also p. 56 and if the angles were measured with high accuracy. The error introduced by an error of 5′ in the determination of α^* in the calculated s value is marked in the figure, as well as the values given by some authors. Open circles: maximum microclines. Full circles: heated microclines still partially ordered. Crosses: intermediate microclines.

The represented values were taken from: Bambauer (1969), Laves (1950, 1952), Baskin (1956), Grundy and Brown (1967), Orville (1967), Smith and Mackenzie (1956), Stewart and Ribbe (1969), Wright and Stewart (1968), Bailey and Taylor (1955).

tions based on optical data. Recently far more accurate powder measurements are available e.g. Smith (1955), Stewart et al. (1967, 1969 etc.), Orville (1967).

From the formulae and also figure 5 and 6 it is evident that small variations (minutes) in the lattice angles when they are close to 90°, cause great changes (several degrees) in the position of the rhombic section. This is one disadvantage of the calculative method.

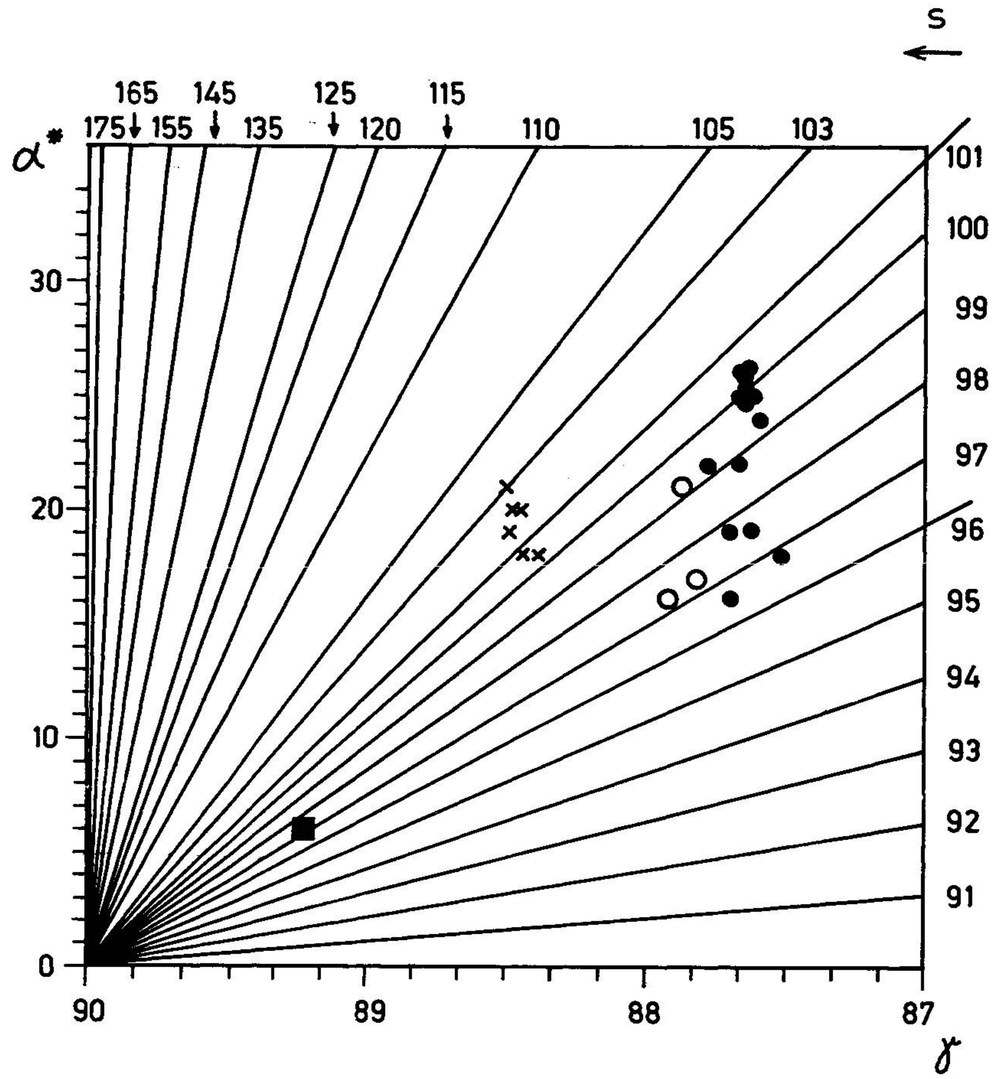


Fig. 6. Nomogram, similar to that drawn in figure 5, for the determination of s in microclines from α^* and γ ($\operatorname{tg} s = \operatorname{tg} \alpha^* \cos \gamma$). Square: Wright and Stewart (1955): Intermediate microcline Spencer U. Crosses: Intermediate authigenic microclines (Baskin 1956). Circles: heated microclines (Grundy and Brown 1967). Full circles: Maximum microclines measured by Laves (1950, 1952), Baskin (1956), Smith and Mackenzie (1956), Grundy and Brown (1967), Michaelis de Sáenz (unpublished).

Starkey (1967) gives calculated σ values with 3 decimals. As the accuracy of the determination of the lattice angles is about 5′, this has no real significance and may be misleading. Barth and Thoresen (1965) publish some confusing calculations (to be commented in a forthcoming paper) where they underestimate considerably the influence of the error in the angular measurement on the calculated σ-value.

Our purpose here is to furnish some nomograms (fig. 5, 6, 7 and 8) that allow a rapid estimation of the actual error for the different lattice angle values. Besides nomogram fig. 5 and 6 are applied in the determination of s (very close to σ) from the lattice angles and for the estimation of accurate

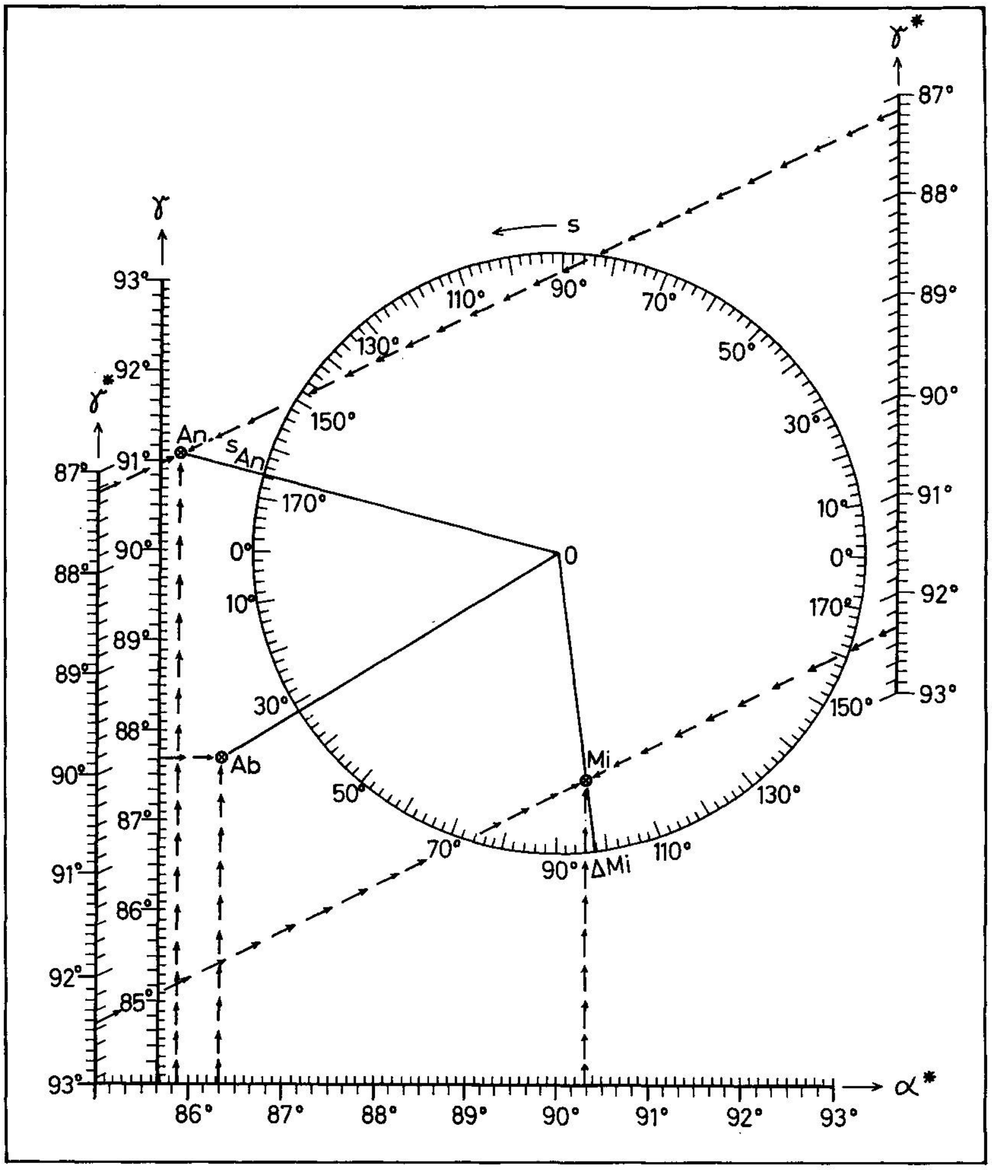


Fig. 7. Nomogram showing the relations of s, α^*, γ^* and γ. β^* was taken as 63° 40′. The highest error introduced by this assumption is 40′ for feldspars with $\beta^* = 64°\ 10'$. In low temperature plagioclases the error is less than 20′. This figure is similar to figures 5 and 6 for microclines, but it is drawn at a convenient scale for plagioclases. Examples are given to illustrate the use of the nomogram.

Example 1: One of the values given by BAMBAUER, EBERHARD and VISVANATHAN (1967) for albite is illustrated. $\alpha^* = 86°\ 22'$, $\gamma^* = 87°\ 43'$. As shown by the arrows, the corresponding point is drawn and marked Ab. Where the line connecting Ab and 0 intersects the s-circle, the values of s can be read ($s = 32°\ 02'$).

Example 2: We suppose that the experimental direct method is used and $s = 97°\ 33'$, $\gamma^* = 92°\ 17'$ for microcline are measured. A line is drawn from 0 through the s value on the s-scale and the γ^* value on the scale given on the right hand side is joined by a straight line with the same value on the scale on the right hand side, of the nomogram. The intersection of both lines is marked Mi. It's abscissa corresponds to the α^* value 90° 19′.

Example 3: The calculative method is used. E.G. $\alpha^* = 85°\ 53'$ and $\gamma^* = 87°\ 11'$ be measured for an anorthite (BAMBAUER et al. sample 116). The perpendicular to the abscissa at the α^* value and the line joining the γ^* value on the right and left hand side scale, are drawn. The intersection of both is marked An. The line 0–An intersects the s-circle at $s_{An} = 165°\ 03'$.

α^*, γ^* and γ values. These nomograms were calculated applying formula 2 and the current formulae relating direct and reciprocal lattice angles.

Nomogram fig. 7 is similar to the former ones but it is drawn at a convenient scale for plagioclases. Examples are given to illustrate the use of this nomogram.

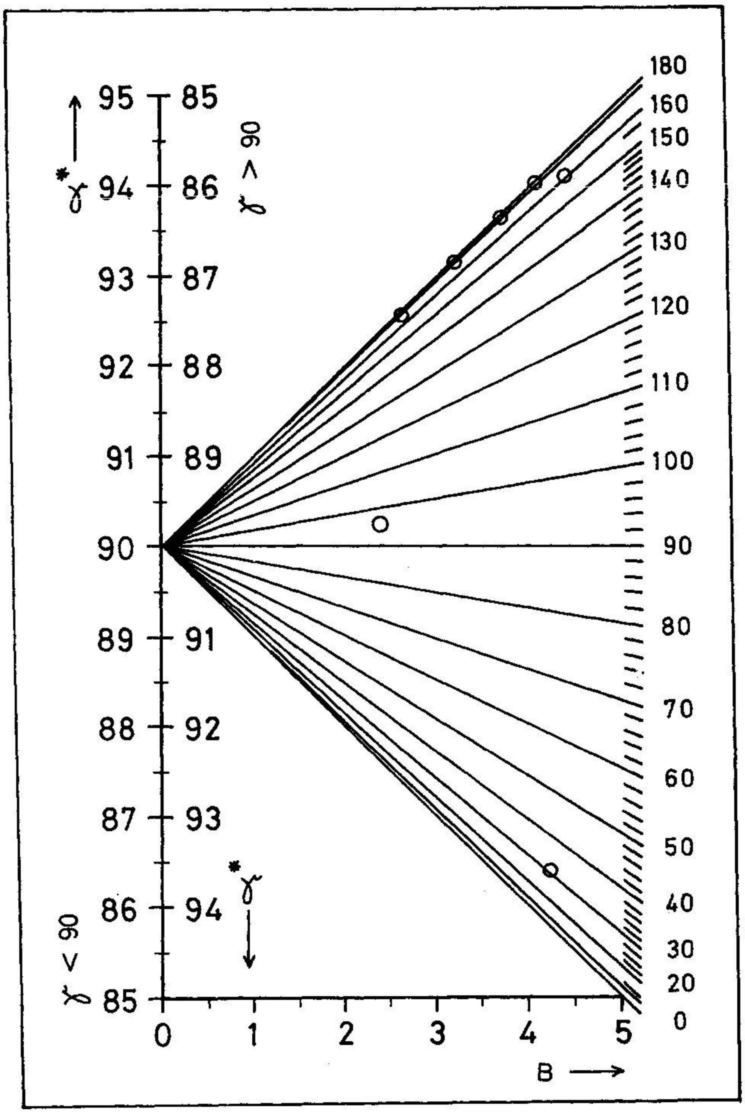


Fig. 8. Determination of α^* from the measured s and B values. This nomogram is calculated from the formula: $\cos\alpha^* = \cos s \sin B$. As examples the values obtained for microcline, albite, anorthoclase and progressively heated Na-rich plagioclases (marked a) are drawn in the graph. As seen in the practical examples described elsewhere these heated plagioclases maintain a very similar position of the rhombic section although the angular values change appreciably. The α^* scale is to be used at the right hand side when $\gamma > 90°$ and on the left hand side if $\gamma < 90°$. It is usually quite evident which scale is to be used.

Nomogram fig. 8 was calculated with the formula:

$$\cos \alpha^* = \cos s \sin B. \tag{3}$$

The examples included in this nomogram are discussed in a forthcoming paper by I. M. de Sáenz.

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