Notes on skiodroms and isogyres.

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PROFESSOR BECKE'S paper[1] on skiodroms marks an important advance in our knowledge of the shadows, or isogyres, which are seen when sections of crystals are examined in convergent polarized light. The isogyres can also be advantageously studied in mineral grains, where the irregular shape disturbs the distribution of the interference colours, but has much less effect on the shadows due to the coincidence of directions of vibration in the crystal with those of one of the nicols.

Throughout Professor Becke's communication[2] the movements of these dark bars or brushes are described as they are seen in a microscope where the stage rotates and the nicols are fixed, such as is almost invariably used in Germany. The fact that the section is not fixed relatively to the field of the microscope is a serious disadvantage, for the movement of the stage is superposed on that of the shadows relatively to the fundamental optical directions of the crystal, so that it is somewhat difficult to realize the true nature of the latter movement.

If, however, a microscope with fixed stage and revolving nicols be employed, the optical directions remain unchanged in position and the whole investigation is simplified, so that the variations in form and position of the shadows, or isogyres, as the nicols rotate, and their connexion with the skiodroms can be easily followed. With rotating nicols there is no difficulty in sketching under a camera-lucida, not only different positions of the isogyres, but also the forms of the skiodroms in the section under examination.

I shall accordingly concisely describe and explain the shadow phenomena seen in a microscope with a fixed stage and revolving nicols and, as in the abstract (p. 278), shall for brevity's sake confine myself to

[1] 'Die Skiodromen. Ein Hilfsmittel bei der Ableitung der Interferenzbilder.' Min. Petr. Mitt. (Tschermak), 1905, vol. xxiv, pp. 1-34; abstracted on p. 276 of this volume.

[2] Except for a brief allusion on p. 12.

sections which do not show an axis of optical symmetry or an optic axis, though the same principles may easily be extended to such cases.

In oblique sections of uniaxial crystals the longitudinal skiodroms (which are here meridian) converge towards the optic axis. They are at the same time slightly concave to the straight longitudinal skiodrom that passes through the centre. As the nicols are rotated, the isogyre moves across the field approximately in the same manner as if it were rotating with the angular velocity of the nicols about the optic axis, but the end further from the optic axis moves slightly faster than if that were the case—a result of the curvature of the lateral longitudinal skiodroms.

The terms homodrom and antidrom are now no longer applicable, as the end nearer the optic axis (the so-called homodrom end) moves round the circumference of the field in the opposite angular direction to that in which the nicols rotate, while the end further from the optic axis (the antidrom end) moves round with the nicols. I, therefore, propose to employ the epithet 'proximal' for the end of the isogyre and the margin of the field nearer the optic axis, and 'distal' for those directed away from it. The same terms may be employed by analogy in the case of biaxial crystals. The margin of the field and the end of the isogyre on the side towards which the longitudinal skiodroms converge will be proximal, and those on the opposite side will be distal. Here, too, the proximal end of the isogyre moves round the circumference of the field in an angular direction contrary to that in which the nicols revolve, and the distal end in the same direction as the nicols. (See figs. 3 and 6.)

In sections whose normal lies in the optic axial plane of a biaxial crystal the disposition of the skiodroms and movement of the isogyres present considerable resemblance to those in an oblique section of a uniaxial crystal. The lateral longitudinal skiodroms converge in the direction of the nearest optic axis, which therefore lies on the proximal side of the field. They are markedly concave towards the central skiodrom and accordingly make a less angle with it on the distal margin than on the proximal. The distal end of the isogyre therefore moves with much greater velocity than the proximal end, and when it reaches the periphery of the field it is strongly curved outwards. The pendulum motion is much more vigorous than when the stage, and not the nicols, rotates. (See figs. 1–3.)

In sections whose normal lies in a plane of optical symmetry, including a bisectrix and the optic normal, the longitudinal skiodroms converge towards the bisectrix, but they are convex towards the central skiodrom and are therefore more inclined to it on the distal than on the proximal side of the bisectrix. The proximal end of the isogyre therefore moves faster than the distal end, but this character is less marked than when the stage rotates instead of the nicols. (See figs. 4–6.)

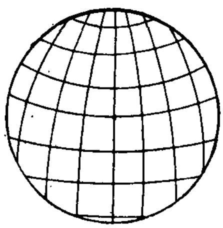
Fig. 1.

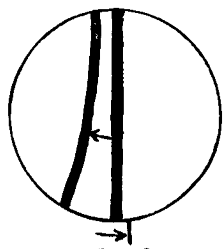
Fig. 2.

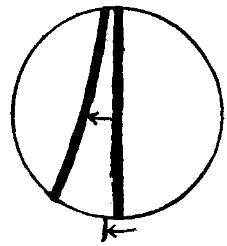
Fig. 3.

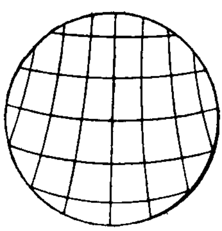
Fig. 4.

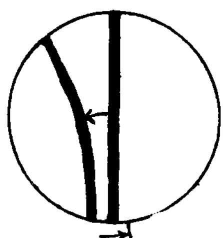
Fig. 5.

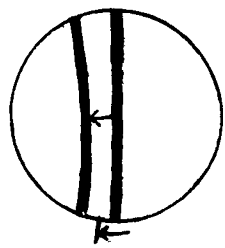
Fig. 6.

EXPLANATION OF FIGURES.

Fig. 1.—Skiodrom-net for a section whose normal lies in the optic axial plane.

Fig. 2.—Movement of the isogyre in such a section when the *stage* is rotated anti-clockwise.

Fig. 3.—Movement of the isogyre in the same section when the *nicols* are rotated through the same angle clockwise.

Fig. 4.—Skiodrom-net for a section whose normal lies in a plane of optical symmetry passing through a bisectrix and the optic normal.

Fig. 5.—Movement of the isogyre in such a section when the *stage* is rotated anti-clockwise.

Fig. 6.—Movement of the isogyre in such a section when the *nicols* are rotated clockwise.

Figs. 2, 3, 5, and 6 each show two positions of the isogyre: (i) the central position parallel to one of the nicols, and (ii) that after rotation of the stage or nicols through an angle equal to that between the lower end of the central isogyre and the short line across the point of the arrow below the circle.

Figs. 1 and 4 are copied from Professor Becke's paper. Compare figs. 1 and 2 on p. 277 of this volume.

If the section-normal does not lie in a plane of optical symmetry, the movement of the isogyre will be essentially similar to one of the types already described, but the movements, like the skiodroms, will be asymmetrical.

There is another point of nomenclature in which I would suggest a change. The use of the expression α- or γ-ellipses is open to misconception, as α properly denotes the minimum and γ the maximum index of refraction in the crystal. I would prefer to speak of fast and slow ellipses, or skiodroms, and of a section where the longitudinal skiodroms are fast or slow as having a fast or slow instead of a positive or negative reaction.

Professor Becke's rule for determining the sign or character of the reaction of a section may be easily employed in a microscope with rotating nicols. The nicols are rotated till the isogyre passes through the centre of the field. The cross-wire that is parallel with the isogyre at the centre, or makes an angle of less than 45° with it, is taken as the geographical meridian and the direction of the proximal margin as the north; the rule will then be applied exactly in the same manner as stated in the abstract (p. 279).

In some cases, especially if the rate of change of the relative retardation from point to point in the image in convergent light be very great, it is difficult to apply the Becke rule. It is then better, after ascertaining the direction of the longitudinal skiodrom at the centre (which is that of the cross-wire parallel to the central isogyre, or making with it an angle less than 45°), to rotate the nicols through 45° and to determine by means of the quartz-wedge in parallel light whether the vibrations parallel to the longitudinal skiodrom are faster or slower than those at right angles to it.

The direction of the cross-wire which is parallel to the central isogyre, or makes an angle of less than 45° with it, may be conveniently referred to as the longitudinal extinction, and that at right angles to it as the transverse extinction. These extinctions may also be referred to as fast or slow, according as they are parallel to the fast or slow vibrations. If, then, the longitudinal extinction be fast or slow, the reaction of the section will have the same character.

There are some sections in which the isogyre is so ill-defined that it is difficult or impossible to determine the direction of the longitudinal skiodroms. This may be due to the fact that the section-normal is too far removed from the optic axial plane, or to strain or other optical abnormalities. In such cases it is useful to remember that the proximal margin of the field is that which shows the lowest relative retardation or 'colour'; for the birefringence diminishes as the optic axes are approached, and with an objective of any ordinary aperture the greater length traversed in the crystals by light in the periphery of the field is not sufficient to counteract the decrease in the birefringence. The portion of the field in which the relative retardation is least may be roughly ascertained by rotating the nicols through 45° from the position of extinction in parallel polarized light, and inserting a gypsum-plate over the image in convergent light. The region of the lowest relative retardation is that in which the colour approximates most nearly to that of the plate when inserted alone [1].

This method is not applicable where the relative retardation is very high; it is then necessary to use a quartz-wedge inserted in the focus of the eyepiece in convergent light under the same conditions as those just mentioned for the gypsum-plate. The coloured bands will then usually be curved or inclined. If the wedge be in the position of compensation, the bands will, where the relative retardation is less, be advanced nearer to the thin end of the wedge. If, on the other hand, the wedge be in the additive position, the bands will, where the birefringence is less, be retracted towards the thick end. By inserting the wedge in parallel light, first in one direction of extinction and then in the other, it is possible to determine the portion of the periphery where the relative retardation is lowest; this will be the direction of the proximal end of the central longitudinal skiodrom. The same observation will also have determined whether this is the direction of the faster or slower vibration, and what is the sign or character of the reaction of the section.

Mr. H. Hilton's paper [2] on the application of the gnomonic projection to isogyres in the neighbourhood of the centre of the field, recalls an unpublished suggestion of my own; namely, that, with a view to using the same projection, an objective with a plane focal surface for light from infinite distance should be employed. I find on inquiry that objectives practically satisfying this condition are already manufactured in this country.

[1] The use of the gypsum-plate in this way to determine the direction of the acute bisectrix in a section at right angles to the optic normal was first introduced by Professor Becke, Min. Petr. Mitt. (Tschermak), 1897, vol. xvi, p. 181.

[2] Zeits. Kryst. Min., 1906, vol. xlii, p. 277; abstract in this vol., p. 281.