XXII. *New Researches upon the Dispersion of the Optic Axes in Harmotome and Wöhlerite, proving these Minerals to belong to the Clinorhombic [Oblique] System.*

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We are already acquainted with a considerable number of crystals, natural as well as artificial, the forms of which have only been determined with precision by the examination of their optical properties as doubly refracting bodies. Harmotome and Wöhlerite furnish two fresh examples of this; and they afford all the more important proof of the necessity of appealing to these properties, inasmuch as the crystals of these substances would appear certainly to be derived from a right rhombic prism, so long as we consider only the apparent symmetry of their external forms, or the orientation of the plane containing their optic axes. The different sorts of dispersion which these axes might be capable of presenting* are so feeble, and so difficult of appreciation on account of the slight transparency of Wöhlerite, and the complex structure of the crystals of Harmotome, that the determination of these dispersions has hitherto been too incomplete to allow of any conclusion being drawn as to the crystalline type they might otherwise serve to characterize.

It was a remark of M. Axel Gadolin, to which I shall make further allusion, that induced me to resume the attentive study of the phenomena of dispersion, first in Harmotome, and then in Wöhlerite, and as a consequence to modify the crystallographic type to which these minerals have been in general referred.

Harmotome.

It is now some years† since I showed that simple crystals of Harmotome did not exist, and that those of Strontian in Scotland (Morvenite), considered as such, presented, in fact, a twinning formed by the interpenetration of two principal individuals. The particular orientation of the plane of the optic axes in each of the crystals of which the least complicated of such groups are composed had led me to refer their crystalline form to a right rhombic prism of 124° 47′; and I had been induced to look on this prism as presenting a peculiar sort of hemihedrism, or rather hemimorphism, such that only the half of the fundamental rhombic octahedron existed, that namely formed of four faces parallel two and two, and lying in the same zone. More recently I had established, in

* See my memoir "Sur l'emploi du microscope polarisant," Annales des Mines, 6me série, t. vi. 1864.

† "Sur l'emploi des propriétés optiques biréfringentes pour la détermination des espèces cristallisées," 2nd memoir, Annales des Mines, t. xiv. 1858.

the modifications which heat induces in the position of the optic axes and of their plane*, a phenomenon less compatible with the hypothesis of a primitive rhombic form; but the slight transparency of the plates on which I had operated, the wide separation of their optic axes, which rendered the examination of the two systems of rings almost impossible in air, and finally the almost complete absence of dispersion, had led me to believe in an anomaly as the result of the always highly complex structure of the crystals.

In a memoir published towards the middle of 1867, "Sur la déduction d'un seul principe de tous les systèmes cristallographiques," M. AXEL GADOLIN suggested the idea that the crystals of Harmotome might probably belong to the oblique system, and that then their forms would no longer present any hemihedrism.

Desirous of verifying the truth of this suggestion, which had been communicated to me by M. GADOLIN in the month of June 1867, I had some new plates cut normal to the *positive* acute bisectrix, from very transparent crystals of the Scotch Morvenite, for which I was indebted to the kindness of my friend Mr. MASKELYNE; and I have been enabled to establish, both in oil and in air, a very decided twisted dispersion. Thanks to a separation of the optic axes less divergent than that of my former plates, I have been able also to satisfy myself directly that the displacement impressed by heat on the plane containing these axes is a rotary one, quite analogous to that which I have shown to exist in the cases of borax and Heulandite.

It is therefore now beyond doubt that the crystalline type of Harmotome is the oblique rhombic prism, and that the figures 185, 186, and 187 (pls. 31 and 32) of the atlas of my 'Manual of Mineralogy,' ought to be turned so as to make the plane p, which presents the crossed striations, into the plane of symmetry of the new form. The simplest plan, then, is to look on the faces $b\frac{1}{2}$ of the figure as forming the lateral faces m of the new primitive prism, one of the former faces m as the base of this prism, and the other as the plane h^1 truncating its obtuse edge.

The figures 1 to 5 (Plate XXXIV.) which represent the principal combinations of the forms observed have the new symbols, the relations of which with the old ones are as follows:—

New symbols.		Former symbols.
Des Cloizeaux's notation.	Miller's notation.	Des Cloizeaux's notation.
m	110	$b\frac{1}{2}$
h^1	100	m
p	001	m
$h\frac{5}{3}$	410	$b\frac{1}{8}$
$h\frac{7}{3}$	520	,,
g^1	010	p
o^1	101	$h\frac{7}{4}$

* Nouvelles recherches sur les propriétés optiques des cristaux naturels ou artificiels, insérées dans les Mémoires présentés par divers savants à l'Institut Impérial de France, t. xviii. 1867.

The figures 1, 2, and 3 belong to the simple macles which constitute the *Morvenite* of Scotland and the greater part of the crystals of Oberstein; the figures 4 and 5 are the double cross-formed macles so common at Andreasberg. In the first the two individuals interpenetrate one into the other so as to form four sectors, usually very unequal in their magnitude. Theoretically these sectors ought to occur following two planes perpendicular to each other, the one parallel to the base, the other parallel to the very simple modification a^1, the inclination of which upon this base is precisely 90°; but in reality these sectors more frequently are united only in an imperfect manner, and there exist between their sides little channels more or less sinuous (fig. 6). It is easy to show this by passing parallel rays of polarized light through plates cut very thin parallel to the plane of symmetry.

In the cross-formed macles (figs. 4 and 5) two individuals, already composite, penetrate one another so as to have their planes of symmetry perpendicular, but their intercrossing, instead of taking place on the planes inclined at 135° on the base, and very nearly in the plane e^1, usually occurs with surfaces that are irregular and jagged: however, the direction of what is theoretically the plane of assemblage is sometimes indicated by a series of plates excessively thin and which fill the little interval, then sensibly rectilinear, which exists between the two individuals (fig. 7).

It is well known that on crystals of Harmotome it is very difficult to obtain measurements for the angles that are at all precise; nor can it be otherwise; for independently of the crossed striæ the points of junction of which form upon the plane of symmetry g^1 two slightly salient lines perpendicular to each other, the base p is almost always more or less decidedly waved with lines parallel to its intersection with h^1, and the faces m are finely striated in the direction of the edge $\frac{m}{g^1}$; furthermore, the individuals of which the macles are composed are hardly ever united in a manner sufficiently perfect for the four faces h^1 and ${}_1y$ of a crystal similar to that represented in fig. 1, to be found exactly in the same zone with the two bases p; the same is true of the faces anterior and posterior $m\,h^1\,m$, which ought to form one single vertical zone. Thus it is only an exceptional case, or where one is operating on very small crystals of Morvenite from Strontian, that one can obtain the inclinations $p\,m$ and $h^1\,m$ with any exactitude.

Combining the results formerly known with those which a new and very numerous series of observations have afforded me, the following Table will give the inclinations at which I have now arrived.

$b:h::1000:1007{,}00$ D=818,02 d=575,19.

Plane angle of the base . . . =109° 46′ 27″.

Plane angle of the lateral faces . =109° 10′ 50″.

Calculated angles.	Measured angles.
*$m\,m$ 120° 1′	120° 1′ (Köhler).
$m\,h^1$ 150° 0′ 30″	150° 0′ 24″, mean (Dx.); 149° 32′ (Phil.)[a].
$m\,g^1$ 119° 59′ 30″	120° 15′, mean (Dx.); 120° 56′ (Phil.).
$h^{\frac{5}{3}}\,h^1$ 171° 47′	171° 4′ (Phil.).
$h^{\frac{5}{3}}\,g^1$ 98° 13′	„
$h^{\frac{7}{3}}\,h^1$ 167° 0′	166° 30′ (Dx.)[b].
$m\,h^{\frac{7}{3}}$ 163° 0′	162° 50′ to 163° (Dx.).
$h^1\,g^1$ 90°	„
$p\,o^1$ 144° 18′	„
$o^1\,h^1$ 160° 32′	„
*$p\,h^1$ 124° 50′	124° 50′ just; 124° 53′, mean (Dx.); 125° 5′ (Phil.).
$o^1\,{}_{\iota}o$ 71° 24′ over h^1	„
$h^1\,{}_{\iota}y$ adj. 110° 20′	110° 28′, mean (Dx.); 110° 26′ (Phil.); 111° 15′ (Köhler).
$h^1\,{}_{\iota}y$ 69° 40′ over p	69° 39′, mean (Dx.).
$p\,m$ 119° 39′	119° 5′ approx. (Dx.).
$m\,u$ adj. 120° 42′	120° 45′ to 121° 37′ (Dx.); 121° 6′ (Lévy); 121° 28′ (Köhler).
$m\,u$ 89° 23′ on g^1	89° 2′, mean (Dx.).
*$p\,a^1$ 90°	Twin plane of the simple macles.
$p\,e^1$ 134° 42′	Face nearly corresponding to the twin plane of the crossed macles.

Instead of the prism $h^{\frac{5}{3}}$ of PHILLIPS, I have observed the prism $h^{\frac{7}{3}}$ on many crystals of Morvenite, and instead of o', given by GREG, I have found $o^{\frac{2}{7}}$ with

	Calculated.	Measured.
$p\,o^{\frac{2}{7}}$	131° 49′	131° 30′
$o^{\frac{2}{7}}$	173° 1′	„

There exist two principal cleavages, the one easy and rather neat parallel to the plane of symmetry g^1, the other less easy parallel to the base p.

The plane of the optic axes and their acute positive bisectrix are perpendicular to the plane of symmetry. The disposition of the coloured rings in plates normal to the two bisectrices had heretofore induced me to look on the mean optic axes as situated exactly in the plane bisecting the angle $p\,h^1$; but I have since assured myself that this was not altogether true. In fact the results from a great number of observations made at 15° C. by means of two Nicol prisms crossed at right angles in the direction in which the maximum of extinction takes place in two neighbouring sectors, taken from many plates of Morvenite parallel to the plane of symmetry, may be stated as—

First. That the plane of the axes corresponding to red rays makes angles of about

25° 42′ with a normal to p,
29° 28′ with a normal to h^1.

Second. That the plane of the axes corresponding with the blue rays makes an angle of about

25° 5′ with a normal to p,
30° 5′ with a normal to h^1.

[a] Phil. = PHILLIPS. [b] Dx. = DES CLOIZEAUX.

There is then a separation of about 0° 37′ between the plane of the red axes and the plane of the blue axes; and this explains the twisted dispersion which shows itself sufficiently sensibly by the colours exhibited in plates of Harmotome that are sufficiently transparent and are normal to the acute bisectrix, when one examines them by aid of the polarizing microscope.

Among the plates of Morvenite which have allowed, as I before said, of my studying afresh the action of heat on the separation and the orientation of the optic axes, the most perfect has given me in oil for the red rays, and at 24° C., $2H_a=87° \ 2'$.

If one compares this number with those which I have published in my 'Manual of Mineralogy,' it will be seen that the optic axes present separations that vary greatly according to the specimens.

The preceding plate, when placed on the heating cell of the microscope in such a manner as to show its optic axes in a horizontal plane perpendicular to the plane of polarization, permits of our seeing, when one inclines it sufficiently to right or left, the greater part of the bar which traverses the central ring of each system. An elevation of the temperature produces an approximation of the axes, and the change in form of each central ring, which have been described in my 'Nouvelles recherches sur les propriétés optiques des cristaux naturels ou artificiels,' while the two transverse bars have a tendency to an inclination in opposite directions and are displaced by the same amount, the one above, the other below the horizontal plane which at first contained them. This displacement, which indicates a rotation of the optic axes, is hardly sensible between 15° and 80° C., but from above 90° it becomes very evident and augments with the temperature.

A peculiar and somewhat abnormal character is imparted to this change by the circumstance observed in one of my experiments in which the temperature had been elevated up to 160° C. In this case the displacement continued on the increase during the cooling of the air-bath from 160° to about 108° C. At the moment of maximum displacement the angle through which the plane of the axes had turned seemed at least equal if not greater than that which I had been enabled to measure in the case of borax. At 92° C. the transverse bars approached again the horizontal position, and began to move in the direction of their first orientation, but they did not exactly attain that orientation until the lapse of about thirty minutes after the thermometer in the air-bath had come back to its original reading. In other experiments, where the temperature was maintained between 50° and 52° C., it took twelve or fifteen minutes for the displacement of the bars to become sensible. In from fifteen to thirty minutes more this displacement had attained its maximum. When the lamp was removed, the return movement of the bars hardly became visible before ten or twelve minutes had elapsed after the thermometer had begun to fall, and thirty to forty-five minutes more subsequently elapsed before they had exactly returned to the position they had occupied at the beginning of the experiment.

Harmotome is up to the present time the only crystallized substance which exhibits

a considerable delay between the moment when certain optical phenomena are manifested, and the moment of the change of temperature. This delay, produced by causes probably very complex, is all the more remarkable from the plate on which I made most of my experiments having dimensions no greater than two millimetres in width by half a millimetre in thickness, dimensions far less than those of the plates which I am in the habit of introducing into my air-bath, and of which the modifications, thermic as well as optical, have always presented themselves to me as nearly as possible simultaneously.

Wöhlerite.

In my 'Manual of Mineralogy' I described the crystals of Wöhlerite as derivable from a prism of very nearly 90°. In the point of view from which I had been induced to look at them, from a consideration of the orientation of their optic axes, they appeared to offer a certain number of homohedral forms, associated with forms that were hemihedral or hemimorphic, analogous to those that I have drawn attention to in Harmotome. Since I have established that this last mineral belonged in reality to the clinorhombic system, I have sought to ascertain whether this was not so also in the case of Wöhlerite, all the forms of which would in that event be homohedral. But in this case a study of the different varieties of dispersion is rendered difficult by the yellow colour, and by the imperfect transparency presented by the substance even when in very thin plates. Besides this, contrary to what one finds in the case of Harmotome, whilst the dispersion belonging to the optic axes is very distinct, the *horizontal and twisted* dispersions, which should be sought for in the plates normal to the two bisectrices, are, on the contrary, but slightly evident. However, on examining in oil some thin plates placed so as to have the plane of their optic axes horizontal and perpendicular to the plane of polarization, I observed in the plates normal to the obtuse *positive* bisectrix, some faint blue and red fringes disposed in contrary directions above and below the bars which traverse the two annular systems. These colours indicate, then, the existence of an appreciable twisted dispersion. In the plates normal to the acute *negative* bisectrix, the transverse bar of each system is bordered on one side by very pale blue, and on the opposite side by an equally pale yellow. The horizontal dispersion is thus feebly indicated. Furthermore, in the former, as in the latter plates, the edges of one system of rings often show a colour decidedly more brilliant than those of the other system; but this apparent dissymmetry is only the result of the imperfection of the plates, and especially of the unequal transparence presented by their different parts in consequence of internal fissures.

The crystals of Wöhlerite ought, then, to be referred to an oblique rhombic prism, in which the plane of symmetry is normal to the plane which contains their optic axes. The primitive form which it seems most convenient to choose is a prism with an angle of very nearly 90°, which presents a cleavage, easy though interrupted, parallel to its plane of symmetry, and cleavages which are more difficult in the directions of the lateral faces m and of the plane h^1, which is parallel to the horizontal diagonals of the base.

The figures 1 to 9 (Plate XXXIV.) represent the actual appearance of the crystals

which carry the different combinations of forms which I have observed. Fig. 10 is the projection upon h^1, of a crystal measured by DAUBER, regarded by him as orthorhombic (POGGENDORFF'S 'Annalen,' t. xcii. p. 242). The spherical projection (fig. 11) made upon the plane of symmetry shows the principal zones in which all the faces are comprised that are hitherto known.

The dimensions of the primitive forms and the calculated inclinations compared with the inclinations as directly measured are given in the following Tables.

$b : h :: 1000 : 487{,}8112 \qquad D=687{,}8636 \qquad d=725{,}7450$

Plane angle of the base . . . . . . $= 86° \, 56' \, 17''{\cdot}8$

Plane angle of the lateral faces . . $=103° \, 50' \, 37''$

Calculated.	Measured.
$m\, m$ 90° 14′ in front	90° 3′ to 30′ (Dx.)[a].
$m\, m$ 89° 46′ on g^1	90° approx. (Dx.).
$h^1\, h^{\frac{9}{5}}$ 164° 7′	164° 15′ (Dx.).
$h^{\frac{9}{5}}\, g^1$ 105° 53′	„
$h^1\, h^3$ 153° 32′	153° 29′, mean (Dx.); 152° 55′ (Dau.)[b].
$h^3\, g^1$ 116° 28′	116° 30′ (Dx.); 116° 51′ (Dau.).
*$h^1\, m$ 135° 7′	135° 7′, mean (Dau.); 135° 16′, mean (Dx.).
$m\, g^1$ 134° 53′	134° 54′, mean (Dau.); 134° 59′, mean (Dx.).
$h^1\, g^3$ 116° 39′ 30″	116° 32′, mean (Dx.); 116° 14′ (Dau.).
$g^3\, g^1$ 153° 20′ 30″	153° to 153° 20′ (Dx.); 153° 30′ (Dau.).
$h^1\, g^2$ 108° 30′	108° 58′, mean (Dx.); 107° 39′ (Dau.).
$g^2\, g^1$ 161° 30′	161° 15′ (Dau.).
$m\, g^3$ adj. 161° 32′ 30″	161° 35′ (Dx.).
$m\, g^3$ 108° 13′ 30″ on g^1	108° 40′ (Dx.).
$m\, g^2$ 153° 23′	153° 40′ (Dx.).
$g^3\, g^2$ 171° 50′ 30″	172° (Dx.).
$h^1\, g^1$ 90°	90° (Dx.).
*$o^1\, h^1$ 136° 42′	136° 42′ (Dx.); 138° (Dau.).
$o^1\, p$ 152° 33′	152° 32′ (Dx.).
*$p\, h^1$ ant. 109° 15′	109° 15′, mean (Dx.); 110° 25′, mean (Dau.).
$p\, a^1$ adj. 140° 49′	140° 48′, mean (Dx.); 140° 15′ (Dau.).
$a^1\, h^1$ adj. 109° 56′	109° 34′, mean (Dx.); 108° 45′ to 109° 40′ (Dau.).
$p\, a^{\frac{1}{2}}$ adj. 113° 41′	113° approx. (Dx.).
$a^{\frac{1}{2}}\, h^1$ adj. 137° 4′	138° 35′? (Dau.).
$p\, h^1$ post. 70° 45′	„
$p\, e^2$ 161° 30′	162° 45′ (Dau.).
$e^2\, g^1$ 108° 30′	„
$p\, e^1$ 146° 12′	145° 35′ to 52′; 146° 15′ (Dx.); 146° 14′ (Dau.)
$e^1\, g^1$ 123° 48′	123° 10′; 50′; 124° 15′; 25′ (Dx.); 124° 7′ (Dau.).
$p\, e^{\frac{1}{2}}$ 126° 45′	„
$e^{\frac{1}{2}}\, g^1$ 143° 15′	143° to 143° 10′ (Dx.).
$p\, g^1$ 90°	90° (Dx.).

[a] Dx.=Des Cloizeaux.

[b] Dau.=Dauber.

Calculated.	Measured.
$p\,d\frac{1}{2}$ 142° 57′	142° 35′; 143°; 143° 30′ (Dx.).
$d\frac{1}{2}\,m$ 140° 34′	140° 35′ (Dx.).
$p\,m$ ant. 103° 31′	103° 15′ approx. (Dx.).
$p\,b\frac{1}{2}$ adj. 130° 10′	129° 35′ to 131° 30′ (Dx.).
$b\frac{1}{2}\,m$ 126° 19′	125° 5′ to 126° (Dx.).
$p\,b\frac{1}{4}$ adj. 106° 48′	„
$b\frac{1}{4}\,m$ 163° 12′	„
$p\,m$ post. 76° 29′	„
$p\,h^3$ ant. 107° 10′	107° 5′ (Dx.).
$p\,x$ adj. 137° 20′	„
$p\,a_3$ adj. 111° 13′	110° approx. (Dx.).
$p\,h^3$ post. 72° 50′	„
$a_3\,h^3$ adj. 141° 37′	„
$p\,y$ 129° 30′	„
$p\,g^3$ ant. 98° 30′	98° 10′ (Dx.)
$p\,\phi$ adj. 117° 43′	„
$p\,g^3$ post. 81° 30′	80° 40′ (Dx.).
$\phi\,g^3$ adj. 143° 47′	143° approx. (Dx.).
$p\,g^2$ ant. 96°	95° 35′ approx. (Dx.).
$e^2\,h^1$ ant. 108° 13′	„
$x\,h^1$ adj. 108° 53′	„
$d\frac{1}{2}\,h^1$ adj. 130° 53′	131° 12′, mean (Dx.); 130° 49′ (Dau.).
$e^1\,h^1$ ant. 105° 54′	106° 10′, mean (Dx.); 106° 54′? (Dau.).
$e^1\,h^1$ post. 74° 6′	73° 20′, mean (Dx.); 73° 31′ (Dau.).
$d\frac{1}{2}\,e^1$ 155° 1′	155° 3′, mean (Dx.).
$e^1\,b\frac{1}{2}$ 147° 37′	147° 30′ (Dx.); 147° 43′ (Dau.).
$b\frac{1}{2}\,a_3$ 155° 15′	155° (Dx.).
$b\frac{1}{2}\,h^1$ 106° 29′ over a_3	106° 25′ to 45′ (Dx.); 105° 44′? (Dau.).
$b\frac{1}{2}\,h^1$ 73° 31′ over e^1	73° 33′, mean (Dx.).
$a_3\,h^1$ adj. 131° 14′	131° 30′ (Dx.); 130° 10′ (Dau.).
$a_3\,d\frac{1}{2}$ 97° 53′ over e^1	97° 40′ (Dx.).
$a_3\,h^1$ 48° 46′ over e^1	49° 8′, mean (Dx.).
$y\,h^1$ adj. 121° 27′	120° 57′ (Dau.).
$e\frac{1}{2}\,h^1$ ant. 101° 23′	101° 45′ to 102° 20′ (Dx.).
$e\frac{1}{2}\,h^1$ post. 78° 37′	78° 18′, mean (Dx.).
$\phi\,h^1$ 101° 48′ over $b\frac{1}{4}$	102° 10′, approx. (Dx.).
$b\frac{1}{4}\,h^1$ adj. 121° 46′	„
$g^1\,y$ 134° 12′	134° 18′ (Dau.).
$g^1\,d\frac{1}{2}$ 115° 56′	115° 18′, mean (Dx.).
$g^1\,o^1$ 90°	„
$g^1\,\phi$ 143° 8′	143° 15′ to 143° 30′ (Dx.).
$g^1\,b\frac{1}{2}$ 123° 41′	123° 49′, mean (Dx.).
$\phi\,b\frac{1}{2}$ 160° 33′	160° 30′ (Dx.).
$g^1\,x$ 108° 26′	„
$g^1\,a^1$ 90°	89° 55′ (Dx.).
$b\frac{1}{2}\,a^1$ 146° 19′	145° 40′ (Dx.).
$x\,a^1$ 161° 34′	„

Calculated.	Measured.
$g^1 b^{\frac{1}{4}}$ 134° 1′	
$g^1 a_3$ 115° 47′	115° 10′ (Dx.).
$g^1 a^{\frac{1}{2}}$ 90°	„
$o^1 m$ adj. 121° 2′ 30″	121° 55′ (Dx.).
$o^1 m$ 58° 57′ 30″ over e^1	„
$e^1 m$ post. 101° 26′	„
$\varphi^1 m$ adj. 135° 12′	135°, approx. (Dx.).
$e^2 m$ ant. 116° 27′	„
$y\ m$ adj. 149° 30′	„
$e^1 m$ ant. 125° 55′	126° 20′, approx. (Dx.).
$a^1 m$ 76° 1′ over e^1	75° 40′, approx. (Dx.).
$a^1 m$ 103° 59′ over a_3	103° 40′; 52′ (Dx.)
$a_3 m$ adj. 140° 43′	140° 2′ to 141° (Dx.).
$a^1 a_3$ 143° 16′	143° 15′ (Dx.).
$e^{\frac{1}{2}} m$ ant. 134° 51′	„
$b^{\frac{1}{2}} m$ 100° 58′ over $e^{\frac{1}{2}}$	„
$a^{\frac{1}{2}} m$ adj. 121° 15′	„
$o^1 h^3$ adj. 130° 39′	130° 30′; 131° (Dx.).
$o^1 e^2$ 147° 18′	„
$e^2 h^3$ 93° 14′ over $b^{\frac{1}{2}}$	„
$b^{\frac{1}{2}} h^3$ adj. 120° 5′	„
$o^1 g^3$ adj. 109° 4′	109° 6′ (Dx.).
$o^1 e^{\frac{1}{2}}$ 122° 5′	„
$e^{\frac{1}{2}} g^3$ post. 128° 52′	„
$d^{\frac{1}{2}} g^3$ ant. 133° 12′	132° 10′, approx. (Dx.).
$e^1 g^3$ ant. 128° 19′	128°; 128° 30′ (Dx.).
$d^{\frac{1}{2}} h^3$ ant. 141° 20′	142°, approx. (Dx.).
$e^2 h^3$ 114° 55′ over $d^{\frac{1}{2}}$	„
$a^1 h^3$ 72° 14′ over e^2	72° (Dx.).
$a^1 h^3$ adj. 107° 46′	„
$e^{\frac{1}{2}} g^3$ ant. 143° 34′	„
$a^1 g^3$ 82° 29′ over $e^{\frac{1}{2}}$	„
$a^1 g^3$ 97° 31′ over $b^{\frac{1}{4}}$	98° 5′ to 20′ (Dx.).
$b^{\frac{1}{4}} g^3$ adj. 149° 0′	„
$e^1 h^3$ ant. 119° 33′	119° 52′ (Dx.).
$x\ h^3$ 98° 33′ over e^1	„
$a^{\frac{1}{2}} h^3$ 49° 3′ over e^1	„
$a^{\frac{1}{2}} h^3$ adj. 130° 57′	„
$\varphi\ g^3$ ant. 128° 33′	127° 40′ to 128° (Dx.).
$\varphi\ a^{\frac{1}{2}}$ 122° 16′	„
$a^{\frac{1}{2}} g^3$ adj. 109° 11′	„
$d^{\frac{1}{2}} g^2$ ant. 128° 30′	128° 30′, mean (Dx.).
$e^1 g^2$ ant. 130° 21′	129°, approx. (Dx.).
$e^1 g^2$ post. 116° 8′	115° 55′, mean (Dx.).
$e^{\frac{1}{2}} m$ post. 115° 11′	114° to 115°? (Dx.).
$b^{\frac{1}{2}} g^3$ post. 128° 32′	128° 50′ (Dx.).
$\varphi\ m$ ant. 114° 48′	114° to 115°? (Dx.).
$\varphi\ g^2$ ant. 133° 55′	134° 30′, approx. (Dx.).
$\varphi\ g^2$ post. 145° 26′	145° (Dx.).

$y = (d^1 b^{\frac{1}{3}} g^1)$ $x = (b^1 b^{\frac{1}{3}} h^{\frac{1}{2}})$.

$a_3 = (b^1 b^{\frac{1}{3}} h^1)$ $\varphi = (b^1 d^{\frac{1}{3}} g^1)$.

The forms which are most frequently met with on the crystals which I have had at my disposal are h^1, h^3, m, g^3, g^2, g^1, o^1, p, a^1, e^1, $d\frac{1}{2}$, $b\frac{1}{2}$, a_3. The forms $h\frac{9}{5}$, $a\frac{1}{2}$ (fig. 7), $e\frac{1}{2}$ (fig. 8), ϕ (fig. 9) are, on the contrary, very rare; e^2 and y have only been announced by DAUBER (fig. 10). I have supposed the existence of x and $b\frac{1}{4}$ corresponding to these two last faces by analogy with what I have observed upon the crystals I myself examined, on which there occur both in front and in rear planes such as p and a^1, o^1 and $a\frac{1}{2}$, e^1 and $b\frac{1}{2}$, $d\frac{1}{2}$ and a_3, $e\frac{1}{2}$ and ϕ, which make respectively almost equal angles with h^1. The plane of the mean optic axes is very nearly parallel to o^1. In a macle artificially formed of two plates cleaved in the direction g^1 and twinned after the plane h^1, the maximum extinction takes place at the same moment for both plates; these plates therefore have their optic axes situated in planes perpendicular to one another, and each of them inclined at 45° to the face of union h^1. As the yellow colour of the substance does not permit of any certain results being obtained with monochromatic glasses of red or blue, it is impossible to determine directly the angle which the plane of the axes corresponding to the red rays makes with the plane of the axes which correspond to the blue rays; this angle must, however, be very small, in consequence of the weak horizontal and twisted dispersion which is exhibited in oil, and to which I have alluded above. The bisectrix of the acute angle formed by the optic axes is negative and normal to the horizontal diagonal of the base. The separation of these axes varies with the crystals, and even with different portions of one and the same crystal. The following are the actual results that I obtained from three different crystals, each of which contributed a couple of plates normal to the acute and obtuse bisectrices:—

First crystal cited in my 'Manual.'

$2H_a=89° 34'$, $2H_o=128° 6'$, whence $2V=76° 10'$, $\beta=1{\cdot}67$ for the red rays.

$2H_a=90° 54'$, $2H_o=127° 6'$, whence $2V=77° 2'$, $\beta=1{\cdot}69$ for the blue rays.

Second crystal recently examined.

$2H_a=85° 41'$, $2H_o=139° 3'$, whence $2V=71° 56'$, $\beta=1{\cdot}69$ for the red rays.

$2H_a=86° 12'$, $2H_o=138° 32'$, whence $2V=72° 18'$, $\beta=1{\cdot}71$ for the blue rays.

Third crystal recently examined.

$2H_a=86° 24'$, $2H_o=144° 24'$, whence $2V=71° 26'$, $\beta=1{\cdot}72$ for the red rays.

$2H_a=87° 30'$, $2H_o=144° 8'$, whence $2V=72° 1'$, $\beta=1{\cdot}74$ for the blue rays.

Plates cut normally to the acute bisectrix in three other crystals gave for the red rays

$$2H_o=\overset{\text{I.}}{141° 17'};\ \overset{\text{II.}}{138° 42'};\ \overbrace{140° 32'\text{, first portion; } 138° 48'\text{, second portion.}}^{\text{III.}}$$

The dispersion belonging to the optic axes, weak in oil and in the interior of the crystals with $\rho<v$ is, on the contrary, very considerable in the air; for on the second

crystal the red axes undergo an apparent separation in air equal to 170° 53′, while the blue axes undergo a total reflexion. If we cast our eyes over the Table of the inclinations of the planes, it is easy to see that the crystals of Wöhlerite, besides the faces indicated above, as making angles almost equal in front and in rear with the vertical axis, present, furthermore, modifications with inclinations which are very nearly identical in two zones at right angles to each other. These crystals being rarely sufficiently good to furnish very precise measurements, it is almost impossible to distinguish crystallographically between the one and the other of the forms m, o^1, and $a^{\frac{1}{2}}$; g^2, p, and a^1; $d^{\frac{1}{2}}$ and a_3; e^1 and $b^{\frac{1}{2}}$; $e^{\frac{1}{2}}$ and φ: one can only do this by looking out for the facile cleavage that runs parallel to g^1 and the orientation of the plane of the optic axes. At the time of my first publications on the subject of Wöhlerite*, it was almost impossible to employ these two methods, in consequence of the scarcity of isolated crystals. This scarcity having become less felt in consequence of Professor NORDENSKIÖLD having been so kind as to send me some specimens, and from my having sacrificed one fine specimen upon its gangue, I have been enabled to obtain the precise interpretation of all the crystals I have figured in Plate XXXIV. accompanying my new investigation. The greater part of these crystals have been described in my two former memoirs and in my 'Manual'†; and as there has been confusion between the zones $h^1\,m\,g^1$ and $h^1\,o^1\,p$, on several of them, it may be useful that I should show here how my new symbols correspond with those of DAUBER and with those which are introduced in my 'Manual,' or in the figures 234, 235, 236, plate 40 of my 'Atlas.'

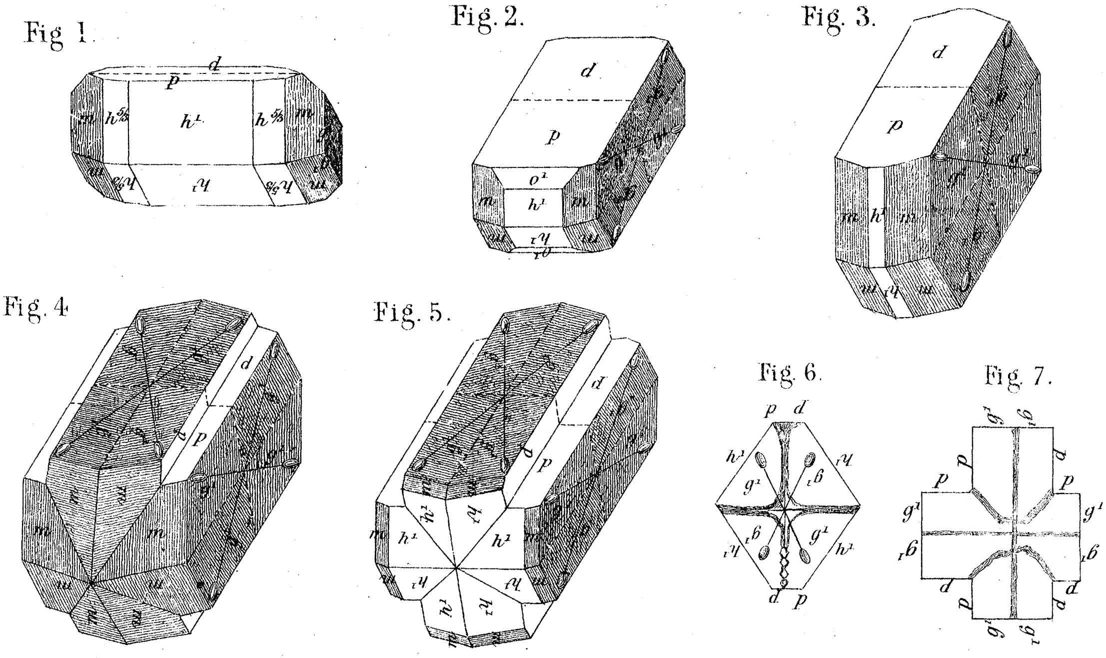
New symbols.	Dauber.	Manual.	Fig. 234, pl. 40.	Fig. 235, pl. 40.	Fig. 236, pl. 40.
h^1	a	m	m	....	m central.
g^1	b	m	p	m	m lateral.
$h^{\frac{9}{5}}$	,,	$b^{\frac{1}{10}}$	,,	,,	,,
h^3	n	$b^{\frac{2}{11}}$	$b^{\frac{2}{11}}$	h^2	h^2 and g^2
m	m	$b^{\frac{7}{20}}$	$b^{\frac{7}{20}}$	h^1 and g^1	h^1 and g^1
g^3	g	$b^{\frac{7}{10}}$	,,	h^2 and g^2	h^2 and g^2
g^2	h	b^1	b^1	h^3 and g^3	h^3 and g^3
p and a^1	k	b^1	h^3 and g^3	,,	b^1
o^1 and $a^{\frac{1}{2}}$	d	$b^{\frac{1}{3}}$	h^1 and g^1	,,	$b^{\frac{1}{3}}$
e^2 and $x=(b^1\,b^{\frac{1}{3}}\,h^{\frac{1}{2}})$	x	a^1 and e^1	,,	,,	a^1 and e^1
e^1 and $b^{\frac{1}{2}}$	o	a_2 and e_2	,,	a_2 and e_2	a_2 and e_2
$e^{\frac{1}{2}}$ and $\varphi=(b^1\,d^{\frac{1}{3}}\,g^1)$	,,	a_4 and e_4	,,	e_4	,,
$d^{\frac{1}{2}}$ and a_3	p	k and χ	,,	,,	k and χ
$y=(d^1\,b^{\frac{1}{3}}\,g^1)$ and $b^{\frac{1}{4}}$	i	s and σ	,,	,,	s and σ

The faces formerly (v and φ) were erroneously placed upon my figure 236; they belong to the zone $g^1\,e^1\,p$ (new symbols), and are the same as a_4 and e_4. The former prism, $h^{\frac{7}{4}}\,g^{\frac{7}{4}}$, having only been met with once and having yielded but one, and that a very imperfect measurement, must, it seems to me, be abandoned.

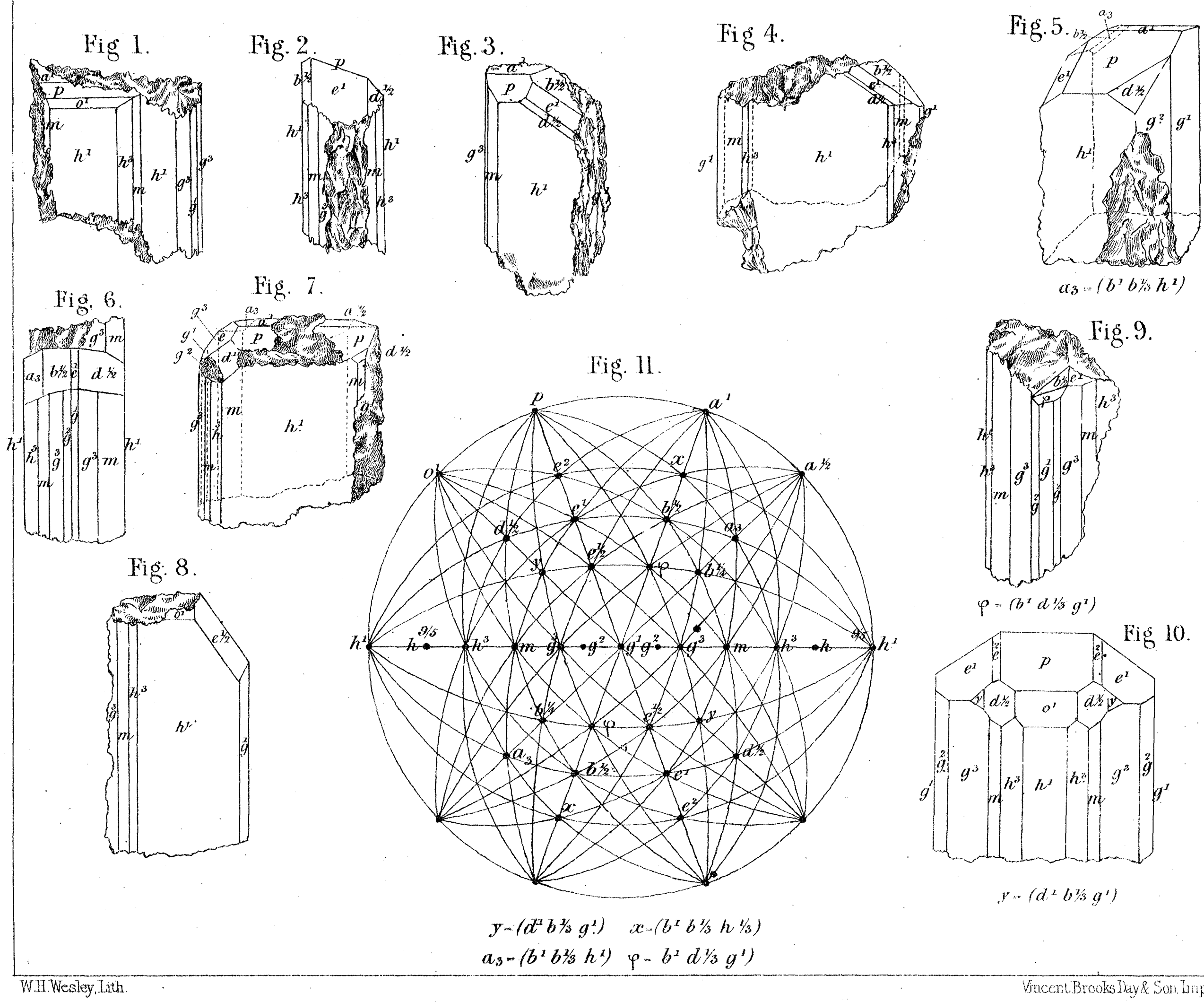
* Annales de Chimie et de Physique, 3rd series, vol. xl.

† Annales des Mines, 5th series, t. xvi. 1859. Manuel de Minéralogie, vol. i. 1862.

HARMOTOME.



WÖHLERITE.



$y = (d^1\, b^{1/3}\, g^1)$ $x = (b^1\, b^{1/3}\, h^{1/3})$

$a_3 = (b^1\, b^{1/3}\, h^1)$ $\varphi = b^1\, d^{1/3}\, g^1)$