

be definitely determined. Such faces are not indicated by a letter in our figure. This richness of faces recalls to mind the meteoric enstatite of the Breitenbach iron, which were determined by von Lang's sagacity. The cause of the remarkable monoclinic formation of the Norwegian enstatite is quite hidden. The first thought may be that it is the result of pressure. But that explanation must be surrendered if we observe that the monoclinic dislocation is only to be seen in the faces of the summit, and never in the vertical faces. So this anomaly seems to have its origin in crystallonomic causes. The exhausted apatite-mine of Kjørrestad is hitherto the only known locality of these enstatite giants. No doubt implanted enstatite crystals will be found in other plutonic localities. If we shall there be able to observe the crystals not merely among the materials thrown away, but also in their natural position *in situ*, we may possibly find a solution for the dislocation of the terminating faces, which is at present an enigma.

Bonn, October 4, 1876.

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V. *On Ludlamite, a new Cornish Mineral.*

By FREDERICK FIELD, F.R.S.\*

LUDLAMITE is found associated with quartz, chalybite, Vivianite, iron pyrites, and mispickel. In the gangue of some specimens galena, blende, and fluor have also been noticed

Hardness 3·4. Specific gravity 3·12. Colour clear green, from pale to dark, transparent and brilliant. Streak very pale green, approaching white; powder greyish white. Before the blowpipe on charcoal, tinges the flame slightly green, and yields a semifused blackish residue.

In closed tubes yields water on heating, decrepitating violently, breaking up into brilliant crystalline plates of an intense bluish-green colour by transmitted light. Soluble in dilute hydrochloric and sulphuric acids; oxidized and dissolved by nitric acid. Perfectly insoluble in glacial acetic acid. Decomposed immediately by boiling with solution of potassium or sodium hydrate into ferrous oxide and phosphate of the alkali metal. Consists entirely, when pure, of ferrous oxide

\* Read December 15, 1876.

phosphoric acid, and water. Oxidizes slightly, like Vivianite, by long exposure to air, with the formation of ferroso-ferric phosphate. The crystals contain generally minute particles of chalybite, which are very difficult to separate, also specks of iron pyrites.

*Estimation of Water.*—As the mineral, when heated in air, is more or less oxidized, and that very readily, it was evidently necessary to prevent oxidation. The crushed crystals were pressed between folds of warm bibulous paper to remove any small amount of mechanical water, wrapped in thin platinum-foil, and heated to low redness in an atmosphere of carbonic acid.

0.214 grm. lost 0.036 = 16.82 per cent.

0.192     "     0.033 = 17.18     "

0.230     "     0.039 = 16.95     "

Mean of analyses ... 16.98 per cent.  $H_2O$ .

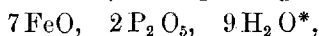
*Estimation of Iron.*—The iron was estimated by a standard solution of potassium permanganate. When the crystals are *pure*, there is no difference in the quantity of the test-solution employed, whether before or after the addition of a deoxidizing reagent to the solution of the mineral in dilute hydrochloric acid, showing the absence of the higher iron oxides.

Mineral.	Per cent.	Per cent. FeO.
0.196 gave	40.80 iron	= 52.45
0.184     "	41.24     "	= 53.02
0.243     "	41.13     "	= 52.85
0.201     "	40.95     "	= 52.64
Mean of iron.....		41.03
Mean of ferrous oxide .....		52.76.

*Estimation of Phosphoric Acid.*—The phosphoric acid was estimated as magnesium pyrophosphate.

Mineral.	$Mg_2''P_2O_7$ .	Per cent. $P_2O_5$ .
0.214 gave	0.101	= 30.13
0.236     "	0.111	= 30.09
Mean of analyses .....		30.11.

This gives a formula closely corresponding to

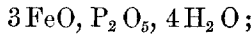


\* *Ludlamite* is doubtless a basic ferrous phosphate; and its relation to

which requires the following numbers:—

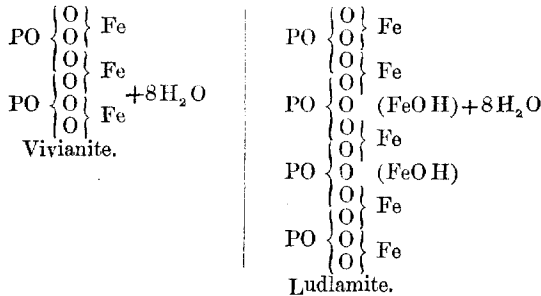
	Calculated.	Found.
7 FeO .....	53·05	52·76
2 P <sub>2</sub> O <sub>5</sub> .....	29·88	30·11
9 H <sub>2</sub> O .....	17·05	16·98
	99·98	99·85

That different specimens of the mineral vary somewhat in their composition there can be little doubt. Owing to the kindness of Mr. Ludlam and Mr. Talling, I had sufficient for many other analyses, not published here; and in one or two instances the amount of iron was a per cent. or two under the mean of the numbers given above, as estimated by potassium permanganate. In a preliminary note sent to the 'Chemical News' on this mineral, it was suggested that its probable composition might be represented by the formula



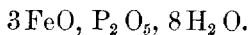
and in this case the amount of water is 16·7 per cent., within 0·3 per cent. of that in the formula I have adopted; but the ferrous oxide is lower, and the phosphoric acid higher, than subsequent analyses yielded. In more than ten estimations of iron made from the clear green crystals of the minerals, 40·5

Vivianite or normal ferrous phosphate may with much probability be represented by the following formulæ:—



It may be regarded, in fact, as formed by the addition of a single molecule of ferrous hydrate, Fe(OH)<sub>2</sub>, to two molecules of Vivianite, this addition being accompanied by the separation of a part of the water of crystallization of the latter.

per cent. iron was the lowest number obtained. In the analyses of Vivianite, it is well known that the results of chemists have varied much as to the amount of water in the mineral. Vogel, for instance, gives 31.0 per cent., Stromeyer 27.48, and Brandes 25.00 only. Messrs. Maskelyne and Flight found 28.26, which agrees best with the recognized formula



Vivianite, on heating, turns white, exfoliates, and does not decrepitate in the slightest, and, moreover, when in the crystalline form, is oxidized only to a very slight extent. It is a striking experiment to heat small crystals of Ludlamite in the ordinary atmosphere, and another portion in carbonic acid: the decrepitation is the same; but in the former case the crystals, as before observed, change their colour to a splendid bluish black, while in the latter atmosphere they become brilliantly pearly white.

This new mineral I have named *Ludlamite*, after my friend Mr. Ludlam, a gentleman who for many years has cultivated the science of mineralogy, and possesses, perhaps, the finest private collection of minerals in Great Britain. I have to return my best thanks to Mr. Talling for having first called my attention to the mineral, and for affording me specimens necessary for its examination.

I am also extremely indebted to Professor Maskelyne, F.R.S., of the British Museum, who kindly undertook the crystallographic part of the investigation, the results of which are subjoined.

The crystals of Ludlamite belong to the oblique system, the elements of the crystal being

$$\begin{aligned} 101.100 &= 42^\circ 46', & 111.010 &= 36^\circ 37', \\ 101.001 &= 36^\circ 41'. \end{aligned}$$

Otherwise, the angle of the axes Z-X is  $79^\circ 27'$ , and the parametral ratios  $a:b:c=1:0.4439:0.8798$ . The forms met with on the different crystals examined are

$$\begin{aligned} a, 100; & c, 001; & m, 110; & g, \bar{1}11; & d, \bar{1}01; \\ k, \bar{2}01; & t, 201; & l, 011; & r, 112; & p, 111. \end{aligned}$$

The face  $c$  is a prominent face with vitreous lustre, and is

parallel to the only distinct cleavage. It presents fine striations parallel to its intersections with the faces  $q$ . The face  $a$  is small, usually triangular, and remarkable for its lustre: the faces of the form  $q$  are the most developed after the faces  $c$ , often equally developed with the latter, and then imparting to the crystal a rhombohedral aspect. They are furrowed with striation-planes parallel to the edges they form with the cleavage-plane. See fig. 5.

The faces of the form  $m$  are brilliant but very narrow, replacing the acute edges in which a face  $c$  meets a pair of the faces  $q$ . They are somewhat rare. The faces of the form  $d$  truncating those edges of the faces  $q$  which lie in the plane of symmetry are very small, but occur not unfrequently; the composite character of the crystal, however, renders a good measurement of the angle  $ad$  very difficult. The faces  $l$ ,  $t$ , and  $p$  have been only once observed.

Owing to the difficulty of taking accurate measurements between the furrowed faces of the form  $q$  and the faces of the forms  $c$  or  $a$ , an evaluation of the various measurements of the angles on the crystals was made, and the method of least squares applied for the determination of the angles  $ac$ ,  $am$ , and  $qq'$ , from which the Table of calculated angles (column 1) is reckoned. Angles obtained from the measurement of four crystals were as follows\* :—

Calculated angles.	Measured angles.
$ac = 79\ 27$	$79^\circ 26\frac{1}{2}' \mid 79^\circ 27' \parallel 80^\circ 20'$
$ca' = 100\ 33$	
$cd = 45\ 53$	$45^\circ 56'$
$da' = 54\ 40$	$54^\circ 33' \mid 54^\circ 9' \parallel 54^\circ 3'$
$ad = 125\ 20$	$125^\circ 27'$
$at = 26\ 49\frac{1}{2}$	
$tc = 52\ 37\frac{1}{2}$	$52^\circ 50'$
$ck = 68\ 36\frac{3}{4}$	
$ka' = 31\ 56\frac{1}{4}$	$31^\circ 37'$
$am = 65\ 41\frac{1}{2}$	$65^\circ 56' \mid 65^\circ 55\frac{1}{2}'$
$mm' = 48\ 37$	$48^\circ 8'$
$m'm = 131\ 23$	$131^\circ 52'$

\* In the original description of this crystal, an omission of a unit in one of the angles used in the calculation vitiated the numbers given in the first column. Those given above are, however, founded on data that are better than those previously used.

Calculated angles.	Measured angles.
$a q = 107 \ 42\frac{2}{3}$	$107^\circ \ 43'$
$q a' = 72 \ 17\frac{1}{3}$	$72^\circ \ 17' \parallel 72^\circ \ 35' \mid 72^\circ \ 39\frac{1}{2}' \parallel 108^\circ$
$a p = 64 \ 1\frac{1}{3}$	$64^\circ \ 9'$
$a l = 85 \ 12$	$85^\circ \ 23'$
$p l = 21 \ 10\frac{1}{4}$	$21^\circ \ 24'$
$l a' = 94 \ 48$	
$l q = 22 \ 30\frac{2}{3}$	
$c m = 85 \ 40\frac{2}{3}$	$86^\circ \ 6'$
$m c' = 94 \ 19\frac{1}{3}$	$93^\circ \ 54'$
$c' q = 111 \ 29$	$110^\circ \ 59' \parallel 111^\circ \ 52' \mid 111^\circ \ 4' \parallel 111^\circ \ 30'$
$c q = 68 \ 31$	$69^\circ \ 1' \parallel 68^\circ \ 6' \text{ to } 68^\circ \ 56' \parallel 68^\circ \ 30' \parallel 68^\circ \ 49'$
$m' q = 25 \ 48\frac{1}{3}$	$25^\circ \ 29'$
$c r = 44 \ 36\frac{1}{2}$	$\parallel 44^\circ \ 12'$
$r m = 41 \ 4\frac{1}{2}$	
$c p = 61 \ 25\frac{1}{2}$	
$p m = 24 \ 15$	$23^\circ \ 55'$
$q q' = 63 \ 28\frac{1}{2}$	$63^\circ \ 24' \parallel 63^\circ \ 38'$
$d q = 58 \ 15\frac{3}{4}$	$58^\circ \ 32' \mid 58^\circ \ 10\frac{1}{2}' \parallel 58^\circ \ 14' \parallel 58^\circ \ 33'$
$q d' = 121 \ 44\frac{1}{4}$	
$q \bar{q}' = 116 \ 31\frac{1}{2}$	$116^\circ \ 36' \qquad 116^\circ \ 32' \parallel 116^\circ \ 13'$
$k q = 60 \ 58\frac{1}{2}$	$60^\circ \ 40'$
$k m = 110 \ 27$	$110^\circ \ 19'$
$q m = 49 \ 28\frac{1}{2}$	$49^\circ \ 39' \parallel 49^\circ \ 57'$
$m k = 69 \ 33$	$70^\circ \ 12' \ 69^\circ \ 48'$
$p n = 53 \ 23$	
$p b = 36 \ 37$	
$c l = 62 \ 50$	$61^\circ \ 5'$
$l b = 27 \ 10$	

The crystals are generally composite—the faces of the forms  $\{\bar{1} \ 1 \ 1\}$  and  $\{0 \ 0 \ 1\}$  being not only furrowed but often also tessellated, and, from this cause also, not planes; and occasionally, where the crystal is thin in the direction of the normal to  $c$ , the faces  $q$  in the zone  $[c m]$  assume a rounded character, and the angle  $q c$  offers various values, the limits of which are about  $64^\circ$  and  $74^\circ \ 17'$ .

Besides the very perfect cleavage parallel to the face  $0 \ 0 \ 1$ , there is a second and more difficult cleavage parallel to the faces of the form  $1 \ 0 \ 0$ .

The figures 1 to 5 represent the distribution of forms on different crystals.

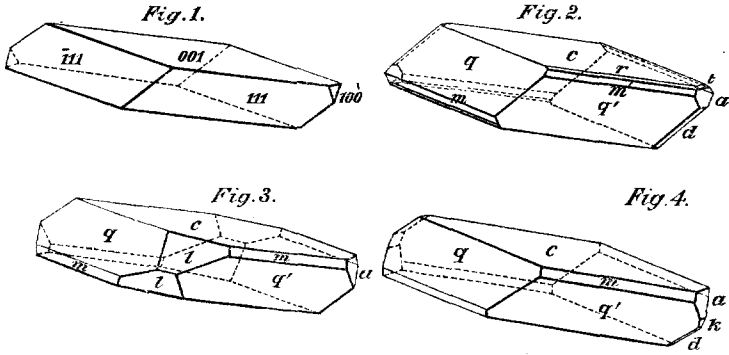
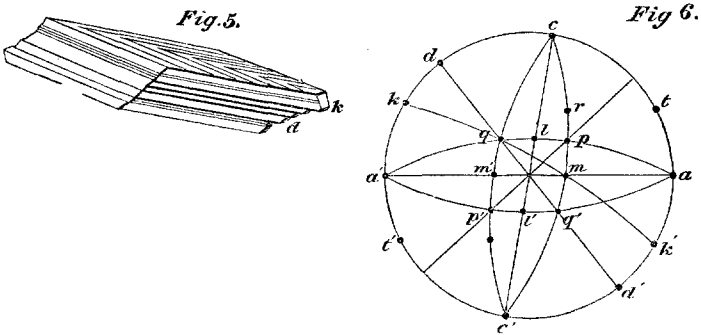


Fig. 6 is a stereographic projection of the poles of the crystal.



On looking through a plate of a crystal of Ludlamite parallel to a cleavage-plane in a Nöremberg's polarization-apparatus, one of the optic axes may be discerned near the edge of the field; and it is also seen that the optic axes lie in the principal section parallel to the plane of symmetry.

Accordingly two faces were ground on a crystal as nearly as possible parallel to the plane of symmetry. One of the planes thus ground was cemented to a plate of glass and laid upon the revolving stage of a microscope, and by the aid of a goniometer eyepiece, one wire of which was accurately adjusted parallel to the plane of polarization of the light employed, the directions were determined of the principal sections

of the crystal relatively to the trace or edge of the cleavage-plane, 0 0 1. This process gave an angle of  $12^{\circ} 22'$  for the inclinations of the two principal sections upon the trace of the face 0 0 1 and on its normal respectively, the greater angle of  $102^{\circ} 22'$  for one of the principal sections lying on the positive\* side of the normal 0 0 1. Consequently the normal of the face 1 0 0 makes an angle of  $22^{\circ} 55'$  on one of the principal sections. A plate was accordingly ground from this crystal in a direction as nearly perpendicular as was attainable to this principal section; and a second plate was formed from a cleavage fragment of another crystal as nearly as possible perpendicular in direction to that of the former plate and to the plane of symmetry.

Examined in oil, the optic axes were found to make an apparent angle of  $97^{\circ} 50'$  in the former plate and of  $119^{\circ}$  in the latter. The first mean line is therefore inclined on the normal of the face 1 0 0 at  $22^{\circ} 55'$ , and on the normal of the face 0 0  $\bar{1}$  at an angle  $77^{\circ} 38'$ ; and the acute angle between the optic axes within the crystal, as obtained by calculation, is  $88^{\circ} 54'$ .

The dispersion of the optic axes for the different colours appears to be inconsiderable. The striated structure of the crystal from which the plate was cut perpendicular to the first mean line somewhat obscured the tints close to the hyperbolas; but in both the eyes representing the optic axes a blue fringe on the convex side of the hyperbola was discernible. In the other plate this characteristic was more marked, as in it each hyperbola presented a blue fringe within the first ring on the side nearest, and a red fringe on the side opposite, to the second mean line. Consequently the mean lines for these colours can be very little dispersed; for their dispersion is not recognizable in the plates experimented on; but the optic axes for the red rays present a slightly wider divergence in respect of the first mean line than do those for blue light.

The optical character is *positive*, as shown by the dilatation of the rings in the former of the two plates when a plate of quartz, cut perpendicular to the axis, is rotated on a line per-

\* In my first communication the contour of the fragment of a rough crystal on which I experimented led me to the erroneous conclusion that this angle was on the negative side of the normal.



pendicular to that which joins the optic axes in a Nöremberg polarization-apparatus.

It may be worth while observing that the directions of the principal sections in a small plate can be determined with ease and with considerable accuracy by the method above described, since, if the point of maximum obscuration is difficult to be hit upon with precision, this determination can be much facilitated by a slight rotation of the analyzing prism to right or left; for then tints developed in the crystal assist in indicating a slight inclination of its principal section to the plane of polarization. Of course the relative directions of the principal sections of the crystal, and of the trace (or edge) of one of its faces perpendicular to the plane of symmetry, are readily determined either by the revolution of the crystal on the rotating stage till the trace of the plane is in contact with the wire of the eyepiece, or by bringing the rotating wire of the eyepiece into apparent contact with the edge of the face in question.

The method is available and chiefly useful in cases where it is almost impossible, or at least requires a refined lapidary's skill to form an artificial twin according to the elegant method of Des Cloizeaux.

VI. *Notice of Crystallographical Forms of Glaucodote.* By  
 W. J. LEWIS, M.A., *Fellow of Oriel College, Assistant in the  
 Mineral Department, British Museum* \*.

[Plate II.]

THE mineral from Häkansbo in Sweden is found in large crystals of metallic lustre and dull tin-white colour, imbedded in towanite and pyrites. The crystals are, for the most part, twins, most of them being twinned about the normal to the face (0 1 1), so far not described, some about the normal to the prism-face (1 1 0). The specific gravity and the prism-angle agree fairly well with those of Breithaupt's acontite.

	Glaucodote.	Acontite (Br.).
	Sp. gr. 5·985-6·18.	6·008-6·059.
Prism-angle . . .	69° 32'	69° 31'
Brachydome-angle .	100 2	102 0

\* Read December 15, 1876.