

*Fibrolite (= Sillimanite) as a gem-stone from Burma and Ceylon.*¹

By L. J. SPENCER, M.A., F.G.S.

Assistant in the Mineral Department of the British Museum.

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THE only book on precious stones in which fibrolite² is taken into account appears to be that of J. Escard, 'Les pierres précieuses' (Paris, 1914, p. 190). He mentions the prehistoric stone implements made of dense fibrolite found in France, and also states that the mineral is sometimes used as an ornamental stone. Examples of such material are represented in the British Museum collection of minerals by: a hatchet, measuring $11 \times 5\frac{1}{2}$ cm., of pale yellowish-grey, compact fibrolite from N.W. France; and a polished knife-handle, 9 cm. long, of greyish-white, translucent, fibrous material with silky lustre. Clear material of good colour and cut in the form of a faceted gem has not hitherto been described.

Although fibrolite is a mineral of wide distribution in metamorphic rocks, crystals of appreciable size are, with one exception, unknown. A single crystal of long-prismatic habit (4 mm. across), and evidently very similar to the blue, pleochroic crystals described below, was found by F. Grünling³ amongst the waste material of a gem-merchant at Colombo. As minute crystals, the mineral appears to be of frequent occurrence in Ceylon: it has been described as a rock-constituent by A. Lacroix⁴ and by A. K. Coomaraswamy⁵; and as a heavy mineral in river sands it has been identified in numerous samples collected by the

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² There appears to be no good reason for rejecting Bournon's earlier (1802) name fibrolite in favour of the name sillimanite proposed by G. T. Bowen in 1824. J. D. Dana in the fifth edition (1868) of his 'System of Mineralogy' adopted the name fibrolite.

³ F. Grünling, Zeits. Kryst. Min., 1900, vol. 33, p. 236, and described, with detailed determinations of the optical constants, by G. Melzer, *ibid.*, p. 258.

⁴ A. Lacroix, Bull. Soc. franç. Min., 1889, vol. 12, p. 29.

⁵ A. K. Coomaraswamy, Spolia Zeylanica, 1904, vol. 2, p. 60; 1905, vol. 3, p. 59 (here the remark 'Very rarely in good crystals in gem gravels').

officers of the Mineral Survey of Ceylon.¹ Its occurrence as a rock-constituent at the ruby mines of Mogok in Upper Burma has been noted by C. B. Brown and J. W. Judd.² The present account, therefore, by no means records new localities for the mineral, but only its occurrence as comparatively large crystals of gem-quality.

The specimens from the ruby mines at Mogok, Upper Burma, now to be described, were generously presented to the British Museum early this year by Mr. A. H. Morgan, a member of this Society and formerly superintendent of the Burma Ruby Mines. They had been labelled as 'andalusite', and were correctly identified in the first place by Dr. G. T. Prior. They include a fine, faceted gem (reg. no. B.M. 1920, 18) and a parcel of water-worn crystals and pebbles (B.M. 1920, 17). Amongst the latter was one very pale sapphire, but the eighteen others proved to be fibrolite. The only information given with the specimens was that they were picked out of the hill wash at the ruby mines. The cut stone is perfectly clear, transparent, and flawless, and is of a pale sapphire-blue colour, somewhat resembling cordierite ('water-sapphire') in appearance. Its weight is 0.816 gram, and sp. gr. 3.25.

The rough stones have the form of rhombic prisms which are considerably rounded, and, when still more water-worn, of elongated pebbles. They are 1–1½ cm. long by ½–¾ cm. across. On most of them the highly perfect pinacoidal cleavage b (010) [Dana's orientation] is a prominent feature. On some there are indications of domes in the zone [010, 001], but unfortunately the faces are too rough and rounded for crystallographic determination. When in their original matrix they evidently were perfectly developed crystals. They are quite clear and transparent, and of a pale sapphire-blue colour, ranging in some crystals to almost colourless. Pleochroism is strong. The maximum colour is seen when the crystals are viewed across the prism-zone, whilst in the direction of the vertical c -axis they are colourless. There is no appreciable difference in the blue colour when the crystals are viewed first along the a -axis and then along the b -axis. The axial colours determined under the microscope are:—

Axis a (vibration-direction a), very pale yellowish.

„ b („ „ β), colourless with perhaps a tinge of green.

„ c („ „ γ), sapphire-blue.

¹ Ceylon, Report on the results of the Mineral Survey in 1905–6, Colonial Reports, Miscellaneous No. 42, London, 1907; ditto for 1906–7 and 1907–8, *ibid.*, No. 74, 1910 (see, e.g., p. 35); *ibid.*, No. 87, 1914.

² C. B. Brown and J. W. Judd, *Phil. Trans. Roy. Soc. London*, 1896, ser. A, vol. 187, pp. 195, 213.

The specific gravity is 3.25 (determination with specific gravity bottle on sixteen crystals weighing together 9.694 grams $D_4^{20}=3.252$; with pyknometer on five crystals $D_4^{20}=3.255$). Hardness¹ $7\frac{1}{2}$; a sharp corner readily scratches the faces of a quartz crystal.

This material being eminently suitable for the determination of the optical constants of fibrolite,² a very pale-blue crystal was selected for the purpose. This was cleaved on the two sides, and two prisms of about 60° were ground³ on the edges of the thick cleavage-plate, one giving the indices α and β and the other α and γ . The mean results are:—

	α	β	γ	$\gamma - \alpha$	$\beta - \alpha$
Red light (Li) ...	1.6544	1.6557	1.6743	0.0199	0.0013
Yellow light (Na) ...	1.6584	1.6596	1.6789	0.0205	0.0012
Green light (Tl) ...	1.6614	1.6625	1.6821	0.0207	0.0011
Dispersion (Tl-Li) ...	0.0070	0.0068	0.0078	0.0008	-0.0002

The optical orientation is given above under the pleochroism. The plane of the optic axes is parallel to the cleavage b (010), and the acute, positive bisectrix coincides with the vertical c -axis. From the above table of refractive indices it will be noticed that whilst the maximum birefringence $\gamma - \alpha$ on the cleavage is moderately strong, the birefringence $\beta - \alpha$ on the basal plane is very feeble. The latter would, however, be rarely observed in the long, acicular crystals of the more usual 'sillimanite' habit; and different faces in the prism-zone will show only slight variations in the strength of the double refraction.

As a check, approximate determinations of the indices α and γ were also obtained with the darker blue, faceted stone. In this stone, the very small culet facet is formed by the cleavage, and the table facet is about 3° from the parallel position. The longer axis of the oval girdle is, as near as could be observed, parallel to the vertical c -axis of the crystal. By setting the table facet perpendicular to the collimator of the goniometer, four half prisms (of about 21°) were obtained with step

¹ The value ($H.=6-7$) given in the textbooks is too low, due, no doubt, to determinations made on aggregates of crystals rather than on a single crystal.

² Previous determinations of the optical constants of fibrolite have been tabulated by G. Melezer (1900, loc. cit.). Later determinations are by E. Taubert (1905) and, on artificial material, by W. Eitel (1914) and by G. A. Rankin and F. E. Wright (1915). These show a greater range of variation than would be expected in a substance of simple composition (Al_2O_3, SiO_2) and without isomorphous replacements.

³ This was done with the small and handy form of crystal-grinding apparatus designed by H. H. Thomas and W. Campbell Smith, this Magazine, 1914, vol. 17, p. 86. When grinding a surface perpendicular to a perfect cleavage, it is a good plan to slightly bevel the edges to prevent fraying.

facets at the back.¹ Or again, eight larger angle prisms (about 47° and 62°) are formed each by a front bezel facet and a back step facet; but, since these facets are not symmetrically disposed to the table (and the optic axial plane), such prisms give only one true value (α or γ). In all these prisms the difference in intensity of the two refracted images in sodium-light is very striking: that corresponding to the γ index, with vibration-direction parallel to the vertical axis of the crystal, is quite faint. And in white light the corresponding spectrum shows scarcely any yellow. The reason for this is that yellow is the complementary colour to the sapphire-blue axial colour.

For the purpose of measuring the optic axial angle, an attempt was made to cut a plate, perpendicular to the acute bisectrix, on the cleavage-flakes from the same crystal on which the refractive indices had been determined: this, however, was unsuccessful, owing to the perfect cleavage. A well-rounded pebble of the same pale-blue colour, but showing no cleavage cracks, was selected, and the first approximate orientation was obtained by means of the pleochroism. The optic axial angle 2E measured in air at the ordinary temperature is:

	2 E.	2 V	2 V
		(calc. from 2 E and β).	(calc. from α , β , γ).
Red light (Li) ...	52° 25'	30° 56'	30° 12'
Yellow light (Na) ...	52 2	30 39	28 2
Green light (Tl) ...	51 12	30 8	27 2
Dispersion (Li—Tl) ...	1 13	0 48	—

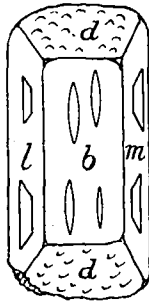
The material from Ceylon (without further information as to locality) has recently been acquired from two sources. In 1914 Mr. Francis Powell brought to me for identification one-half of a pale blue, elongated pebble which had been split along a marvellously perfect cleavage. It measures 2 cm. long by 1 cm. across, and is of a pale blue colour with strong pleochroism; being, in fact, very similar to the elongated pebbles from Burma, described above, only somewhat larger. The half weighs 0.936 gram and has sp. gr. 3.23 (this rather lower value being evidently due to the presence of cleavage cracks). Being quite different from any fibrolite then in the British Museum, Mr. Powell was good enough to present this specimen (B.M. 1914, 1421) for the collection.

A second lot, of four crystals (B.M. 1920, 267), was picked out from a small collection presented to the Museum during the present year by

¹ In a properly proportioned faceted gem this should, of course, not be possible, since all light entering the stone by the table should be totally reflected inside by the back facets.

Lieut.-Colonel C. F. Call. This collection consisted mainly of fragments of gem-stones brought from Ceylon about the year 1812 by the donor's father-in-law, Mr. E. T. Trelawny, and some of them were accompanied by labels in native script. These crystals differ from those from Burma in being much etched and corroded, rather than water-worn; and they are of two types.

One crystal has the same long-prismatic habit with pale blue colour and distinct pleochroism as the Burmese crystals. It measures $1 \times \frac{1}{2}$ cm. by about $1\frac{1}{2}$ mm. thick, and shows the forms b (010), m (110), l (450),



Fibrolite crystal from Ceylon. Orthographic projection on the cleavage plane b (010). Etch-figures shown diagrammatically.

d (011), as represented in the accompanying figure. At the back are two more d faces and a large, etched cleavage surface. The forms of the minute etch-figures are indicated diagrammatically in the figure: on b and on the cleavage plane they are long spindle shaped, and on the prism-faces they are elongated, four-sided pits. The faces d are hummocky, rounding off with a suggestion of pyramidal forms. Owing to this etching, the faces, though plane (except d), do not give reflected images. Approximate measurements, obtained by fixing pieces of microscope cover-glass on the faces (cf. this vol., p. 6), are $bm = 45^\circ 46'$, $bl = 39^\circ 38'$ (calc. from bm , $39^\circ 25'$), $bd = 36^\circ 48'$, corresponding with the axial ratio¹

$$a : b : c = 0.97 : 1 : 1.34.$$

¹ E. Taubert (Das Achsenverhältnis des Sillimanit. Centralblatt Min., 1906, p. 372) gives the axial ratios $a : b : c = 0.9696 : 1 : 0.7046$, the value for c being given by a single terminal face q (052) observed on a small crystal from Chester, Connecticut. Referred to the axial ratio given above this form becomes (043): calculated to b $29^\circ 18'$, measured by Taubert $29^\circ 35'$. Some early measurements were given by G. T. Bowen (1824) and J. D. Dana (System of Mineralogy, 2nd ed., 1844), but these were later rejected by Dana as being too approximate.

The three other crystals of this lot are pale greyish-green and of a short-prismatic habit. They are deeply corroded and minutely etched on the corroded surfaces: definite crystal-faces (*b* and *m*) are rare. The pleochroism is the same as before, only much feebler. Specific gravity 3.25. This material is of interest in presenting another character shown by certain gem-stones, and it may be described as *fibrolite cat's-eye*.¹ Further, the three crystals show this character in different stages of development. In the clearest, transparent specimen a few very fine straight lines, parallel to the *c*-axis were noticed inside the stone; in another, these lines are more numerous, especially in a cloudy region; whilst in the third they are closely crowded together, and the stone is translucent with a high degree of chatoyancy. The last two crystals closely resemble cymophane in appearance. The third crystal presents another peculiarity: a series of sharply-defined cracks, arranged perpendicularly to the system of fine lines (i.e. parallel to the basal plane) extend from the surface for a short distance into the stone.

¹ The same term would also apply to the finely fibrous, translucent mineral (as in the knife-handle mentioned above), but in that case the optical effect is due to the aggregation of fibrous crystals, and not to the inclusion of fibres (or lines) in a single crystal.