Microscope accessory plates and colour blindness

By F. E. Tocher, B.Sc., Ph.D.

Department of Geology and Mineralogy, University of Aberdeen

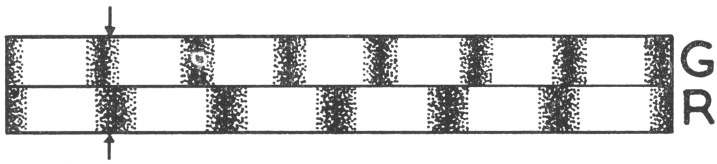
[Exhibited 7 November 1963]

Summary. The ordinary quartz wedge is adapted for use by the colour blind by the superposition of a two-colour isotropic auxiliary plate. A birefringent plate of suitable retardation may also be used in conjunction with the same auxiliary plate to replace the standard sensitive tint plate. In both cases, diagnostic colour changes are replaced by relative intensity changes.

The quartz wedge and the sensitive tint plate can safely be regarded as among the most widely used microscope accessories in the field of crystal optics. However, in parallel light, their efficient employment depends, to a large extent, on the ability of the observer to identify the various colours of Newton's scale and on his knowledge of the order in which they occur; and, for a variety of reasons, including imperfect colour perception or mere inexperience in the observer or both, this is not always easy. Of course, the colour-blind observer may have recourse to refinements, such as observation of the movement of colour bands on the lateral slopes of 'valleys' or other depressions on a mineral plate of otherwise fairly uniform thickness, but there are times when such aids are absent; and, even when they are present, the inexperienced observer might be unable to utilize them.

There is thus a need for simple accessory plates of both fixed and variable retardation that will provide, in parallel light and without the necessity for colour identification, conclusive evidence, both qualitative and quantitative, of compensation or reinforcement. The need is especially acute amongst the few advanced students afflicted with colour blindness who annually aspire to competence in crystal optics.

The quartz wedge. The need for a variable retardation accessory plate with the above properties can be met very simply by using, optically in series with the quartz wedge, an easily constructed isotropic auxiliary plate consisting of two narrow-band colour filters enclosed, side by side, in glass. With the straight colour-boundary of the auxiliary plate parallel to the length of the wedge, the latter is effectively divided longitudinally into two components, each of which is viewed in near-monochromatic conditions. With incident white light, the spacing, in each section, of the resultant dark bands is proportional to the wavelength passed by the associated filter (fig. 1, *a*). Since the dark bands occur where the relative retardation, δ, is a multiple of the appropriate wavelength, it is clear that in only one case—where $\delta = 0$—will the dark

a


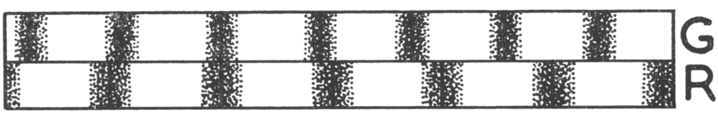
b


FIG. 1. (*a*) 'Bichromatic' quartz wedge (G = green, R = red), as viewed alone between crossed nicols, showing collinearity of $n\lambda$ black bands only at left end where $n = 0$. Arrows indicate suitable retardation for the 'bichromatic' sensitive plate. (*b*) The same, as viewed optically in series with a birefringent plate such that compensation is achieved. Compensation is indicated by the collinearity of black bands at a point other than the tip of the wedge.

bands in both components be collinear. This is valid provided, of course, that the chosen wavelengths have no common multiple that permits collinearity at any other point within the functional range of the wedge.

Colour filters found satisfactory for the construction of the auxiliary plate are Nos. 29 (red) and 61 (green) in the normal Wratten Light Filter series, as supplied by Kodak Ltd. It is not, of course, claimed that the filters specified are critical to the construction of the plate: any other filters with similar band-width and transmission-intensity characteristics will doubtless be equally satisfactory. It may be noted here that very narrow-band filters tend to reduce the intensity too much for good visibility. The filters used have the advantage that they pass fairly widely separated wavelengths in the visible spectrum and, as a consequence, the dark bands in the two components, with the exception of those where $\delta = 0$, are clearly non-collinear.

Although the colour filters specified are of reasonably narrow-band type, they are by no means monochromatic: consequently, after a few orders, coloured light transmission, of progressively increasing intensity, occurs where the dark bands should ideally occur. This, however, is no disadvantage, for with the 'bichromatic' wedge interest is centred entirely upon the single continuous dark band whose components are, at the same time, the most sharply defined in each section.

There are at least two ways in which the auxiliary plate may be optically combined with the quartz wedge. In a petrological microscope fitted with both a slotted ocular and an accessory slot at the base of the tube, the auxiliary plate may be used as a unit separate from the wedge: the former is left stationary in the ocular slot while the wedge is moved in the lower accessory slot. Alternatively, in microscopes fitted with only one slot, the auxiliary plate must be incorporated, above or below the wedge, within the boundaries of the wedge frame, and the two plates moved as one unit within the single slot. It may be noted that, in the latter case, the efficiency of the quartz wedge in conoscopic work is in no way impaired.

In all cases it is desirable to have in focus simultaneously two physical units and one optical effect: the mineral plate, the colour boundary of the auxiliary plate, and the dark bands produced on the insertion of the wedge. The first is easily focused in the normal way. When the slotted ocular is utilized, the colour boundaries of the auxiliary plate are easily brought into focus; and, when the low-level slot is used, an acceptable degree of focus is achieved by the combination of a reasonably high-power objective and a stopped down sub-stage diaphragm. The focusing of the first two normally results in the maximum attainable sharpness of the dark bands, a degree of sharpness that, in the final analysis, is a function of the wedge gradient: the steeper the gradient, the sharper and narrower the dark bands. In general, the wedge used with the auxiliary plate should, for acceptable results, cover, within the standard length, at least 6 orders of Newton's scale. This is particularly important when working with small mineral grains or with those showing both high birefringence and high relief.

When used in the normal way in parallel light, in conjunction with a birefringent crystal plate, the 'bichromatic' wedge will produce reinforcement or compensation, as the case may be. With reinforcement no continuous dark band will be observed; but, with compensation, provided that the retardation of the crystal plate does not exceed the maximum retardation of the quartz wedge, and provided that dispersion is not too high, one continuous dark band will appear at some point in the wedge (fig. 1, *b*). The observation of this continuous dark band is all that is necessary to confirm compensation.

To render the determination of compensation fully quantitative, a graduated quartz wedge may be employed. Alternatively, the bichromatic auxiliary plate can equally well be combined with a Berek or Babinet or other variable retardation compensator.

The sensitive plate. Here, the retardation, and hence the colour in white light, is fixed over the whole area of the plate, so that the colour changes normally observed are best replaced by simple changes in relative intensity. This can be achieved by using the above bichromatic auxiliary plate in series with a birefringent plate of uniform thickness and suitable retardation. In the 'bichromatic' quartz wedge the dark bands occurring at one wavelength retardation in each of the coloured portions are offset slightly with respect to each other so that the high retardation flank of that in the green area abuts against the low retardation flank of that in the red area (fig. 1, *a*). There thus occurs, in this overlap region, a point (arrows, fig. 1, *a*) where the green and red portions are illuminated equally, as if in a uniform field of low intensity. The retardation at this point, intermediate in value between the wavelengths passed by the two colour filters, is suitable for the birefringent component of the sensitive plate. For the red and green colour filters already used, it is slightly higher than the retardation of the standard sensitive tint plate.

A birefringent plate of the requisite retardation can be easily made from one of the minerals commonly used for this purpose: from selenite or muscovite or quartz. The components of the 'bichromatic' sensitive plate—the birefringent plate and the bichromatic auxiliary plate—may then, as in the case of the 'bichromatic' quartz wedge, be combined in one unit, or not, as desired.

It is clear that when a sensitive plate, constructed as above, is viewed optically in series with a birefringent specimen of low retardation, both being in the 45° position and between crossed nicols, the resultant retardation will be either slightly above or slightly below that of the sensitive plate alone. The apparent intensity of illumination of one half of the field will then be distinctly greater than that of the other: with reinforcement, the green half will appear brighter than the red half; with compensation, the reverse will occur.

Since the colour-blind observer will, in general, be unable to distinguish the two halves of the field in terms of the transmitted colour, some simple symbols, in addition to those indicating the fast and slow vibration directions, are necessary to permit this distinction and thus to facilitate interpretation of the observations. Although the symbols may either be on the sensitive plate itself or on its holder, the former position is favoured in view of the possibility that the plate may, at some time, be used in an optical system that forms a reversed image. The only markings necessary are a plus (+) and a minus (−) engraved on the mounting glass on the green and red sides of the colour boundary respectively, and at a level within the whole mount such that they can be readily brought to a focus. Should the birefringent and the bichromatic portions of the plate be mounted and used separately, the symbols must, of course, be on the bichromatic portion. The nature of the symbol in the more brightly illuminated half of the field then indicates whether, in any determination, reinforcement (+) or compensation (−) is taking place.

In cases where the birefringence of the specimen is so low that it is difficult to differentiate between the relative intensities of illumination in the two halves of the field, rapid oscillation between the two 45° positions by rotation of the stage, or of the nicols and sensitive plate, will normally provide the answer. Reinforcement is indicated when the green half (+) is at its brightest, and compensation when the red (−) is at its brightest.

The 'bichromatic' sensitive plate can also be used for the conoscopic determination of the optical sign of both uniaxial and biaxial crystals, in those cases where the sensitive tint plate would preferentially be used by normally sighted observers. For simplicity of interpretation, the colour boundary of the 'bichromatic' sensitive plate should be suitably orientated with respect to the interference figure when the latter is in the 45° position. In biaxial cases, the colour boundary should be more or less perpendicular to the isogyre and should intersect it at or close to an optic axis. In uniaxial cases, it should pass through the optic axis.

In the biaxial case, the isogyre is replaced, on insertion of the 'bichromatic' sensitive plate, by the one-wavelength dark bands in the green and red portions of the plate (fig. 2, left). The dark bands themselves, more or less normal to the colour boundary in their respective halves of the field, are, of course, offset with respect to each other and occur one on the acute bisectrix side and the other on the obtuse bisectrix side of the pre-existing isogyre. The existence of reinforcement or compensation, as the case may be, on the acute and obtuse bisectrix sides of the optic axis, may then be deduced by a comparison of the brightness on either side of the colour boundary at those points where the two one-wavelength dark bands abut against it. In each case, the relationship is that indicated by the symbol engraved on the more brightly illuminated side of the colour boundary (fig. 2, left).

In the uniaxial case, conditions are equally simple: the arms of the pre-existing black cross are replaced by the overlap region between the dark bands of the green and red areas; and, in each of the two quadrants of the interference figure bisected by the colour boundary of the bichromatic plate, the black band in only one of the coloured halves will

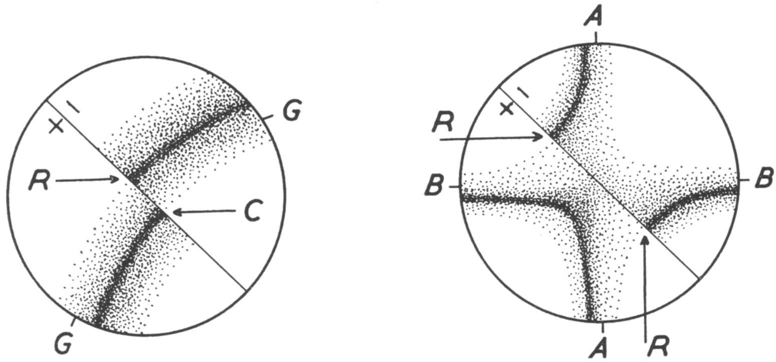


FIG. 2. Conoscopic determinations with the 'bichromatic' sensitive plate. Central portions of interference figures showing offset of one-wavelength retardation bands in green (+) and red (−) portions of the field. These replace the pre-existing biaxial isogyre (*GG*, left) and uniaxial cross (*AA*, *BB*, right). *R* = reinforcement; *C* = compensation.

abut against the colour boundary (fig. 2, right). The nature of the symbol engraved on the more brightly illuminated side of the colour boundary at these points indicates the presence of compensation or reinforcement, as the case may be, in those two quadrants.

In conclusion, although these auxiliary plates were originally devised as a means of combating, in some small measure, the handicap of colour blindness, they can be of considerable value to the ordinary observer, particularly the novice, in the rapid detection of compensation: the process is not retarded by the continual need for colour identification.