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The new physiology of vision—Chapter XL. The colours of iolite

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An attractive display of colour by a mineral serves to gain for it a position of esteem as a gemstone. The colour is determined, in the first place, by the absorption of light in its passage through the solid. But this is only one aspect of the matter. Scarcely less important is the role played by the physiology of vision. For, the perceived colour of a gemstone results from the synthesis by the visual mechanism of the different spectral components of the light emerging from its interior. This field of investigation was traversed in an earlier chapter, but we return to it to consider the particularly interesting case of iolite.

The name iolite is derived from the Greek word for violet and is indicative of the colour of the gemstone. It is found in gem-gravels as water-worn pebbles, one of the principal sources being Ceylon. Iolite is also known by another name as cordierite, a mineral which is found associated with gneisses and schists and exhibits the phenomenon of pleochroism in a very striking fashion. It is with cordierite that Sir David Brewster discovered the optical effect known as "Brewster's brushes" which we shall refer to later in this paper and which stands in close relationship to the colour and pleochroism of biaxial crystals.

Cordierite is found in various parts of South India and especially in the Coimbatore district. Its optical properties were made the subject of a penetrating study by Dr S Pancharatnam and the memoirs describing his results were illustrated by a striking and beautiful series of photographs. These will be found in the *Proceedings of the Indian Academy of Sciences*, Vol. 42, 1955, as plates V, VI and VII and in Vol. 40, 1957, as plates I and II. We shall have occasion later to refer to Dr Pancharatnam's publications.

The pleochroism of iolite: Though much of the material from Coimbatore is in the form of irregular lumps, some specimens are available which were evidently the result of the cleavages or partings of crystalline blocks. These specimens were ground to the form of plates and then polished, thereby enabling the colour and other optical characters of the crystal to be critically examined. The plates, each a few mm thick, prepared in this manner, fell into two distinct groups. The first group shows a brownish-yellow colour by transmitted light. Viewed through a polaroid, this light is found to be completely polarised; it comes through freely in one setting of the polaroid and is extinguished in a perpendicular setting. Viewed edgewise, plates of this group allow light of a brownish-yellow colour to filter through in one direction, but are perfectly opaque in a perpendicular direction.

The second group of plates shows a wholly different behaviour. The light transmitted by them exhibits a blue colour, the thicker specimens showing a deeper colour as is to be expected. Viewed normally through a polaroid, the plates of this group show a noticeable variation in the colour and intensity of the transmitted light as the polaroid is rotated. The transmitted light appears brighter and less saturated in colour in one setting of the polaroid and less bright and of a deeper blue in a perpendicular setting. The edges of one such plate were smoothed and polished, so that it could be held edgewise and its optical behaviour examined. Despite the rather long path which the light has then to traverse, it comes through freely and allows distant objects to be seen quite distinctly. The colour of the light thus perceived is reddish-brown. Examination through a polaroid shows it to be completely polarised.

Observations have also been made with a small piece which was cut and polished to the shape of an approximately cubical block of about 4 mm edge-length. The light transmitted by the block in the three mutually perpendicular directions showed three different colours. One was a very pale yellow, the second a deep blue and the third a light blue. The pale yellow light emerging through one pair of faces when viewed through a polaroid is found to be completely extinguished in one setting of the polaroid, and comes through freely in the perpendicular setting. The light of a deep blue colour coming through the second pair of faces was found to be much weakened but not totally extinguished in a particular setting of the polaroid, but comes through with little noticeable change in the perpendicular setting. The light of a pale blue colour coming through the third pair of faces behaves differently. It is not extinguished in any setting of the polaroid but shows alternations of colour and intensity as the polaroid was turned round, exhibiting a pale yellow colour in one setting and a pale blue colour in the perpendicular setting.

A polished sphere of iolite 6 mm in diameter has also been used to exhibit the pleochroism of the gemstone. Held between the finger-tips, a distant window may be viewed through it. Both the colour and the luminosity of the image as seen through the sphere alter as this is rolled between the finger-tips. The changes depend on the way the sphere is held, in other words, on the axis of its rotation. In certain cases, the image seen is brilliant and its colour a pale yellow and then alters quickly to a deep blue of low luminosity. In other cases, the changes in colour and luminosity are less rapid and less striking.

Brewster's brushes: The specimen of iolite with which Dr Pancharatnam obtained his photographs was specially prepared in the form of a polished plate about 2 mm thick and having its faces normal to one of the two optic axes of the crystal. Held at arm's length and viewed against the bright sky, the appearance of the plate changes in a remarkable way as the angle which it makes with the line of vision is altered. When held in a particular position and tilted about a vertical axis in either direction, it exhibits a beautiful blue colour. Held in the same position but tilted about a horizontal axis, it appears bright and of a pale yellow colour in one setting and much less bright and a pale bluish-grey in another setting.

The origin of the effects described above becomes evident when the plate is held close to the observer's eye and the bright sky is viewed through it. Brewster's brushes then appear in the field of view and are seen extending outwards on either side of a narrow gap which covers the region of the optic axis. The brushes are for the most part of a brilliant blue colour. But the areas above and below the brushes have a quite different appearance. They also differ from each other in colour and luminosity, one side being dimmer and of a pale blue colour, and the other side much brighter and a pale yellow. That the colour and configuration of Brewster's brushes are closely related to the pleochroism of the crystal is thereby made evident.

To observe Brewster's brushes, it is not essential that the specimen should be cut normal to an optical axis. Indeed, the plates prepared from the available material which present a blue colour when held normally, exhibit Brewster's brushes when held obliquely and the bright sky is viewed through them in an appropriate direction. The thicker the specimen, the more striking are the brushes which are visible. It should be mentioned here that the colours of the brushes are noticeably influenced by the dispersion of the optic axes of the crystal. The blue brushes are seen to be edged with a purplish-red on one side. This effect is particularly conspicuous when the plates are held very obliquely.

The absorption spectrum of iolite: Dr Pancharatnam used the light of a sodium lamp for photographing the various phenomena observed and discussed by him. The monochromatism of this light serves to bring out the interference effects with maximum clarity. But it has also to be noted that the coincidence of the wavelength of the light employed with the region of the spectrum in which the absorption of iolite is particularly strong played an important role and helped to make the photographs as striking as they actually are. That this circumstance is also responsible for the magnificent blue colour which iolite exhibits in certain orientations can be readily demonstrated with the specimen used by Dr Pancharatnam in his work. Holding the plate against the bright sky, the spectrum of the transmitted light is examined through a direct-vision spectroscope. By tilting the plate to one or another of the four positions described earlier, the spectral constitution of the transmitted light in each case and its relation to the observed colour can be conveniently studied. That the practically complete extinction of the yellow sector in the spectrum goes hand in hand with the production of the deep blue colour of Brewster's brushes then becomes evident.

It should be remembered that we are concerned not only with the colour of the transmitted light in the various cases but also with the attendant changes in the brightness which are indeed considerable. The extinction of the blue sector alone would result in the colour changing to yellow, but the luminosity would not be greatly diminished. On the other hand, any weakening of the red, yellow and green sectors while the blue sector is freely transmitted would result in a large reduction of the brightness of the transmitted light, besides a change in its colour. In each case, this is what is actually observed.