

*On an Epidote from Inverness-shire*<sup>1</sup>.

By H. H. THOMAS, M.A., F.G.S.

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THE mineral to be described was found by Mr. C. T. Clough, M.A., of the Geological Survey, near the junction of the two large streams in Coire Dhorrcail, near Barrisdale on the south side of Loch Hourn, Inverness-shire<sup>2</sup>.

Mr. Clough furnishes me with the following description of the mode of occurrence of the mineral:—

‘The crystals were obtained from a band, which, although its sides are not well exposed, seems to form a nearly horizontal vein-like mass. This band crosses both the bedding and the foliation planes of the muscovite-biotite-gneiss in which it occurs, and which occupies a large area near Barrisdale and Ladhar Bheim<sup>3</sup>.

‘The vein from which the specimens were obtained is the only one of its kind which has been met with in the district; it consists essentially of an aggregate of crystals, varying considerably in size, of the mineral epidote, together with red garnet, and white quartz with thin films of a dark green actinolite.

‘Some of these masses are as much as ten feet in width and contain large crystals of epidote embedded in white quartz. Most of the better shaped crystals occur in this way. Many of the crystals are traversed by cracks almost at right angles to their long axis; the various parts have suffered displacement, while the cracks are filled with granular quartz. The largest crystal noticed lay in an aggregate of smaller crystals of the same character, and measured six inches long by two broad.’

Well formed crystals were chosen for analysis, the mineral being crushed and subjected to the separating action of a heavy fluid in order to remove any impurities in the form of included minerals of lower specific gravity. The following are the results of the analysis, kindly made by Dr. W. Pollard, of the Geological Survey:—

<sup>1</sup> Communicated by permission of the Director of H.M. Geological Survey.

<sup>2</sup> Ordnance Survey of Scotland, one inch map, sheet 61.

<sup>3</sup> Summary of Progress for 1900 (Memoir Geological Survey), 1901, p. 10.

Specific Gravity 3.37.		Molecular ratios.	
SiO <sub>2</sub>	. . . . 39.02	. . . . 0.646	6.00
TiO <sub>2</sub>	. . . . trace		
Al <sub>2</sub> O <sub>3</sub>	. . . . 28.64	. . . . 0.2802	} 2.997
Fe <sub>2</sub> O <sub>3</sub>	. . . . 6.81	. . . . 0.0425	
FeO	. . . . 0.34	. . . . 0.0047	} 3.968
MnO	. . . . trace		
CaO	. . . . 23.73	. . . . 0.4238	} 0.91
MgO	. . . . trace		
H <sub>2</sub> O	. . . . 1.76	. . . . 0.0977	
<hr style="width: 20%; margin: auto;"/> 100.30			

The above analysis gives the formula  $\text{Ca}_4\text{Al}_6\text{Si}_6\text{O}_{25}\text{H}_2\text{O}$ , in which the aluminium is partly replaced by ferric iron and the lime by ferrous oxide. Regarding the mineral as containing the group OH, we have



Dr. Pollard states that in the above analysis the ferrous oxide may be as much as 0.1 per cent. too low. As will be seen, the percentage of ferric oxide is very low for an epidote, and is only equalled by a few other epidotes, such as those from Huntington in Massachusetts<sup>1</sup>, and the Zillertal in the Tyrol<sup>2</sup>.

The crystals are dark grey to greyish-brown in colour, but yield an almost white powder. They show a marked prismatic development, being elongated in the direction of the axis of symmetry, and attain in some instances, as has already been stated, a length of six inches. The faces of the orthodiagonal zone are by far the most strongly developed and form in most cases six- or four-sided prisms. Some of the smaller crystals are terminated, usually by simple forms.

The following are the faces which have been identified on the crystals measured:—

$a\{100\}$	$i\{\bar{1}02\}$
$c\{001\}$	$m\{110\}$
$r\{\bar{1}01\}$	$n\{\bar{1}11\}$
$f\{301\}$	$o\{011\}$

All these forms were noticed on one crystal, but the more common habit is represented by those crystals bounded by the faces  $acrn$ .

<sup>1</sup> E. H. Forbes, Amer. Journ. Sci., 1896, ser. 4, vol. i, p. 26.

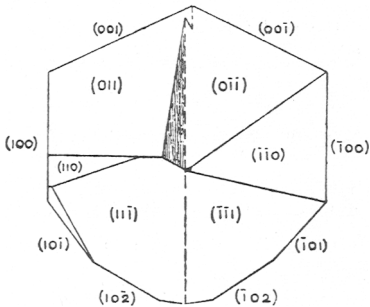
<sup>2</sup> H. Laspeyres, Zeits. Kryst. Min., 1879, vol. iii, p. 562.

Below are given the chief measured angles as compared with those calculated from the axes of N. von Kokscharow, junr.<sup>1</sup>, viz. :—

$$a : b : c = 1.57874 : 1 : 1.80862 ; \quad \beta = 64^\circ 36' 50''.$$

	Measured.	Calculated.
$ca = (001) : (100)$ . . .	$64^\circ 37'$ . . .	$64^\circ 36' 50''$
$am = (100) : (110)$ . . .	$54 48$ . . .	$54 59 54$
$cn = (001) : (\bar{1}11)$ . . .	$75 3$ . . .	$75 11$
$cr = (001) : (\bar{1}01)$ . . .	$63 49$ . . .	$63 42$
$ci = (001) : (\bar{1}02)$ . . .	$34 38$ . . .	$34 21$
$cf = (001) : (301)$ . . .	$98 16$ . . .	$98 37$
$a'r = (\bar{1}00) : (\bar{1}01)$ . . .	$51 34$ . . .	$51 41$
$a'n = (\bar{1}00) : (\bar{1}11)$ . . .	$69 5$ . . .	$69 2$

All these angles were measured on crystals of small size and with bright faces, which gave for the most part good reflections. Only occasionally are the faces in the orthodiagonal zone striated parallel to the zone-axis. The larger crystals are much less perfectly developed, their faces are more irregular, and those of the orthodiagonal zone more deeply striated. The faces of  $c\{001\}$  are usually bright and without irregularities.



Epidote from Inverness-shire.  
(Terminal faces of a small twinned crystal).

The mineral has a perfect cleavage parallel to  $c$  (001) and a less perfect one parallel to  $a$  (100).

Many of the crystals are simple twins with a twin-axis perpendicular to (100) and have (100) as the plane of composition. Polysynthetic twinning is by no means uncommon, following the same law.

A section cut parallel to the plane of symmetry gave the following extinctions for white light :—

Extinction measured to the trace of the good cleavage  $c$  (001),  $23^\circ 20'$ , and to the trace of the face  $a$  (100), approximately  $1^\circ$ .

The axis of least elasticity  $c$  was seen to make nearly a right angle with the face  $a$  (100),

$$\text{therefore } a : c = 1^\circ \text{ approximately.}$$

<sup>1</sup> Verh. russ. min. Ges., 1880, ser. 2, vol. xv, p. 47. The position taken above is that used in Dana's 'System of Mineralogy,' 6th edit., 1892, p. 516.

Owing to this small angle the polysynthetic character of the twinning is far from easy to recognize in sections cut at right angles to the twin-lamellae; but between crossed nicols sections, which are thin enough to show the bright colours of the lower orders, will appear banded, the lamellae say alternately blue and red.

The optical constants were determined from a single crystal, which showed twin-lamellae: fortunately the lamellae were thick enough to permit measurements being made on untwinned parts of the crystal.

For the determination of the refractive indices, two prisms were cut by Mr. John Rhodes. One with a face parallel to (010) and its refracting edge parallel to the *a*-axis, and the other with a face perpendicular to *c* and its refracting edge parallel to the axis of symmetry, or *b*, of the crystal. The first prism placed with the face (010) perpendicular to the incident light gave for sodium-light  $\alpha = 1.714$  and  $\gamma = 1.725$ . By means of the second prism  $\beta$  for sodium-light was found to be  $\beta = 1.7196$ .

The indices of refraction for yellow light are therefore:—

$$\alpha = 1.714, \quad \beta = 1.7196, \quad \gamma = 1.725,$$

giving the relatively very low double refraction

$$\gamma - \alpha = 0.011.$$

A plate cut perpendicular to *a* gave, in cassia oil<sup>1</sup>,  $2H_a = 98^\circ 16'$  for sodium-light. This, with the above value for  $\beta$ , gives for the value in the crystal:—

$$2V_a = 89^\circ 35'.$$

For thallium-light in cassia oil<sup>2</sup>,  $2H_a = 98^\circ 18\frac{1}{2}'$ ;  $2V_a$  therefore for thallium-light =  $90^\circ 29'$ .

The dispersion is slightly inclined;  $v > \rho$ . The optical character is negative for sodium-light, but positive for thallium-light.

The pleochroism is very distinct: for rays vibrating parallel to *b*, in sections 0.5 mm. thick, pale plum-colour; for those parallel to *a*, very pale plum-colour; and parallel to *c*, pale greenish-yellow, yellow predominating. The pleochroism scheme is therefore:—

$$b > a \bar{\bar{c}}.$$

A comparison of the epidote from Inverness-shire with those from Huntington, Zillertal, and Val Maigels (Switzerland) brings out many points of interest, and shows a striking similarity in the chemical compositions. Below are given the analyses of the four epidotes in question.

<sup>1</sup> The refractive index of the oil for sodium-light = 1.60273 at 18°C.

<sup>2</sup> The refractive index of the oil for thallium-light = 1.61461 at 18°C.

	Inverness-shire.	Huntington.	Zillertal <sup>1</sup> .	Val Maigels <sup>2</sup> .
SiO <sub>2</sub> . . .	39.02	37.99	38.46	39.07
Al <sub>2</sub> O <sub>3</sub> . . .	28.64	29.53	28.59	28.90
Fe <sub>2</sub> O <sub>3</sub> . . .	6.81	5.67	5.76	7.43
FeO . . .	0.84	0.53	0.53	—
MnO . . .	trace	0.21	—	—
CaO . . .	23.73	23.85	24.60	24.30
MgO . . .	trace	—	—	0.10
H <sub>2</sub> O . . .	1.76	2.04	1.92	0.63
	<u>100.30</u>	<u>99.82</u>	<u>99.86</u>	<u>100.43</u>
Specific gravity	3.37	3.367	—	3.361

The pleochroism of the Inverness mineral is identical with that described by Forbes in the epidote from Huntington, and is very similar to that of the pale green crystals from the Zillertal.

The mineral under investigation forms an interesting member of those epidotes with a low percentage of ferric iron, and falls naturally into the series. It has been recognized for some time that in the case of the epidotes the percentage of ferric iron has a direct influence on the refractive indices of the mineral, and on the other optical constants: namely, that with an increase in the percentage of Fe<sub>2</sub>O<sub>3</sub>, the values of the refractive indices and of the double refraction increase, while the dependent value of the angle between the optic axes measured over  $\alpha$  decreases. A comparison of the Inverness epidote with those of Untersulzbachthal<sup>3</sup>, Zillertal<sup>4</sup>, and Huntington<sup>4</sup>, clearly illustrates the more or less gradual change in the optical constants (for sodium-light) as the percentage of ferric oxide decreases.

	Fe <sub>2</sub> O <sub>3</sub> .	$\alpha$ .	$\beta$ .	$\gamma$ .	$\gamma - \alpha$ .	2V.
Untersulzbachthal . . .	14.0	1.7305	1.7540	1.7677	0.0372	73° 39'
Zillertal . . . . .	6.97	1.720	1.7245	1.7344	0.0144	87 46
Inverness-shire . . .	6.81	1.714	1.7196	1.725	0.011	89 35
Huntington . . . . .	5.67	1.714	1.716	1.724	0.010	90 32

In the Huntington mineral the acute bisectrix is  $\epsilon$  and the optical character positive, so that measured over  $\alpha$  the angle between the optic axes is 90° 32'.

<sup>1</sup> H. Laspeyres, loc. cit.

<sup>2</sup> G. vom Rath [Grey epidote from Val Maigels], Zeits. Deutsch. geol. Gesell., 1862, vol. xiv, p. 428. See also E. Weinschenk, 'Ueber Epidot und Zoisit,' Zeits. Kryst. Min., 1896, vol. xxvi, p. 176.

<sup>3</sup> C. Klein, Neues Jahrb. Min., 1874, p. 1.

<sup>4</sup> E. H. Forbes, loc. cit.

The band from which the Inverness-shire specimens were obtained is on the Kneydart estate, the property of the late Mr. E. S. Bowlby; and Mr. Clough and myself wish to express our thanks to the factor, Mr. Stewart, for his kindness in ordering a blast to be put into the band referred to. My thanks are also due to my colleague Mr. O. T. Jones, who helped me considerably in my investigations.

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