

Crystals of brookite tabular parallel to the basal plane.

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DURING the last year, Dr. R. H. Rastall has been engaged on an investigation of the mineral content of certain sandstones of Middle Jurassic age in north-east Yorkshire. These sandstones proved to be unusually rich in the titanium minerals rutile and anatase. In some samples the proportion of the last-named is greater than in any other specimen previously recorded, so far as can be ascertained. Some of the heavy-mineral separations also contained a number of crystals of quite unmistakable brookite, with normal crystallographic development and normal optical properties, namely B_x , perpendicular to (100) and intense dispersion $\rho > v$. Associated with these, however, there were often observed a number of smaller crystals of very similar appearance, whose optical orientation seemed to be entirely different. In particular, no optic picture could be obtained, and the extinction between crossed nicols in parallel light was perfectly sharp, with no suggestion of strong dispersion. Dr. Rastall therefore asked me to carry out some further investigations into the nature of these crystals, which were unlike anything he had previously seen in sedimentary rocks.

Precisely similar material has been previously briefly described,¹ from the Main Seam of the Cleveland ironstone at Upleatham, where also it was associated with normal brookite. Basing his conclusion largely on supposed crystallographic agreements, Lindsey states 'As to the identity of the two kinds of crystals I think there can be no doubt.' Dr. Rastall has since examined several samples from the Cleveland ironstone from neighbouring localities (though not from Upleatham itself), but has not found any examples of the mineral in question. The localities noted on the slides which I have examined are Beckhole, Limber Hill, and Ugglebarnby village, all of which are in the valley of the Esk, a few miles from Whitby.

The description and figures by Lindsey apply almost exactly to

¹ C. R. Lindsey, *Min. Mag.*, 1905, vol. 14, pp. 96-98.

this material. The crystals are thin, yellowish-brown, rectangular plates, up to 0.2 mm. long and 0.04 mm. wide. They are usually broken at one end, whilst at the other one or more modifications are present on the corners. The commonest of these makes an angle of 40° with the length of the crystal, whilst a second, measured in several cases, gave a value of 22° . Zones of growth can often be traced, and an elongated hour-glass structure frequently runs through the crystal (fig. 1.). There is distinct pleochroism, from red-dish-brown for vibrations perpendicular to the length to a more yellowish-brown for vibrations parallel to the length (Lindsey, possibly through error, gives the reverse relationship.) The refractive index and double refraction are high, elongation negative, and extinction rigidly straight.

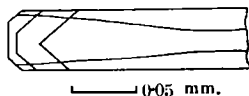


FIG. 1. Brookite crystal tabular parallel to (001), showing zonal growth and hour-glass structure.

This much could readily be observed with the ordinary petrographic microscope, but as noticed above, no optic picture could be obtained in a direction normal to the plate. The conclusion, therefore, as to the identity of the crystals with normal brookite did seem to present considerable doubt, and it was decided to carry out a complete optical determination. By means of sulphur-selenium melts, the average refractive index was found to be distinctly greater than 2.4. By turning a crystal on edge, a positive acute bisectrix was found to lie in the plane of the crystal plate, perpendicular to the length, with the optic axial plane parallel to the length for all colours, but with strong dispersion $\rho > v$. The thickness of the plate was 0.019 mm., and the use of a compensator led to the values $\beta - a = 0.005$, $\gamma - a = 0.2$ approximately. The complete scheme of pleochroism gave α greenish-yellowish-brown, β orange-brown, γ red-brown, and absorption $\gamma > \beta > \alpha$. On examining the crystal whilst on edge, it was noticed that the face perpendicular to the acute bisectrix was strongly striated across its length.

To complete the investigation, it was decided to determine the cell size by X-rays, and I am indebted to Mr. J. D. Bernal for undertaking this for me. Two rotation-photographs gave a cell, $a = 9.20$, $b = 5.44$, $c = 5.14$ Å, identical with that of brookite,¹ and revealed

¹ L. Pauling and J. H. Sturdivant, *Zeits. Krist.*, 1928, vol. 68, p. 255 [Min. Abstr., vol. 4, p. 28], give $a = 9.166$, $b = 5.436$, $c = 5.135$ Å. The observed halvings also corresponded with those of brookite.

that the striated face normal to the acute bisectrix is (100), and the length of the crystal the b crystallographic axis. The crystals are therefore tabular parallel to the basal plane (001), the frequent modification at an angle of 40° to (100) is (110), [for brookite, (100) : (110) = $40^\circ 5'$]; whilst that at an angle of 22° is (210), [(100) : (210) = $22^\circ 49'$]. For comparison, a brookite crystal of normal habit (fig. 2 *a*) is figured, together with the tabular habit parallel to the basal plane (fig. 2 *b*) in corresponding orientation.

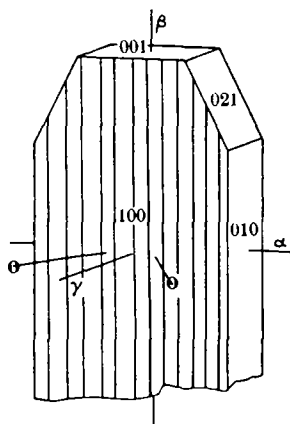
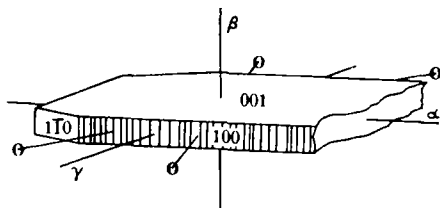
FIG. 2 *a*.FIG. 2 *b*.

FIG. 2. Brookite crystals: (*a*) tabular parallel to (100); (*b*) tabular parallel to (001), showing the optical orientation.

It is interesting to notice that the unusual habit is due entirely to unusual relative development, the actual forms present being amongst those most commonly found on brookite. Arnold¹ has recently carried out a statistical study, and gives the following relative frequencies H, locality-persistencies F, and combination-persistencies P:—

Symbol.	H.	F.	P.
(100)	95.1 %	100 %	94.6 %
(110)	93.4	94.1	92.9
(001)	69.7	92.2	72.3
(010)	36.1	50.0	35.7
(210)	34.4	64.7	34.8

¹ W. Arnold, Zeits. Krist., 1929, vol. 71, pp. 344-405. [Min. Abstr., vol. 4, p. 185.]

Whilst the normal brookite associated in the same concentrates has all the appearance of having been derived, it is possible that these smaller crystals have grown in situ. It is difficult, however, to suggest even a possible controlling factor in the environment which influenced the growth in this unusual habit.

I wish in conclusion to express my gratitude to Dr. Rastall for handing over to me for investigation this interesting material.
