Binnite from Imfeld in the Binnenthal.

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THIS rare mineral, the Dufrenoysite of von Waltershausen and others, crystallising in the cubical system, has been made the subject of careful investigation by several observers, with the result that, up to the present moment, it is doubtful whether the character of its forms is holohedral or hemihedral with inclined faces. Hessenberg[1] found that the mineral crystallised holohedrally, but Groth,[2] confirming Kenngott's[3] view, states that the best crystal in the Strassburg University collection shows a distinctly hemihedral development. Mr. Lewis,[4] having examined the specimen in the British Museum, found that several forms were developed only in alternate octants, and were consequently hemihedral, yet that others appeared in adjacent octants, and therefore possessed holohedral symmetry, and concluded that further researches were desirable to permit of a final decision of the question.

As a further contribution towards its solution, it is hoped that the following description of two very perfect crystals, brought by the writer from the Binnenthal in the year 1875, may prove of interest, the more so, as in this instance the hemihedral character is typically exemplified, both in the distribution of the forms and in the physical nature of the faces, which upon one of the crystals could be examined in all the eight octants, a somewhat unusual occurrence in the case of an attached crystal.

A comparison of the results given below, with Hessenberg's lucid description, leads to a suspicion that possibly two different cubical minerals are here involved, and that the holohedral and hemihedral crys-

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1 *Mineralog. Notizen*, Heft. IX., 1875, p. 6. *Abhandl. d. Senckenberg. Naturforsch. Gesellsch. in Frankf.*, Bd. X.

2 *Mineralien Sammlung d. Univ. Strassburg*, 1878, p. 59.

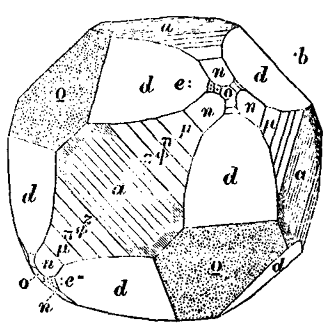
3 *Uebers. Min. Forsch.*, 1856, u. 57. *Die Minerale der Schweiz*, 1866, p. 378.

4 *Proceed. Crystallog. Soc.* II., 53, 1877, and *Zeitschr. f. Kryst.* II., 192, 1878.

tals may not be of the same substance, a suspicion strengthened somewhat by the fact that the results of chemical analysis are conflicting, and that the true chemical composition, generally assumed as conforming to the formula $Cu_6As_4S_9$, is as yet a matter of some doubt. It would certainly be of interest if a chemical investigation could be carried out upon crystals of holohedral character on the one hand, and of hemihedrally developed ones on the other. The great rarity of the mineral, and the restriction of its occurrence to a single locality,[1] will in all probability preclude the solution of this question by chemical means. The possibility of the existence of two distinct minerals is negatived again to a large extent by the occurrence of the same crystallographic forms on the specimens hitherto described, and also by the coincidence of the general physical characters, such as colour, lustre and fracture.

The crystals to be described were on different specimens of the white dolomite; crystal No. 1, in size about 3·5 mm. in its longest dimension, being attached in a small cavity immediately to the dolomite, and associated with yellow blende, pyrites, massive sulpharsenite (probably jordanite), barytocelestine, quartz and hyalophane. On this crystal four octants, namely, three positive and one negative, could be satisfactorily examined. The other crystal, No. 2, about 2 mm. long and very symmetrically developed, was attached to a group of small pyrites crystals within a small cavity of the dolomite, in such manner that, after removal from the matrix, it could be examined in all its octants, the point of attachment only covering a portion of a hexahedral and a few adjoining faces. The accompanying minerals in this case are pyrites, a rhombic sulpharsenite (probably dufrenoysite, v. Rath), and minute crystals of magnesite and white mica.

In both crystals the forms (110), (100), and κ $(1\bar{1}1)$ are about equally developed and dominant, with κ (211) prominent in the positive octants; κ (111) is well developed in crystal No. 2, but excessively minute as a single face in crystal No. 1, while the distribution and relative size of the principal subordinate forms is illustrated in the accompanying figure, which has been drawn to represent the natural crys-



[1] G. vom Rath, *Ueber d. Mineral-Fundstätte des Binnenthals*, *Pogg. Ann.* 122, p. 395.

tals as closely as possible. Most of the crystal faces are smooth, even and highly polished, with sharp and well defined combination edges, but faint striations are noticeable on the faces of (100) and κ (211) and the subordinate κ (*hkk*) in the zone (100) : κ (111) ; κ (1$\bar{1}$1) is slightly dull in crystal No 1 and dull and corroded in No. 2, the corrosion producing striæ parallel to the combination edges with (110). If a small spot of light is allowed to reflect from the disintegrated surface of κ (1$\bar{1}$1) into the eye, an optical figure ("Licht-figur") is seen which forms a symmetrical six-rayed star, the rays meeting in angles of 60° and being vertical to the above combination edges. In the positive octants of crystal No. 2 surrounding the κ (111) faces there is an assemblage of curved faces of hexakistetrahedrons, which are not all determinable, and appear to be due to subsequent corrosion of the combination edges, and in crystal No. 1 the combination edges of (100) with (110) and κ (1$\bar{1}$1) are apparently slightly truncated by a striated corrosion face, as represented in the figure, which coincides in its reflection in the telescope of the goniometer with the face κ (16 1 1) and appears to be due to an oscillatory recurrence of this form upon the boundaries of (100).

The hemihedral nature of these crystals is therefore well characterised by the striations on the faces in the zone (100) : κ (111) and by the corrosion of the κ (1$\bar{1}$1) faces, and finally by the almost complete restriction to the positive octants of the (*hkk*), (*hhl*) and (*hkl*) forms, the exceptions being the occurrence of a single isolated narrow and ill defined face of κ (2$\bar{1}$1) and of several very small κ (*h$\bar{h}$l*) faces in the negative octants of crystal No. 2.

Both crystals were measured in all the principal zones, and all the forms hitherto established on the mineral binnite were recognised, with the exception of (321). In addition to these, a number of other forms, of which the data are given in the table below, were determined. The chief interest among these centres in the extraordinary number of reflections obtained from narrow κ (*hkk*) faces in the zone (100) : κ (111), most of which were sufficiently distinct to permit goniometrical measurement, and their calculated indices conform fairly well with axial intersections which form terms of an arithmetical series, progressing by decimal parts of the unit intersection.[1]

[1] Compare: H. A. Miers, Contributions to the study of Pyrargyrite and Proustite, *Min. Mag.* VIII., 87.

TABLE

	Indices. Miller.	Indices. Naumann.	Axial Ratio $na : a$.	Calculated : 100.	Crystal No. 1. No. of Edges.	Crystal No. 1. Measured Mean.	Crystal No. 1. Limits.	Crystal No. 2. No. of Edges.	Crystal No. 2. Measured Mean.	Crystal No. 2. Limits.	Observer.	Remarks.
a	100	∞0∞		0°0′	1	0°3′		2	0°0¼′	0°0′–0°0½′	Heusser	Finely striated
d	110	∞0		90°0′	2	90°1½′	90°0′–90°3′	11	90°0′	89°54′–90°4′	Damour	Smooth and brilliant
o	κ (111)	$+\frac{0}{2}$	1·0	54°44′8″	1	54°35′		9	54°44′	54°43′–54°44¾′	Heusser	Smooth and brilliant
o̱	κ (1̄11)	$-\frac{0}{2}$		54°44′8″	2	54°46¾′	54°43½′–54°50′	12	54°44′2″	54°42′–54°46½′	,,	Corroded and striated
	κ (755)	$+\frac{\frac{7}{5}0\frac{7}{5}}{2}$	1·4	45°15′22″				1	45°17′15″			Linear, very faint reflection
	κ (855)	$+\frac{\frac{8}{5}0\frac{8}{5}}{2}$	1·6	41°28′23′				1	41°27′			Linear, weak reflection
	κ (17.10.10)	$+\frac{\frac{17}{10}0\frac{17}{10}}{2}$	1·7	39°45′24″				1	40°23½′			Linear, exceedingly faint
	κ (955)	$+\frac{\frac{9}{5}0\frac{9}{5}}{2}$	1·8	38°9′21″				1	37°40′			Linear, distinct reflection
	κ (19.10.10)	$+\frac{\frac{19}{10}0\frac{19}{10}}{2}$	1·9	36°39′40″				2	36°44¼′	36°37½–36°51″		Linear, faint reflections
n	κ (211)	$+\frac{202}{2}$	2·0	35°15′52″	4	35°16′38″	35°15½′–35°18′	10	35°14′18″	35°9¼′–35°16½′	Damour	Smooth or faintly striated, brilliant
	κ (21.10.10)	$+\frac{\frac{21}{10}0\frac{21}{10}}{2}$	2·1	33°57′28″				1	33°37′			Linear, indistinct reflection
	κ (12.5.5)	$+\frac{\frac{12}{5}0\frac{12}{5}}{2}$	2·4	30°30′32″	1	30°24½″						Linear, fairly good reflection
x	κ (522)	$+\frac{\frac{5}{2}0\frac{5}{2}}{2}$	2·5	29°29′46″				4	29°34′53″	29°26½′–29°42′		Linear, good reflections

TABLE—*Continued.*

	Indices.		Axial Ratio $na : a$.	Calculated : 100.	Crystal No. 1.			Crystal No. 2.			Observer.	Remarks.
	Miller.	Naumann.			No. of Edges.	Measured Mean.	Limits.	No. of Edges.	Measured Mean.	Limits.		
	κ (13.5.5)	$+\frac{\frac{13}{5}O\frac{13}{5}}{2}$	2·6	28°32′50″				2	28°40′	28°26′–28°54′		Linear, fairly good reflections
	κ (27.10.10)	$+\frac{\frac{27}{10}O\frac{27}{10}}{2}$	2·7	27°38′41′				1	27°35′			Linear, approximate
	κ (14.5.5)	$+\frac{\frac{14}{5}O\frac{14}{5}}{2}$	2·8	26°47′50″				2	26°43′	26°36′–26°50′		Linear, do.
m	κ (311)	$+\frac{3O3}{2}$	3·0	25°14′22″				4	24°53′53″	24°39′–25°24′		Linear, fairly good reflections
	κ (16.5.5)	$+\frac{\frac{16}{5}O\frac{16}{5}}{2}$	3·2	23°50′34″				1	23°43′			Linear, very faint
ψ	κ (722)	$+\frac{\frac{7}{2}O\frac{7}{2}}{2}$	3·5	22°0′6″				3	21°54½′	21°40½′–22°10′		Linear, good and distinct reflections
	κ (19.5.5)	$+\frac{\frac{19}{5}O\frac{19}{5}}{2}$	3·8	20°24′48″				3	20°25′	20°5′–20°36′		Do. do.
μ	κ (411)	$+\frac{4O4}{2}$	4·0	19°28′16″	1	19°21′		2	19°16¼′	19°1′–19°32½′	Hessenberg	Linear, good reflections
	κ (922)	$+\frac{\frac{9}{2}O\frac{9}{2}}{2}$	4·2	17°26′47′	1	17°19½′		2	17°55½′	17°55′–17°56′		Linear, distinct
	κ (47.10.10)	$+\frac{\frac{47}{10}O\frac{47}{10}}{2}$	4·7	16°44′47″	1	16°41′		2	16°45½′	16°36′–16°55′		Do. do.
ρ	κ (511)	$+\frac{5O5}{2}$	5·0	15°47′36″	1	15°30′		1	15°36′			Linear, weak reflections
	κ (11.2.2)	$+\frac{\frac{11}{2}O\frac{11}{2}}{2}$	5·5	14°25′12′				1	14°30′			Linear, very indistinct

TABLE—*Continued.*

	Indices.		Axial Ratio *na* : *a*.	Calculated : 100.	Crystal No. 1.			Crystal No. 2.			Observer.	Remarks.
	Miller.	Naumann.			No. of Edges.	Measured Mean.	Limits.	No. of Edges.	Measured Mean.	Limits.		
π	κ (611)	$+\frac{606}{2}$	6·0	13°15′46″	3	13°15′50″	13°12′–13°20½′	10	13°22′3″	12°57′–13°45′	Heusser	Very good reflections
	κ (13.2.2)	$+\frac{\frac{13}{2}0\frac{13}{2}}{2}$	6·5	12°16′29″	2	12°4½′	12°2′–12°7′					Linear, very faint
	κ (711)	$+\frac{707}{2}$	7·0	11°25′18″	1	11°24′					Lewis	Do. do.
	κ (37.5.5)	$+\frac{\frac{37}{5}0\frac{37}{5}}{2}$	7·4	10°49′10″	1	10°50½′						Do. do.
	κ (811)	$+\frac{808}{2}$	8·0	10°1′30″				1	9°56½′			Do. faint
ϕ	κ (911)	$+\frac{909}{2}$	9·0	8°55′48″	2	8°50½′	8°36′–9°5′	1	8°23½′			Do. do.
y	κ (10.1.1)	$+\frac{10010}{2}$	10·0	8°2′58″				2	7°52¼′	7°36½′–8°8′	Hessenberg	Do. very faint
	κ (12.1.1)	$+\frac{12012}{2}$	12·0	6°43′17″				1	6°46′			Do. faint
z	κ (16.1.1)	$+\frac{16016}{2}$	16·0	5°3′4″	2	5°12½′	5°0′–5°25′	1	5°23′			Do. very faint
	κ (28.1.1)	$+\frac{28028}{2}$	28·0	2°53′29″				1	3°4½′			Do. do.
	κ (34.1.1)	$+\frac{34034}{2}$	34·0	2°22′55″	1	2°22′						Do. do.
	κ (76.1.1)	$+\frac{76076}{2}$	76·0	1°3′58″				2	1°4¼′	0°50½′–1°18′		Do. fairly distinct

TABLE—*Continued.*

	Indices.		Axial Ratio $na : a$.	Calculated : 100.	Crystal No. 1.			Crystal No. 2.			Observer.	Remarks.
	Miller.	Naumann.			No. of Edges.	Measured Mean.	Limits.	No. of Edges.	Measured Mean.	Limits.		
n	κ $(2\bar{1}\bar{1})$	$-\frac{202}{2}$	2·0	35°15′52″				1	34°29′			Linear, indistinct, apparently a corrosion face
	κ $(28.\bar{1}.\bar{1})$	$-\frac{28028}{2}$	28·0	2°53′29″	1	2°50½′						Linear, very faint
				100 : *hhl*								
b	κ (332)	$+\frac{\frac{3}{2}0}{2}$		25°14′22″	2	25°7′	25°5′–25°9′	8	25°3′	24°50′–25°12′	Heusser	Small faces, good reflections
r	κ (885)	$+\frac{\frac{8}{5}0}{2}$		23°50′34′				4	23°57′	23°21′–24°28′		Not distinct
	κ (994)	$+\frac{\frac{9}{4}0}{2}$		17°26′47″				1	17°18½′			Fairly distinct
e	κ (552)	$+\frac{\frac{5}{2}0}{2}$		15°47′36″	1	16°3′		2	15°51′	15°50′–15°52′		Well defined reflections
	κ (12.12.1)	$+\frac{120}{2}$		3°22′20″	1	3°23′						Uncertain, not quite zonal
	κ (30.30.1)	$+\frac{300}{2}$		1°21′	1	1°19′						Distinct reflections

TABLE—*Continued.*

	Indices.		Axial Ratio $na : a$.	Calculated : 100.	Crystal No. 1.			Crystal No. 2.			Observer.	Remarks.
	Miller.	Naumann.			No. of Edges.	Measured Mean.	Limits.	No. of Edges.	Measured Mean.	Limits.		
$\underline{\tau}$	κ $(8\bar{8}5)$	$-\frac{\frac{8}{5}0}{2}$		23°50′34″				1	24°15′			Very faint[1]
$\underline{p}$	κ $(2\bar{2}1)$	$-\frac{20}{2}$		19°28′16″				1	18°46′			Very faint[1]
	κ $(5\bar{5}2)$	$-\frac{\frac{5}{2}0}{2}$		15°47′36″				1	15°24′			Very faint and ill defined
$\underline{q}$	κ $(3\bar{3}1)$	$-\frac{30}{2}$		13°15′46″				2	13°44¾′	13°29½′–14°0′		Very faint[1]
	κ $(4\bar{4}1)$	$-\frac{40}{2}$		10°1′30″				1	9°39′		Hessenberg	Very faint[1]
	κ $(13.\overline{13}.1)$	$-\frac{\frac{13}{2}0}{2}$		6°12′30″				1	6°18′			Very faint and ill defined
				hkl : khl								
s	κ (321)	$+\frac{30\frac{3}{2}}{2}$		21°47¼′							v. Waltershausen	*Not observed*
σ	κ (23.12.11)	$+\frac{\frac{23}{11}0\frac{23}{12}}{2}$		2°52′44″				2	2°53′	2°48′–2°58′		Very faint, but fairly well defined, faces rounded

[1] Forming a group.

A number of these narrow faces, some of which need further confirmation, belong apparently to the class of vicinal planes, and others, such as κ (16 1 1), may be due to subsequent corrosion, and thus belong to the order of prerosion planes, as defined by Hamberg.[1]

The preceding table gives the forms observed on these crystals, with the calculated and measured angles, the arithmetical mean and the limits, and the number of edges measured is stated when observed more than once.

A reference to the calculated angles reveals quite a series of analogous ones between faces of different forms, especially between the inclinations of the (100) : (hkk) and the (110) : (hhl) faces, where the general expression obtains; angle (100) : $(h11)$ = angle (110) : $(hh2)$. Hessenberg (l.c.) already refers to such analogies as the expression of an interesting crystallographic problem. Among such cases of identity, which could no doubt be easily multiplied, may be noticed :

$$(111) : (1\bar{1}1) = (211) : (2\bar{1}\bar{1}) = 70°31'44''$$
$$(111) : (100) = (110) : (112) = 54°44'8''$$
$$(211) : (121) = (110) : (411) = 33°33'26''$$
$$(100) : (511) = (110) : (552) = (211) : (411) = 15°47'36''$$
$$(111) : (110) = (100) : (211) = 35°15'52''$$
$$(111) : (211) = (100) : (411) = (110) : (221) = 19°28'16''$$
$$(111) : (441) = (100) : (311) = (110) : (332) = 25°14'22''$$

The forms represented on the figure are :

a = (100), d = (110), o = κ (111), o = κ $(1\bar{1}1)$ n = κ (211), μ = κ (411), π = κ (611), ϕ = κ (911), ζ = κ (16 1 1), b = κ (332), e = κ (552), the last six forms being slightly exaggerated in size.

Note.—Subsequent to the reading of this paper, the author found that the same subject had been treated by Baumhauer in an interesting investigation under the title "Distinct hemihedral Binnite crystals" (Zeitschr. f. Kryst. xxi. p. 202, 1893). He has been led to accept the hemihedral nature of the mineral from the examination of six crystals which exhibited a similar distribution of the forms and similar physical differences in the faces to those described above. Of forms not hitherto recognised, he announces—

$$\kappa\,(433) + \frac{\frac{4}{3}O\frac{4}{3}}{2}$$

$$\kappa\,(322) + \frac{\frac{3}{2}O\frac{3}{2}}{2}$$

$$\kappa\,(19.6.6) + \frac{\frac{19}{6}O\frac{19}{6}}{2}$$

[1] *Bihang t. Svenska Vet.-Akad. Handl.*, 1887, Vol. 13, and *Zeitschr. f. Kryst.* XV., 84.