which derived its green colour from copper; but this is by no means necessary.

King[1] identifies the chalcedonian smaragdus with 'crystals of transparent Chrysocolla,' an identification which will hardly recommend itself to mineralogists. Corsi[2] had supposed it to be the amazon-stone.

The use of fuchsite for decorative purposes in prehistoric times has been noted by Max Bauer[3], who found pierced beads from Guatemala to consist of this material.

Note on the Refractive Indices of Pyromorphite, Mimetite, and Vanadinite.

By H. L. Bowman, M.A.

[Read February 3, 1903.]

IT is somewhat remarkable that a group of minerals, of which such excellent transparent crystals are known as of pyromorphite, mimetite, and vanadinite, should not have hitherto been submitted to a detailed optical examination, except as regards the nature of the interference figures visible in a cross-section. The only reference to the refractive indices of these substances, which I have been able to find, is one by Schroeder van der Kolk[4], who states that those of pyromorphite and vanadinite are above 1·93 (as found by immersion in highly refracting liquids), and that they have a birefringence of 0·02 and 0·01 respectively.

The object of the present note is to record the results of some determinations of the refractive indices of the three minerals, made with material in the Oxford Museum from various localities, by means of the prism method.

Unfortunately the angle (60°) between alternate natural faces of the

[1] 'Natural History of Precious Stones and Metals,' 1883, p. 288.
[2] 'Delle Pietre Antiche,' Roma, 1828, p. 170.
[3] Centralblatt f. Mineralogie, 1900, p. 291.
[4] Zeits. anal. Chem., 1899, Jahrg. xxxviii, p. 656.

hexagonal prism is too great to admit of the determination being carried out by their means, and so the following measurements have been made with prisms having at least one face artificially ground and polished, except in one case, in which, owing to the occurrence of faces of both $m\{10\bar{1}0\}$ and $a\{11\bar{2}0\}$, a convenient prism of 30° was available. The prisms used had in every case their edge parallel to the vertical axis of the crystal. They were made by grinding with oil on a sheet of ground glass (the crystal being cemented to a simple form of guide, which ensured the flatness of the faces), and were polished with putty-powder.

The exact position of the vertical axis within the crystals was somewhat uncertain owing to the striated and uneven character of the natural prism-faces, which frequently do not fall accurately into a zone, and a measurement of the angles between the ground faces and the basal plane (where present) was used to determine the accuracy of the orientation of the prisms, although this face also generally gave a blurred or multiple image in the goniometer.

Since, in a uniaxial crystal, any prism whose vertical bisecting plane contains the optic axis, will give the true values of ϵ and ω in the position of minimum deviation, any error (in ϵ) due to faulty cutting will depend only on the inclination of the optic axis to the plane bisecting the prism-angle. This inclination (θ) is given below for the various prisms, and (except in two cases) does not exceed $\frac{1}{2}°$—an amount which will scarcely affect the value of the index[1].

In the biaxial varieties the indices given under ϵ will correspond to α, while those given as ω will have a value intermediate between β and γ.

The indices were determined by the method of minimum deviation, for light of three colours, using—

Red glass,
Sodium flame,
Blue glass.

The last is a combination of a plate of 'signal green' with one of flashed blue glass, devised by H. G. Madan[2]. From the spectrum of direct sunlight it absorbs the whole of the red end as far as b, with the exception of a narrow band in the green, midway between D and E. The whole of the blue is transmitted, the brightest part being slightly beyond F. In most cases the source of light used was a Welsbach mantle, and the green

[1] If the true value of ϵ be calculated from the observed indices and θ, the result obtained in the worst case (No. 4) does not differ from the observed value by so much as one in the fourth place of decimals.

[2] Nature, 1885, vol. xxxi, p. 263.

image was not seen; but in one case, with the electric arc, it was visible, and the corresponding indices are given (prism No. 2). The red glass transmits a well-defined band, whose centre is close to C.

Repeated readings for the deviation-angles were as a rule fairly concordant—the extreme values differing from the mean by less than 6′ to 7′—but in two cases the difference reached as much as 13′ (No. 1, ω_{Blue}) and 14′ (No. 4, ϵ_D). The maximum error possible in the refractive index (as compared with that calculated from the extreme readings) would then be 0·004, but the actual error is probably much less than this.

The values for red are the most reliable, while those for blue are the least certain, owing to want of light and the rather wide range of colour of the blue glass.

The material used for the various determinations is described below, and the results are collected in the table, p. 328.

It will be seen from the table that the substitution of arsenic for phosphorus, and of vanadium for arsenic, in each case causes an increase in the refractive indices.

(1) *Pyromorphite* from Braubach, Nassau.

A prism with two ground faces at 32° 17′[1], from a pale liver-coloured crystal (hexagonal prism with flat ends; forms[2]: *m*, *c*, *a*, *x*; *m* and *x* bright, *a* and *c* dull). $\theta = 0° 12'$[3].

This is a pure pyromorphite, and contains no arsenic or fluorine. On analysis it gave the following figures:

PbO	81·12
FeO (or Fe_2O_3) . . .	trace
P_2O_5	16·51
Cl	2·71
Ba, Ca	traces
	100·34
Less O for Cl . .	0·61
	99·73

[1] Each of the two faces gave two equally good images of the goniometer-signal 4′ apart. The prism-angles corresponding to these images are 32° 13′, 32° 17′, 32° 21′. The effective refracting angle is here taken as the mean (= 32° 17′). The difference in the refractive index caused by taking one of the extreme values would be about 0.0024.

[2] The lettering of the forms is that used by Dana (System, 1892), viz.:—*a* {11$\bar{2}$0}, *m* {10$\bar{1}$0}, *c* {0001}, *y* {20$\bar{2}$1}, *x* {10$\bar{1}$1}, *u* {21$\bar{3}$1}, *s* {11$\bar{2}$1}.

[3] θ = inclination of the optic axis to the plane bisecting the prism-angle.

A cross-section of another similar crystal showed a uniform negative uniaxial figure over its whole area, with the exception of a narrow zoned border, which showed wavy extinction and (in places) a narrow-angled biaxial figure, with the axial plane at 90° or at 60° to an edge of the hexagon.

(2) *Mimetite* from Wheal Alfred, Cornwall (?).

A small crystal (1 mm. long), of a pale yellowish green colour, of unknown origin, but probably from Wheal Alfred. It shows the prism *m*, with two faces of *a*, and is terminated by *x* and a minute basal plane. The prism used was a natural one of 29° 58′ formed by a pair of plane and brilliant faces belonging to *a* and *m*.

(3) *Mimetite* from Wheal Alfred (?).

A prism of 36° 2′, with two ground and polished faces, made from a larger crystal off the same specimen as (2). Forms: *m*, *x*, *c*. $\theta = 0° 37'$.

(4) *Mimetite* from Wheal Alfred (?).

A pale green prismatic crystal with basal plane, having a bright yellow band at the free end. Locality uncertain, but probably Wheal Alfred. Forms: *m*, *c*, *y*, *x*. This must be referred to mimetite, as a small fragment (chiefly of the green material) showed only a trace of phosphoric acid.

The prism used had two ground faces at 30° 14′. $\theta = 1° 40'$.

A section (0·6 mm. thick) of the yellow end-material, cut perpendicular to the axis, shows a complex lamellated structure, and only extinguishes in places, in which traces of a negative biaxial figure are visible, having an axial angle $2E = 62°$, the axial plane being parallel to one or other of the sides of the hexagonal section. The lamellae appear to make an angle of about 40° with the hexagon-sides.

(5) *Mimetite* from Tintic District, Utah.

A prism of 30° 36′ with ground faces, from a slender, white, striated, hexagonal needle with broken ends. A natural prism-face is 40′ out of the zone of the two ground planes between which it lies.

Another crystal from the same specimen shows *m*, *x*, *c*.

A cross-section of a similar crystal shows a division into sectors and indistinct zonal structure. The sectors extinguish at 60° to the edges of the hexagon, and show a wide-angled negative bisectrix, with the axial plane in the same direction.

This specimen is a pure mimetite, being free from phosphoric acid.

	Red (C)			Yellow (D)			Blue (F)		
	ϵ	ω	$(\epsilon-\omega)$	ϵ	ω	$(\epsilon-\omega)$	ϵ	ω	$(\epsilon-\upsilon)$
(1) Pyromorphite (Braubach)	2·042	2·0504	−0·0084	2·0494	2·0614	−0·0120	2·0832	2·0964	−0·0132
(2) Mimetite (Wheal Alfred?)	2·1236	2·1392	−0·0156	2·1346	2·1488	−0·0142	Green (D–E) 2·1730	2·1891	−0·0161
							Blue (F) 2·2053	2·2220	−0·0167
(3) Mimetite („ „)	2·1180	2·1349	−0·0169	2·129	2·144	−0·015	2·1762	2·1915	−0·0153
(4) Mimetite („ „)	2·1178	2·1344	−0·0166	2·129	2·1475	−0·0185	—	—	—
(5) Mimetite (Tintic)	2·1178	2·1326	−0·0148	2·1286	2·1443	−0·0157	2·1750	2·1932	−0·0182
(6) Endlichite (Hillsboro')	2·292	2·341	−0·049	2·311	2·358	−0·047	—	—	—
(7) Vanadinite (Tucson)	2·299	2·354	−0·055	—	—	—	—	—	—

It is probably similar to the material from the Richmond Mine, Eureka, Nevada, analysed by Massie[1].

(6) *Endlichite* from Hillsboro', New Mexico.

A prism of 31° 3′ with two ground faces, cut from a pale yellow hexagonal prism (2·5 mm. diam.) with basal plane and narrow faces truncating the vertical edges. The basal plane gave several images, and the angles from it to the ground planes varied between 89° 51′ and 90° 30′ and between 89° 35′ and 90° 7′. Taking the mean values, $\theta = 0° 11'$. The natural prism-faces do not fall into a zone.

A cross-section (0·8 mm. thick) of another crystal from the same specimen, does not extinguish in any position, but shows in places a banded structure, suggesting zones of varying composition. Most of the section shows a normally emergent negative bisectrix ($2E = 14°$). The axial plane varies in position in different parts of the section, being in some places parallel to a face of a hexagonal prism, and in others inclined to it at various angles.

(7) *Vanadinite* from the Old Mammoth Mine, Tucson, Arizona.

A prism of 21° 10′ with one ground and one natural face, from a dark ruby-red crystal (hexagonal prism with flat ends, *m*, *c*, *u*). [Some other crystals off the same specimen show *m* and *c*, narrow *x*, and minute planes of *u*, *s*.] $\theta = 0° 24'$.

The indices were determined for the nearly monochromatic red light transmitted by the crystal, which lies between the lines C and D.

The crystal is markedly pleochroic, the colours being :—

ω brownish-red.

ϵ brownish-yellow.

Note on some rare twins of Calcite from Somerset.

By H. L. Bowman, M.A.

[Read February 4, 1902.]

THE crystals to which this note refers, occur in a quarry in the New Red Sandstone at Bindon, in Somerset, on the property of Mr. H. H. Worthington, and were presented to the Oxford Museum a few months ago by his son, Mr. J. H. Worthington. I have lately had an opportunity of visiting the locality and examining the mode of occurrence of the specimens.

[1] Chem. News, 1882, vol. xlvi, p. 215.