Supplementary notes on the mineral Kaolinite.

By Allan B. Dick.

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In the year 1888 I gave before the Mineralogical Society an account of the forms and optical characters of some minute crystals of kaolinite from Anglesey.[1] At that time I was unable to ascertain whether the mineral was optically positive or negative, and it was stated that the axial angle 2V would approximate to 90°. Subsequently, by the aid of oil-immersion lenses and condensers of high angular aperture (numerical aperture = 1·25), it was found that the mineral is optically positive and that the acute bisectrix is normal to the clino-pinacoid (the obtuse negative bisectrix emerging through the basal plane). The optic axial angle in air was determined with an eye-piece micrometer to be 2E = 121°, with a possible error of one or two degrees, due to the small size of the crystals and the consequent weak interference-figures.

The mean refractive index, which was previously stated to be about the same as that of Canada-balsam, is in reality somewhat higher, being 1·563 for sodium-light. This value was determined by the Becke method in a mixture of oils, the refractive index of the oil being found on the total reflectometer. No difference could be observed in the refractive index when the crystals were viewed through the basal plane and through the clinopinacoid. Calculated from this refractive index and from 2E = 121°, the value for 2V is about 68°, instead of near 90°.

It is to correct these errors that the present communication is made. It was also stated that the angle of extinction on the plane of symmetry relative to the trace of the basal plane had a maximum value of 20°. This observation is, however, not very reliable, owing to low double refraction and to the dispersion. But until thicker crystals are available for study this must remain, although it would have been better to have said that the extinction-angle lies somewhere between 15° and 20°.

[1] A. B. Dick, 'On kaolinite.' Min. Mag., 1888, vol. viii, pp. 15-27, plate III. Compare H. A. Miers, Min. Mag., 1890, vol. ix, p. 4.

The strength of the double-refraction, which was previously stated to be rather less than that of quartz, has been determined afresh by means of a mica-wedge. This wedge was constructed in the following manner. A sheet of muscovite with a uniform thickness of approximately 0·02 mm. was cut into strips along lines parallel to the trace of the optic axial plane, and of suitable width to pass through the eye-piece of the microscope. These strips were then laid one upon another, each strip being a little shorter than the one beneath it; and the pile of strips was mounted in Canada-balsam between two thin plates of glass. There were nine of these strips, and each one of them was large enough to fill the field of vision. The wedge had thus an increasing thickness, step by step, from about 0·02 to about 0·18 mm. The first step produced a retardation of one-sixth of an undulation of sodium-light, and at the thicker end of the wedge the retardation was one-and-a-half undulations. Examined in convergent polarized sodium-light, the sixth step gave an interference-figure showing the first ring around each optic axis meeting in the centre of the field and remaining dark during the entire rotation of the nicols. This step also remained dark in parallel polarized sodium-light during an entire rotation, as though the mineral were isotropic; thus showing that the wedge was accurately constructed.

A microscope-slide was strewn with the larger of the kaolin crystals from Anglesey. Crystals resting on the basal plane and of uniform thickness were examined between crossed nicols by crossing them at 45° with the mica-wedge. One crystal was found which gave compensation with the second step of the wedge. It was picked out on a waxed needle, which could be turned in the focus of the microscope, and its thickness measured by comparison with a stage-micrometer ruled to $\frac{1}{10}$ and $\frac{1}{100}$ mm. The thickness of the crystal was 0·05 mm., that of the muscovite being 0·04. The double-refraction of kaolinite on the basal plane is therefore one-fifth lower than that of the muscovite of which the wedge was made.

The slide was then searched for a crystal resting on the clinopinacoid, like crystal No. 3 figured in the previous paper. None was found thick enough to compensate the second step of the wedge, as did the crystal resting on the basal plane. Accordingly, one was selected which compensated the first step of the wedge. It was picked out as before and measured. Its thickness was found to be 0·063 mm., that of the muscovite being 0·02 mm. The strength of the double-refraction on the plane of symmetry is therefore rather less than half of that on the basal plane.

The same crystal was then turned on its edge so as to look along a direction perpendicular to the orthopinacoid. When set at 45° to the crossed nicols it showed at its thickest end (the base of the crystal) the bluish-green colour of the second order, and was compensated by the eighth step of the wedge. The thickness of the crystal at this part was 0·20 mm., so that the double-refraction in this direction has about the same strength as on the basal plane. It must, however, be remarked that this observation is less accurate than those made on the basal plane and the clinopinacoid, on account of the wedge-shaped form of the crystal and the absence of the orthopinacoid.

The strength of the double-refraction ($\gamma-\beta$) on the cleavage-surface of the muscovite employed in making the wedge was determined by a comparison with the colour-diagram of birefringences given by Michel Lévy and Lacroix.[1] The sixth step of the wedge, with a thickness of 0·12 mm., gives the deep indigo-blue adjacent to the first sensitive tint, corresponding to a birefringence of 0·005 in the diagram.

The birefringences of the Anglesey kaolinite are therefore approximately :—

$$\text{On the basal plane, } \gamma-\beta = \frac{0{\cdot}04 \times 0{\cdot}005}{0{\cdot}05} = 0{\cdot}004,$$

$$\text{On the plane of symmetry, } \beta-\alpha = \frac{0{\cdot}02 \times 0{\cdot}005}{0{\cdot}063} = 0{\cdot}002 \text{ nearly.}$$

Well-crystallized kaolinite appears to be of rather rare occurrence. The crystals which I have previously described, and on which the determinations given above have been made, are from the neighbourhood of Amlwch in Anglesey. Mention may therefore be made in this place of the following additional British occurrences.

In the year 1895 Mr. R. H. Tiddeman met with a cream-coloured powder filling small veins in the limestone of Hambleton quarry, near Bolton Abbey in the West Riding of Yorkshire. This I examined at the time and found to be kaolinite. It is slightly stained by iron oxide, but becomes white on digestion in hydrochloric acid. The crystals are as perfect as those from Anglesey, but they are about a fourth smaller, and on none of them are the clinopinacoidal faces largely developed. In a letter written at the time Mr. Tiddeman said: 'Briefly, it occurs in veins running through about six feet of limestone lying at high angles, 60° or 70°, between two partings of shale. The surface of the shale seems also to be lined with it. The whole mass of the rock is much contorted.'

[1] A. Michel Lévy and A. Lacroix, 'Les Minéraux des Roches.' 1888.

Another occurrence of the mineral was observed at about the same time by Mr. W. M. Hutchings in the sandstone of a coal mine near Newcastle-on-Tyne. It was there found as a loose, snow-white powder, filling, to the thickness of some inches, a crack or parting in connexion with a small vein of lead-ore. The crystals are all very minute; they have a hexagonal outline, and none are specially developed in the direction of the clinopinacoid.

A third occurrence is in the millstone grit of a quarry at Congleton in Cheshire. Here the mineral fills the spaces between the grains of grit, and forms a loose aggregate of very small, white scales, some of which show perfect hexagonal outlines, whilst others are grouped in chlorite-like forms.

The statement in the textbooks that kaolinite is optically negative would appear to have originated from the examination made by A. Des Cloizeaux[1] of the varieties pholerite and nacrite, he having observed through the basal cleavages a wide-angled, negative bisectrix. I have been unable to obtain a specimen of pholerite for examination, and have met with only two of nacrite, both of which are probably from the Einigkeit mine near Freiberg in Saxony. These consist of fan-shaped aggregates of pearly scales, which have the same chemical composition,[2] hardness, specific gravity, and refractive index as the Anglesey kaolinite; but they differ from this in being optically negative with the acute bisectrix practically normal[3] to the cleavage and $2E = 103°$ approximately (hence $2V = 60°$). Through the basal cleavage of the Anglesey crystals only a diffuse negative bisectrix with the axes far outside the field is to be observed. The same is also the case with the other British kaolinites mentioned above, and with that described in 1887 by H. Reusch from the National Bell mine, Colorado, which I have had an opportunity of examining.

It must, therefore, be concluded that there are two varieties of kaolinite, one optically positive and the other optically negative; the former being the more common and better crystallized type.

1 A. Des Cloizeaux, 'Manuel de Minéralogie.' 1862, vol. i, pp. 190, 549.

2 An analysis made on a very small amount of material gave: SiO_2, 47·1; Al_2O_3, 39·1; H_2O, 14·0 = 100·2.

3 The cleavage flakes usually show a division into three sectors; in the central one the emergence of the negative bisectrix is normal, whilst in the adjacent sectors it is inclined slightly away from the centre on either side.