Sulpharsenites of Lead from the Binnenthal.

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With Analyses by H. Jackson, B.A., B.Sc.

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Part I.

General Description and Chemical Analyses, with a Crystallographic Account of Jordanite. [Plates IV, V].

Historical and Introductory.

THE metallic grey minerals which are found in the white saccharoidal dolomite of the Binnenthal have been known ever since the old priest Walpen of Binn and R. von Ritz began collecting them nearly seventy years ago.

The name "binnite" was first given indiscriminately to the grey metallic minerals; afterwards these were subdivided into "Kugel Binnit" and "Stangen Binnit."

The first division, "Kugel Binnit" (so called from its pea-shaped form), is tennantite, locally known as "Kupfer Binnit." The second division, "Stangen Binnit" (so called from its rod-shaped form), comprises the minerals sartorite, rathite, dufrenoysite and jordanite.

Lardy,[1] in 1833, is the first to notice in print the occurrence of these minerals, and specimens from the Binnenthal at that time were usually labelled "Grey Copper from St. Gotthardt."

In 1839 and 1840 Wiser[2] published the results of some qualitative analyses of these minerals in which he found Pb,S,Sb,As,Cu,Ag. The antimony is noteworthy on account of its great rarity, as will be seen later.

In 1845 Damour[3] analysed two specimens of "Stangen Binnit"; his crystallographic description, however, refers to a crystal of "Kugel Binnit." To this combination he gave the name dufrenoysite. The

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[1] *Denksch. Schweiz. Ges.* 1833, Bd. I, Abth. 2, p. 244.

[2] Leonhard's *Neues Jahrb. für Min.* 1839, pp. 414, 559; 1840, p. 217.

[3] *Ann. Chim. Phys.* 3rd Series, XIV, p. 379.

analysis seems to have been made upon fairly pure specimens of dufrenoysite (see Table of Analyses, Nos. 27, 28).

In 1855-7 von Waltershausen, Des Cloizeaux, Marignac and Heusser published their researches on this group; v. Waltershausen[1] pointed out Damour's mistake mentioned above, but he himself curiously made a similar mistake, describing and drawing a characteristic crystal of dufrenoysite, and combining it with Uhrlaub's three analyses of impure sartorite crystals (Nos. 4, 8, 10); to this combination he gave the name arsenomelane. Heusser[2] described and drew a typical crystal of sartorite with its characteristic dome planes, but added to the confusion of names by calling it binnite.

Des Cloizeaux and Marignac[3] visited the Binnenthal, and brought back a number of crystals of jordanite and sartorite.

Des Cloizeaux combined their measurements of crystals of jordanite and sartorite, and calculated a set of crystallographic elements, calling the mineral dufrenoysite. They figured three typical crystals of jordanite and two of sartorite. If Des Cloizeaux had taken the densities of each, or examined the streak, he would have separated his crystals, as the density of jordanite is 6·45, while that of sartorite is 4·98; and the streak of jordanite is black, while that of sartorite is reddish-brown.

In 1857 Uhrlaub and Nason[4] each undertook two analyses on material sent to them by v. Waltershausen. (Nos. 17, 18, 19, 20.)

A little later Stockar-Escher[5] published four analyses made on impure sartorite or rathite. (Nos. 6, 7, 9, 22.)

In 1862 vom Rath[6] began a thorough investigation of this group, and published in 1864 the first full account.

He divided the sulpharsenites of lead into three species :—

Scleroclase (or Sartorite of Dana).
Dufrenoysite.
Jordanite.

Reference to this work will be made under the description of each species.

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[1] *Pogg. Ann.* 1855, XCIV, 115.
[2] *Pogg. Ann.* 1856, XCVII, 120.
[3] *Ann. Mines*, 1855, Ser. 5, VIII, 389.
[4] *Pogg. Ann.* 1857, C, 540.
[5] Kenngott, *Uebersicht*, 1859, for 1856–7, 176.
[6] *Pogg. Ann.* 1864, CXXII, 371.

In 1864 Berendes[1] gave two analyses of dufrenoysite (Nos. 21, 23).

In 1866 T. Petersen[2] published two analyses (Nos. 15, 16) without any crystallographic account. One analysis agrees with Mr. Jackson's new analysis of rathite.

In 1873 vom Rath[3] described some more crystals of jordanite, and had an analysis made in Prof. Ludwig's laboratory by Sipöcz[4] of some of these crystals, giving a formula $4PbS.As_2S_3$, with S.G. 6·384 and 6·401 (Nos. 32, 33).

In the same year Tschermak[5] described some crystals of jordanite from Nagyág, and had some of the material analysed by Ludwig,[6] which agreed with Sipöcz's determination, except that he found 1·87 per cent. of Sb. (No. 34.)

In 1877 Lewis described a crystal of jordanite, in the British Museum, associated with a crystal of binnite on a crystal of blende. He notified 5 new forms, but added that of these (025) was not determined, and gave no measurements for (225). (052 and 252 of Baumhauer.)

In 1891 Baumhauer[8] published two papers on jordanite, removing it from the rhombic system to the oblique. It will be seen under the description of jordanite that I have confirmed this alteration.

In 1894 Baumhauer[9] described a new twin law of jordanite, viz. twin plane ($\bar{3}01$) (printed by mistake $\bar{1}03$). In the same volume (p. 87) he describes a large crystal of dufrenoysite, with an analysis by König (No. 24).

In 1895 Baumhauer[10] published a long paper on sartorite, giving a number of new forms, and an analysis by König (No. 5).

In 1896 Baumhauer[11] added a new mineral to this group, which he called rathite, and gave an analysis of it by Bömer (No. 14).

In 1897 Baumhauer[12] added to our knowledge of the rare mineral dufrenoysite by measurements of three fine crystals with new forms.

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[1] *Inaug. dissert.* Bonn, 1864.

[2] *Ber. Offenb. Ver.* 1866, VII, 128. *Jahrb. für Min.* 1867, 203.

[3] *Pogg. Ann. Erg. Bd.*, 1873, 6, 363.

[4] *Min. Mitth.* 1873, 29.

[5] *Min. Mitth.* 1873, 215.

[6] *Min. Mitth.* 1873, 216.

[7] *Proc. Cryst. Soc.* 1, 52.

[8] *Ber. Akad.* Berlin, 697 and 915, 1891.

[9] *Zeits. Kryst.* XXIV, 78 and 87.

[10] *Ber. Akad.* Berlin, 243, 1895.

[11] *Zeits. Kryst.* XXVI, 593.

[12] *Zeits. Kryst.* XXVIII, 545.

In 1898 Guillemain's[1] *Beiträge zur Kenntniss der natürlichen Sulfosalze* contains analyses of dufrenoysite and jordanite, with some measurements of the latter (Nos. 25, 26, 31, 35).

MODE OF OCCURRENCE.

In 1898 I spent part of the summer in the Binnenthal, and there collected a large quantity of material which became the basis for the following investigation.

I handed over to Mr. Spencer the whole of the binnites, comprising about 50 or 60 crystals. Messrs. Prior and Spencer[2] have now published the result of their work on these and other crystals, in a lucid and exhaustive paper, in which they show that binnite is identical with tennantite, so that the name binnite must now be regarded as a local one for tennantite from the Binnenthal.

Though the saccharoidal dolomite is largely developed all along the south side of the Binnenthal, these metallic grey minerals have only been found in the bed of the little Lengenbach, where it cuts through the dolomite deposit, about half a mile from the junction of the little stream with the Binn, nearly opposite Imfeld.

The minerals are obtained by blasting, and the right of doing this is granted by the Commune to a syndicate of seven farmers, who pay a fixed sum yearly for this right. On account of the altitude (5,500 feet) the quarries can only be worked during three months of the summer, and as that is the busiest time for the farmers, it is only on occasional wet days that they can be induced to work for the specimens.

The bed of dolomite, which is nearly vertical, is about 100 to 150 feet thick. In the centre is a layer about 50 feet in width, impregnated with numerous thin veins of small crystals of iron pyrites. These veins carry with them three lodes remarkable for the grey metallic minerals they sparsely contain. Two of them are called the upper lode, and are close together, while the lower lode is about 20 feet lower down the stream. They vary in width from 1 to 3 feet.

Damour's specimens of binnite and dufrenoysite, with all the earlier finds, were obtained from the two upper lodes on the right bank. At the present time the work is carried on upon the left bank, as the old deposit is worked out. Though a good deal of blasting was done on these lodes while I was there, I found no dufrenoysite, but some rathite and

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[1] *Inaug. dissert.* Breslau, 1898.

[2] *Min. Mag.* 1898, XII, 184.

jordanite, with a comparative abundance of sartorite. In the lower lode a tunnel has been run a short distance under the left bank. It was here that the three fine specimens of dufrenoysite described by Baumhauer were found. I found two small crystals of dufrenoysite, also jordanite, rathite, binnite and sartorite. Sometimes when blasting, a geode about a foot across is exposed, and there the finest crystals are found. The cavity is largely filled with massive yellow dolomite, with a good deal of realgar and blende.

The shock of blasting shatters a number of beautiful crystals; also the mere increase of temperature due to exposure to the sun has often the same effect. I have noticed, especially with rathite, that the warmth of the hand will sometimes cause the crystals to explode with a sharp report, when they break parallel to their best cleavage.

I began working on these minerals in Dresden during the winter of 1898-9, and take this opportunity of recording the fact that I was enabled to do so through the kindness of Prof. Kalkowsky, who gave me the use of the dark room and Fuess goniometer in his well appointed Mineralogical Laboratory. I was not able to continue the work until I returned to Cambridge in the summer of 1899.

The following are the minerals which I have found in the dolomite of the Lengenbach:—

Sartorite
Rathite
Dufrenoysite
Jordanite
Tennantite ("Binnite")
Galena
Realgar
Orpiment
Blende
Iron pyrites
Barytes
Dolomite
Calcite
Quartz
Rutile
Hyalophane
Tourmaline
Muscovite

Chemical Composition.

Mr. Jackson has made analyses of specimens of sartorite, rathite, dufrenoysite and jordanite, the results of which will be found in the tables on pp. 287, 289.

Sartorite.—The crystals of sartorite analysed by Mr. Jackson had been measured, and the density 4·980 was obtained after adding to them the best of my measured crystals.

Analysis No. 1 was from a number of very small brilliant crystals. Nos. 2 and 3 from larger crystals.

Rathite.—Analysis No. 13 was made from crystals very similar to the material analysed by Bömer, and they contained a great many twin lamellæ. The percentage of Pb and S is too high, owing very probably to the inclusion of very minute crystals of galena. Galena is

SUMMARY OF ANALYSES.

			Pb.	S.	As.	Sb.	Ag.	Cu.	Fe.	Total.	S.G.
$PbS+As_2S_3$		Sartorite	42·68	26·39	30·93	..	..	..	..	100	..
	1	Jackson	43·24	25·81	30·80	..	..	..	..	99·85	4·980
	2	,,	43·93	25·60	30·46	..	..	..	..	99·99	..
	3	,,	43·72	25·12	30·12	..	..	..	..	98·96	..
	4	Uhrlaub	44·56	25·91	28·56	..	0·42	..	0·45	99·90	5·393
	5	König	46·08	25·26	26·28	..	..	..	..	97·62	5·05
	6	Stockar-Escher	46·83	25·30	26·33	..	1·62	..	..	100·08	5·177
	7	,,	47·39	25·77	26·82	..	..	.	..	99·98	
	8	Uhrlaub	47·58	24·66	25·74	..	0·94	..	..	98·92	5·405
	9	Stockar-Escher	49·22	24·22	25·27	..	0·94	..	0·25	99·90	5·074
	10	Uhrlaub	49·66	23·95	26·46	..	0·63	..	..	100·70	5·469
$3PbS+2As_2S_3$		Rathite	51·37	23·82	24·81	..	..	..	..	100	..
	11	Jackson	51·51	23·41	24·62	..	..	..	..	99·54	5·412
	12	,,	51·62	23·62	24·91	..	..	.	..	100·15	5·421
	13	,,	52·43	24·12	21·96	0·43	..	..	0·33	99·27	..
	14	Bömer	52·98	23·72	17·21	4·53	..	..	0·56	99·0	5·32
	15	Petersen	50·74	23·22	25·83	..	0·21	..		100·0	..
	16	,,	51·32	25·0	23·93	..	0·12	..	..	100·38	..
	17	Uhrlaub	51·18	24·66	23·32	..	0 02	..	..	99·18	Dark lead grey 5·074
	18	,,	51·40	24·05	23·95	..	0·02	..	..	99·42	Clear lead grey 5·459
	19	Nason	51·48	23·54	25·14	..	0·17	..	0·08	100·41	..
	20	,,	51·65	23·82	23·81	..	0·12	..	..	99·40	..
	21	Berendes	52·02	23·11	21·35	.	..	..	..	96·83	..
	22	Stockar-Escher	53·30	23·97	22·01	..	0·24	..	..	99·52	5·355
	23	Berendes	53·62	23·27	21·76	..	0·05	..	0·30	99·00	5·55
$2PbS+As_2S_3$		Dufrenoysite	57·18	22·10	20·72	..	..	..	..	100	..
	24	König	57·42	22·55	20·89	..	..	..	..	100·86	5·52
	25	Guillemain	57·38	21·94	21·01	..	..	..	..	100·33	..
	26	,,	56·73	21·18	20·04	..	..	..	..	97·95	..
	27	Damour	56·61	22·30	20·87	..	0·17	0·22	0·32	100·49	5·549
	28	,,	55·40	22·49	20·69	..	0·21	0·30	0·44	99·53	
$4PbS+As_2S_3$		Jordanite	68·83	18·64	12·48	..	..	..	..	100	..
	29	Jackson	68·61	18·19	12·32	..	..	..	..	99·12	6·413
	30	,,	68·83	18·42	12·46	..	..	..	..	99·71	..
	31	Guillemain	68·67	18·81	12·46	..	..	..	..	99·94	5·484
	32	Sipőcz	68·95	18·13	12·86	..	..	..	..	99·94	6·384
	33	,,	69·99	18·18	12·78	..	..	..	..	100·95	6·401
	34	Ludwig	70·80	17·06	9·90	1·87	..	..	..	99·63	..
	35	Guillemain	72·42	18·50	8·97	..	..	..	..	99·89	..

only found in small quantities, often in small curiously rounded crystals, and interpenetrating the other grey metallic substances, especially crystals of jordanite.

I had the opportunity in May 1899 of visiting Freiburg, and through the kindness of Prof. Baumhauer, of comparing his specimens of rathite with those I had found. There is no doubt of the close similarity between the specimen since analysed by Mr. Jackson and Prof. Baumhauer's best specimen.

There is a great difference between the amount of Sb found by Bömer and by Jackson, as will be seen on comparing their analyses Nos. 14 and 13, since the former found 4·53 per cent. and the latter 0·43 per cent. Jackson also made a qualitative analysis of a fragment similar to No. 13, and found only a trace of Sb.

These crystals (No. 13) always contain a visible quantity of iron pyrites, so their density would be misleading. Baumhauer found the specific gravity to be 5·32.

Analysis No. 11 was from two crystals similar in facial development and twinning to Baumhauer's crystal II. The density 5·412 was obtained from five similar measured crystals.

Analysis No. 12 was from large rough crystals with very perfect (010) cleavage given to me by Dr. Grünling. The density 5·421 was obtained from a number of brilliant cleavage fragments. On breaking them open I found some minute crystals.

Dufrenoysite.—I have not yet been able to obtain enough material for Mr. Jackson to analyse, but hope to do so.

Jordanite.—Nos. 28 and 29 from good measured crystals. The density 6·413 was obtained from material including some of my best measured crystals. Total weight of crystals used, 0·775 gram.

Of Guillemain's analyses, No. 31 was made from bright crystals; No. 35 from dull, black material, much fractured, and coated with a white crust of arsenious acid; it is probably altered jordanite.

He gives for the density 5·48024, the mean of five determinations, and cannot explain the great difference between his determination and that of Sipőcz.

This discrepancy is due, I think, to the inclusion of minute crystals of iron pyrites. I first weighed 1·151 gram of jordanite crystals and obtained 5·986 as density, and then by removing crystals which showed the presence of iron pyrites I obtained 6·413, but even this, I think, is a little below the true value for a pure crystal.

The following is Mr. Jackson's account of his method of analysis:—

"The mineral, after being crushed, was examined with a pocket lens, and all traces of iron pyrites carefully removed. A qualitative analysis was first made, the elements present being lead, sulphur and arsenic. In the case of one sample small quantities of iron and antimony were found.

"The quantitative estimation was performed by placing a weighed quantity of the mineral in a porcelain boat, placed inside a piece of wide combustion tubing. A current of dry chlorine was passed over it. The decomposition began in the cold, but was completed by gently heating, and finally the mineral was melted. The lead chloride remained behind, as a cream-coloured hard solid, which was allowed to cool, and then weighed.

"The volatile chlorides of sulphur and arsenic were then passed through a couple of flasks containing chlorine water.

"The chloride of sulphur formed readily decomposes in presence ot chlorine water into sulphuric acid and hydrochloric acid. The sulphuric acid set free was estimated in the usual way with barium chloride. This method of estimating the sulphur was found to be the best, as there would be a great difficulty in applying the usual method of fusing the mineral with oxidising agents, owing to the insoluble lead sulphate formed.

"The contents of the two flasks having been made up to a given volume, and one portion having been used for estimating the sulphur, the remaining solution was evaporated to a small bulk, to get rid of excess of chlorine, and the estimation of the arsenic was performed by magnesia mixture. The ammonium magnesium arsenate, after precipitation, was dissolved in hydrochloric acid, and precipitated with ammonia and a little magnesia mixture, and finally converted into magnesium pyroarsenate. If antimony was present in the filtrate it was precipitated by sulphuretted hydrogen as pentasulphide, and weighed as such. The results obtained are given in the following table.

	Pb.	S.	As.	Sb.	Fe.	Total.
Sartorite	43·24	25·81	30·80	—	—	99·85
,,	43·93	25·60	30·46	—	—	99·99
,,	43·72	25·12	30·12	—	—	98·96
Rathite	51·51	23·41	24·62	—	—	99·54
,,	51·62	23·64	24·91	—	—	100·15
,,	52·43	24·12	21·96	0·43	0·33	99·27
Jordanite	68·61	18·19	12·32	—	—	99·12
,,	68·83	18·42	12·46	—	—	99·71

"In each case the weight of material used for analysis was between one gram and 0·9 gram." (H. J.)

JORDANITE $4PbS+As_2S_3$.

Literature.

Vom Rath, 1864, *Pogg. Ann.* CXXII, 387.—Characters.

Sipöcz, 1873, *Min. Mitth.* I, 29.—Analysis.

Wartha, 1873, *Min. Mitth.* 131, 132.—Formula.

Tschermak, ditto, 215.—Crystallography (Nagyág).

Ludwig, ditto, 216.—Analysis.

Vom Rath, 1874, *Pogg. Ann. Erg. Bd.*, VI, 363.—Crystallography.

Lewis, 1877, *Phil. Mag.* (5), V, 139, 1878; *Proc. Crystal. Soc.* I, 52. —Crystallography.

Baumhauer, 1891, *Sitz. Ak. Berlin*, 697.—Crystallography.

Baumhauer, 1891, *Sitz. Ak. Berlin*, 909.—Crystallography.

Baumhauer, 1894, *Zeits. Kryst.* XXIV, 78.—Crystallography

Guillemain, 1898, *Inaug. Diss. Breslau.*—Cryst. and anal.

In the *Zeitschrift für Krystallographie* (Vol. VIII, 1883, pp. 612-622; Vol. IX, 1884, p. 294), and in the *Mineralogical Magazine* (Vol. V, 1884, p. 330), the question of the isomorphism of Jordanite and Meneghinite was discussed by Schmidt, Krenner, Miers and Hintze.

Miers points out that there is a close crystallographic relation between meneghinite and stephanite. The chemical analyses of meneghinite, on which the isomorphism is based, were made upon somewhat unsatisfactory material. The crystals are rare and in the form of needles, of which a great number would be required to obtain a correct analysis.

In my opinion it will probably be found that geocronite is isomorphous with jordanite, having the chemical composition denoted by $4PbS+Sb_2S_3$.

The only crystallographic determination of geocronite was made by Kerndt[1] in 1845 from a rough dull crystal from Pietrasanta, Val di Castello, Tuscany. When I was at Pisa in May, 1899, G. D'Achiardi showed me two large fine crystals from the same locality which A. D'Achiardi had briefly described in 1873.[2] They were found to exhibit the characteristic twin lamellæ of jordanite.

All the analyses that have been made of geocronite were from massive material, and therefore unlikely to be correct.

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[1] *Pogg. Ann.* LXV, 302.

[2] D'Achiardi, *Min. Tosc.* Vol. II, 352.

CRYSTALLOGRAPHY.

System : Oblique.

$a : b : c = 0{\cdot}4945 : 1 : 0{\cdot}2655.$ $\beta = 89°26\frac{1}{2}$ (Baumhauer).

The crystallographic observations were made on 20 crystals obtained from the Lengenbach quarries in August 1898. I have also examined specimens in various museums.

The following table contains a list of 115 known forms, 11 of which have not been observed before.

On account of the change of system, it is not always possible to say which of Baumhauer's planes were observed before by vom Rath, Lewis or Tschermak.[1]

The letters B_1 B_2 B_3 refer to Baumhauer; the subscripts 1, 2 and 3 to his three papers. L to Lewis. R_1 R_2 to vom Rath; the subscripts 1 and 2 to his two papers. S to Solly. T to Tschermak. Those forms marked × I have not observed in the [010, 100] and [010, $\bar{1}$01] zones.

I have always found a great dissimilarity between the + [010, $\bar{1}$01] and − [010, 101] pyramid zones.

Thus in the + zone the planes are clustered about the (010) face, viz. (1.18.$\bar{1}$) (1.17.$\bar{1}$) (1.14.$\bar{1}$) (1.13.$\bar{1}$) (1.12.$\bar{1}$), while in the − zone they are clustered about the (111) face, viz. (121) (131) (141) (151); also as a rule the − zone is always more developed than the + zone.

The prism zone [010, 100] is usually tarnished red, the − pyramid zone bright green, and the + pyramid zone bluish green.

The following four twin laws may be distinguished :—

(I) Twin plane ($\bar{1}$01). This twin plane is always indicated by numerous twin lamellæ.

(II) Twin plane (301) always combined with law (I). This is a new twin law. I have observed it on two crystals.

(III) Twin plane (101). Baumhauer expressed doubt as to the existence of this twin plane. Crystal No. 2, described on page 295, exhibits some striations on the plane (010) parallel to its intersection with (101), which may be very thin twin lamellæ parallel to (101).

(IV) Twin plane (30$\bar{1}$). Baumhauer gives ($\bar{1}$03), but this is a printer's error for (30$\bar{1}$). He determined this law on a small crystal, partly red and partly green, united in nearly parallel position to a beautifully tarnished crystal twinned according to law (I).

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[1] The following are the positions of the axes adopted by different authors—*a*, *b*, *c* vom Rath, Dana, = *b*, *a*, *c*, Lewis, = *c*, *a*, *b*, Baumhauer.

LIST OF KNOWN FORMS.

Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.	Symbol.	Indices.	Observer.
a	100	B_1	$\frac{5}{2}r$	250	R_1	$-17q$	1.17.1	$\times B_1$	$+17q$	$1.17.\bar{1}$	S	$+6x$	$36\bar{1}$	B_1
b	010	R_1	$\frac{7}{3}r$	370	B_1	$-14q$	1.14.1	$\times B_2$	$+14q$	$1.14.\bar{1}$	S	$-5x$	351	B_1
c	001	B_1	$\frac{27}{12}r$	12.27.0	$\times B_1$	$-10q$	1.10.1	B_1	$+13q$	$1.13.\bar{1}$	S	$+5x$	$35\bar{1}$	B_1
$-h$	101	B_1	$2r$	120	R_1	$-9q$	191	B_1	$+12q$	$1.12.\bar{1}$	B_1	$-4x$	341	B_1
$+h$	$10\bar{1}$	B_1	$\frac{7}{4}r$	470	B_3	$-8q$	181	B_1	$+11q$	$1.11.\bar{1}$	B_2	$+4x$	$34\bar{1}$	B_1
$-2h$	201	B_1	$\frac{3}{2}r$	230	R_1	$-7q$	171	B_1	$+10q$	$1.10.\bar{1}$	B_1	$-3p$	331	B_1
$+2h$	$20\bar{1}$	B_1	$\frac{4}{3}r$	340	S	$-6q$	161	B_1	$+9q$	$19\bar{1}$	B_1	$+3p$	$33\bar{1}$	B_1
$-3h$	301	B_1	$\frac{5}{4}r$	450	B_1	$-\frac{11}{2}q$	2.11.2	S	$+8q$	$18\bar{1}$	B_1	$-3v$	321	L
$+3h$	$30\bar{1}$	B_1	$\frac{7}{6}r$	670	B_1	$-5q$	151	B_1	$+7q$	$17\bar{1}$	B_1	$+3v$	$32\bar{1}$	B_1
$-5h$	501	B_2	r	110	R_1	$-\frac{9}{2}q$	292	S	$+6q$	$16\bar{1}$	B_1	$-3u$	311	B_1
$+5h$	$50\bar{1}$	B_2	$\frac{7}{4}s$	740	B_3	$-4q$	141	B_1	$+5q$	$15\bar{1}$	B_1	$+3u$	$31\bar{1}$	B_1
..	..	..	$2s$	210	R_1	$-\frac{7}{2}q$	272	B_1	$+\frac{9}{2}q$	$29\bar{2}$	B_3	$-5v$	521	B_2
$8r$	180	B_1	$3s$	310	S	$-3q$	131	B_1	$+4q$	$14\bar{1}$	B_1	$+3z$	$23\bar{1}$	B_1
$\frac{15}{2}r$	2.15.0	$\times B_2$	$4s$	410	B_1	$-\frac{5}{2}q$	252	L	$+\frac{7}{2}q$	$27\bar{2}$	B_1	$+\frac{5}{2}z$	$45\bar{2}$	B_1
$\frac{11}{2}r$	2.11.0	$\times B_2$	$5s$	510	S	$-2q$	121	B_1	$+3q$	$13\bar{1}$	B_1	$-\frac{3}{2}z$	432	S
$5r$	150	B_1	..	..	..	$-\frac{3}{2}q$	232	S	$+\frac{5}{2}q$	$25\bar{2}$	S	$-2u$	211	B_1
$\frac{9}{2}r$	290	R_2	$\frac{7}{2}k$	072	B_1	$-p$	111	B_1	$+2q$	$12\bar{1}$	B_1	$+2u$	$21\bar{1}$	B_1
$\frac{49}{12}r$	12.49.0	B_1	$3k$	031	R_2	$-\frac{3}{2}t$	323	T	$+p$	$11\bar{1}$	B_1	$-2y$	412	B_1
$4r$	140	$\times R_1$	$\frac{5}{2}k$	052	L	$-2t$	212	B	$+2t$	$21\bar{2}$	B_1	$+2y$	$41\bar{2}$	B_1
$\frac{32}{9}r$	9.32.0	$\times B_1$	$2k$	021	R_2	$-3t$	313	B_3	$+\frac{28}{3}t$	$28.3.\overline{28}$	B_1	$-\frac{7}{3}w$	173	B_1
$\frac{7}{2}r$	270	B_1	$\frac{3}{2}k$	032	L	$-4t$	414	T	..	..	..	$+2w$	163	B_1
$\frac{24}{7}r$	7.24.0	$\times B_1$	k	011	R_2	..	..	..	$-8x$	381	B_2	$-\frac{5}{3}w$	153	B_1
$3r$	130	R_1	$\frac{4}{7}k$	047	R_2	..	..	..	$-7x$	371	B_2	$+\frac{5}{3}w$	$15\bar{3}$	B_1
$\frac{11}{4}r$	4.11.0	$\times B_1$	$\frac{1}{2}k$	012	B_1	$+18q$	$1.18.\bar{1}$	B	$-6x$	361	B_1	$+\frac{4}{3}w$	$14\bar{3}$	B_1

Figure 4 is a stereographic projection representing the law (II) combined with (I). (For Figures 1-3 see Plates 4, 5).

The sign I represents the positions into which the zones are brought by twinning about ($\bar{1}01$).

The sign II represents the positions into which the zones are brought by twinning about (301).

TABLE OF CALCULATED ANGLES.

[100 ; 001]
100, 501 = 20°21½′
, 301 = 31 40½
, 201 = 42 42
, 101 = 61 20
, 001 = 89 26½
.. ..
100, 501 = 20 30
, 301 = 31 59
, $20\bar{1}$ = 43 13
, $10\bar{1}$ = 62 12
, 001 = 90 33½
.. ..
[010, 100]
010, 180 = 14 11
, 2.15.0 = 15 5½
, 2.11.0 = 20 11
, 150 = 22 1
, 290 = 24 12
, 12.49.0 = 26 21
, 140 = 26 49
, 9.32.0 = 29 38
, 270 = 30 1
, 7.24.0 = 30 32
, 130 = 33 59
, 4.11.0 = 36 10
, 250 = 38 58
, 370 = 40 55
, 12.27.0 = 41 57
, 120 = 45 19
, 470 = 49 8
, 230 = 53 26
, 340 = 56 37
, 450 = 58 17
, 670 = 60 2
, 110 = 63 41½
, 740 = 74 13
, 210 = 76 7

010, 310 = 80°38½′
, 410 = 82 57
, 510 = 84 21
, 100 = 90
.. ..
[010, 001]
010, 072 = 47 6
, 031 = 51 28
, 052 = 56 25½
, 021 = 62 2
, 032 = 68 17
, 011 = 75 8
, 047 = 81 22½
, 012 = 82 26½
, 001 = 90
.. ..
.. ..
.. ..
[010, 101]
010, 1.17.1 = 14 10
, 1.14.1 = 17 3
, 1.10.1 = 23 14
, 191 = 25 30
, 181 = 28 13
, 171 = 31 31
, 161 = 35 35
, 2.11.2 = 37 58
, 151 = 40 38½
, 292 = 43 39
, 141 = 47 1
, 272 = 50 48½
, 131 = 55 3
, 252 = 59 47
, 121 = 65 1
, 232 = 70 44
, 111 = 76 53
, 323 = 81 10
, 212 = 83 21½

010, 313 = 85°33½′
, 414 = 86 40
, 101 = 90
.. ..
[010, $10\bar{1}$]
010, $1.18.\bar{1}$ = 13 18½
, $1.17.\bar{1}$ = 14 3½
, $1.14.\bar{1}$ = 16 55
, $1.13.\bar{1}$ = 18 10
, $1.12.\bar{1}$ = 19 32
, $1.11.\bar{1}$ = 21 9½
, $1.10.\bar{1}$ = 23 3½
, $19\bar{1}$ = 25 19
, $18\bar{1}$ = 28 1½
, $17\bar{1}$ = 31 18½
, $16\bar{1}$ = 35 21½
, $15\bar{1}$ = 40 25
, $29\bar{2}$ = 43 25
, $14\bar{1}$ = 46 47
, $27\bar{2}$ = 50 34½
, $13\bar{1}$ = 54 50
, $25\bar{2}$ = 59 35
, $12\bar{1}$ = 64 50½
, $11\bar{1}$ = 76 47
, $21\bar{2}$ = 83 18
, $28.3.\overline{28}$ = 88 33½
, $10\bar{1}$ = 90
.. ..
[010, 201]
010, 432 = 74 53
, 211 = 79 47½
, 412 = 84 51½
.. ..
[010, $20\bar{1}$]
010, $23\bar{1}$ = 61 23½
, $45\bar{2}$ = 65 33½
, $21\bar{1}$ = 79 41½
, $41\bar{2}$ = 84 48½

[010, 301]
010, 381 = 41°52½′
, 371 = 45 42
, 361 = 50 5
, 351 = 56 7
, 341 = 60 51
, 331 = 67 18
, 321 = 74 25
, 311 = 82 4
, 301 = 90
.. ..
[010, $30\bar{1}$]
010, $36\bar{1}$ = 49 50
, $35\bar{1}$ = 54 53
, $34\bar{1}$ = 60 38½
, $33\bar{1}$ = 67 7½
, $32\bar{1}$ = 74 17½
, $31\bar{1}$ = 81 59½
, $30\bar{1}$ = 90
.. ..
[010, 501]
010, 521 = 79 32
, 501 = 90
.. ..
[010, 103]
010, 173 = 58 40
, 153 = 66 30
.. ..
[010, $10\bar{3}$]
010, $16\bar{3}$ = 62 21½
, $15\bar{3}$ = 66 25½
, $14\bar{3}$ = 70 45½
.. ..
.. ..
.. ..
.. ..
.. ..
.. ..

The colour is always lead grey, with brilliant lustre, but the faces are very often tarnished red, green, bluish green and yellow.

Streak black. Opaque. Very perfect cleavage parallel to (010), also a parting parallel to $(\bar{1}01)$, but interrupted owing to twinning. Fracture conchoidal. Hardness, 3. Specific gravity, 6·384 to 6·413, but according to Guillemain 5·484.

It is sometimes intimately associated with small rounded crystals of galena, and is hardly ever free from included crystals of iron pyrites.

The only other known locality for jordanite besides the bed of the Lengenbach, Binnenthal, is Nagyág in Transylvania.

Description of Specimens.

Out of the 20 crystals measured there are three which are specially worth describing, as they exhibit some new forms, and two show the new twin law on (301).

Crystal 1.

Figure 1, Plate 4.

A flat crystal of rhombic outline, tabular owing to the predominance of (010).

It will be seen from the drawing that the zones [010, 100] and [010, 101] are largely and equally developed, while $[010, \bar{1}01]$ is small.

The crystal is twinned about $(\bar{1}01)$. A third of the crystal is simple, and on this part, which is represented in the drawing, there are 31 forms developed, besides other minute planes in the zone [100, 001].

The new planes are (292), (340), $(\bar{1}.13.1)$ and $(\bar{2}52)$.

The zone [010, 101] contains (171), (151), (292), (141), (131), (121), (111), (101).

Zone $[010, \bar{1}01]$: $(\bar{1}.18.1)$, $(\bar{1}.13.1)$, $(\bar{1}81)$, $(\bar{1}71)$, $(\bar{1}61)$, $(\bar{1}51)$, (131), $(\bar{2}52)$, $(\bar{1}21)$, $(\bar{1}11)$, $(\bar{1}01)$.

Zone [010,] 010: (180), (150), (140), (130), (250), (120), (470), (230), (340), (450), (100).

	Calc.	Found.
010∧292	=43°39′	43°37′
010∧1.13.1	=18°10′	18° 8′
010∧$\bar{2}$52	=59°35′	59°34′
010∧340	=56°37′	56°38′

Crystal 2.

Figure 2, Plate 4, and Fig. 4.

I had unfortunately to detach this crystal from its matrix.

In shape it resembles a flat hexagonal prism, with large base and narrow pyramid and prism planes.

It is a unique and beautiful example of a new twin law, twin plane (301), combined with the common twin law, twin plane $(\bar{1}01)$.

The new forms present are (510), $(\bar{1}.17.1)$ and $(\bar{1}.14.1)$. I also found planes which are probably (350), (450) and (515); but the readings are not sufficiently reliable to establish their identity. There is in this crystal, as in Nos. 1 and 3, a great dissimilarity between the + and − pyramid zones.

There are 50 forms present.

Zone [010, 101]: (1.14.1), (191), (161), (151), (292), (141), (131), (272), (121), (232), (111), (313), (101), (515)?

Zone $[010, \bar{1}01]$: $(\bar{1}.17.1)$, $(\bar{1}.14.1)$, $(\bar{1}.13.1)$, $(\bar{1}.11.1)$, $(\bar{1}.10.1)$, $(\bar{1}91)$, $(\bar{1}81)$, $(\bar{1}71)$, $(\bar{1}61)$, $(\bar{1}51)$, $(\bar{1}41)$, $(\bar{1}31)$, $(\bar{1}21)$, $(\bar{2}32)$, $(\bar{1}11)$, $(\bar{1}01)$.

Zone [010, 100]: (290), (140), (270), (130), (250), (120), (470), (230), (670), (110), (740), (210), (410), (510), (100), (350), (450)

Zone [010, 001]: (052), (021), (032).

Zone [010, 301]: (311), (301).

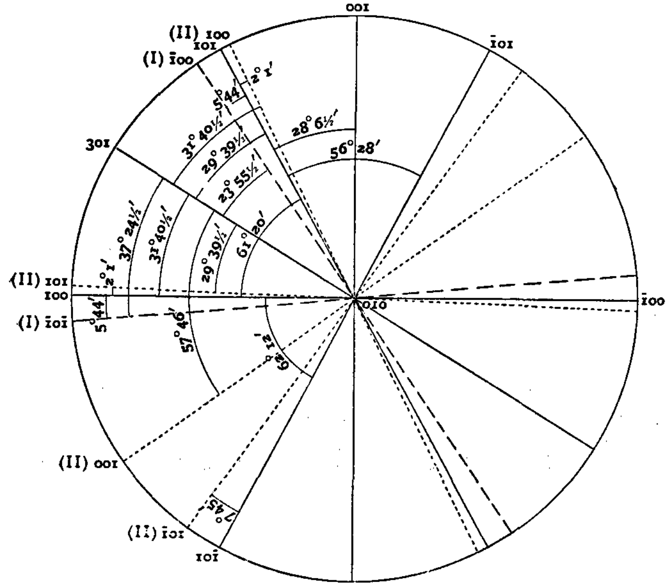

FIG. 4.

	Calc.		Found.
010 ∧510	= 84°21′ ...	...	84°19′
010∧1.14.1	= 16°55′ ...	...	16°50′
010∧1.17.1	= 14°3½′ ..	...	14°

Figure 2 and the stereographic projection, Fig. 4, will explain the manner of growth of this interesting twin.

On each side of the prism zone [010, 100] belonging to the principal crystal is a negative pyramid zone belonging to a crystal twinned upon it; one of these (I) is due to twinning about ($\bar{1}01$), and makes an angle of 5°44′ with the zone [010, 100]; the other (II) is due to twinning about (301), and makes an angle of 2°1′ with the zone [010, 100]; these are shown on the right-hand side of the figure.

The following measurements were obtained:—

	Calc.		Found.
230∧131 (I)	= 4°55½′	...	4°45′
230∧131 (II)	= 2°8′	...	2°10′
$1\bar{3}1$∧131 (II)	= 6°19′	...	6°10′
131∧131 (II)	= 47°51′	...	47°55′

On each side of the zone [010, 101] belonging to the principal crystal is a zone of prism faces, one (I) making with it an angle of 5°44′, and the other (II) an angle of 2°1′.

Alongside the zone [010, $\bar{1}01$] belonging to the principal crystal is a zone [010, $\bar{1}01$], making an angle of 7°45′ with it (II).

The faces in the zone [010, 100] are all more developed, especially (250), (120) and (230), than in the other zones.

In the zone [100, 001] the following angles were obtained. The faces (301) and (100) are well developed, and gave sharp images:—

	Calc.		Found.
301∧101	= 29°39½	...	29°41′
301∧101 (II)	= 29°39½	...	29°45′
301∧100 (II)	= 31°40½	...	31°44′
301∧100 (II)	= 31°40½	...	31°38′
301∧101 (I)	= 37°24½	...	37°27′
301∧100 (I)	= 23°55½	...	23°54′

Crystal 3.

Figure 3, Plate 5.

A portion of a large very brilliant crystal, which broke on being removed from a cavity in the dolomite, where it was impossible to measure it.

The plane (010) is largely developed with very good cleavage.

The crystal, unlike No. I, is elongated parallel to the axis of the zone [010, 101], and the faces in that zone are largely developed.

The crystal is repeatedly twinned about ($\bar{1}01$), some of the twin lamellæ being broad and well defined.

It is also twinned about (301), but the twinned zones due to this twinning are very small, and only in one zone could reflections be seen; this is not indicated in Fig. 3.

The planes (301) and (412) are unusually largely developed.

There are 55 forms present, in addition to a number of minute planes which gave little or no definite reflection.

The new planes are (310), (2.11.2), (432) and (232).

Zone [010, 101] : (1.10.1), (191), (181), (171), (161), (2.11.2), (151), (292), (141), (272), (121), (232), (111), (313), (101).

Zone [010, $\bar{1}01$] : ($\bar{1}$.18.1), ($\bar{1}$.13.1), ($\bar{1}$.12.1), ($\bar{1}$.11.1), (1.10.1), ($\bar{1}91$), ($\bar{1}81$), ($\bar{1}71$), ($\bar{1}61$), ($\bar{1}51$), ($\bar{1}31$), ($\bar{1}01$).

Zone [010, 100] : (180), (2.11.0), (270), (130), (250), (120), (470), (230), (340), (110), (210), (310), (410), (110).

Zone [010, 301] : (381), (371), (361), (351), (341), (331), (321), (311), (301).

Zone [010, 201] : (432), (211), (412), (201).

Calc.		Found.
010∧310=80°38½′	... ...	80°37′
010∧2.11.2=37°58′	... ...	38°
010∧432=74°53′	... ...	74°55′
010∧232=70°44′	... ...	70°41′

NOTE.—I hope subsequently to describe the remaining members of this group, but will now briefly state that sartorite crystallises in the oblique, not in the rhombic system, and that rathite requires new crystallographic elements.

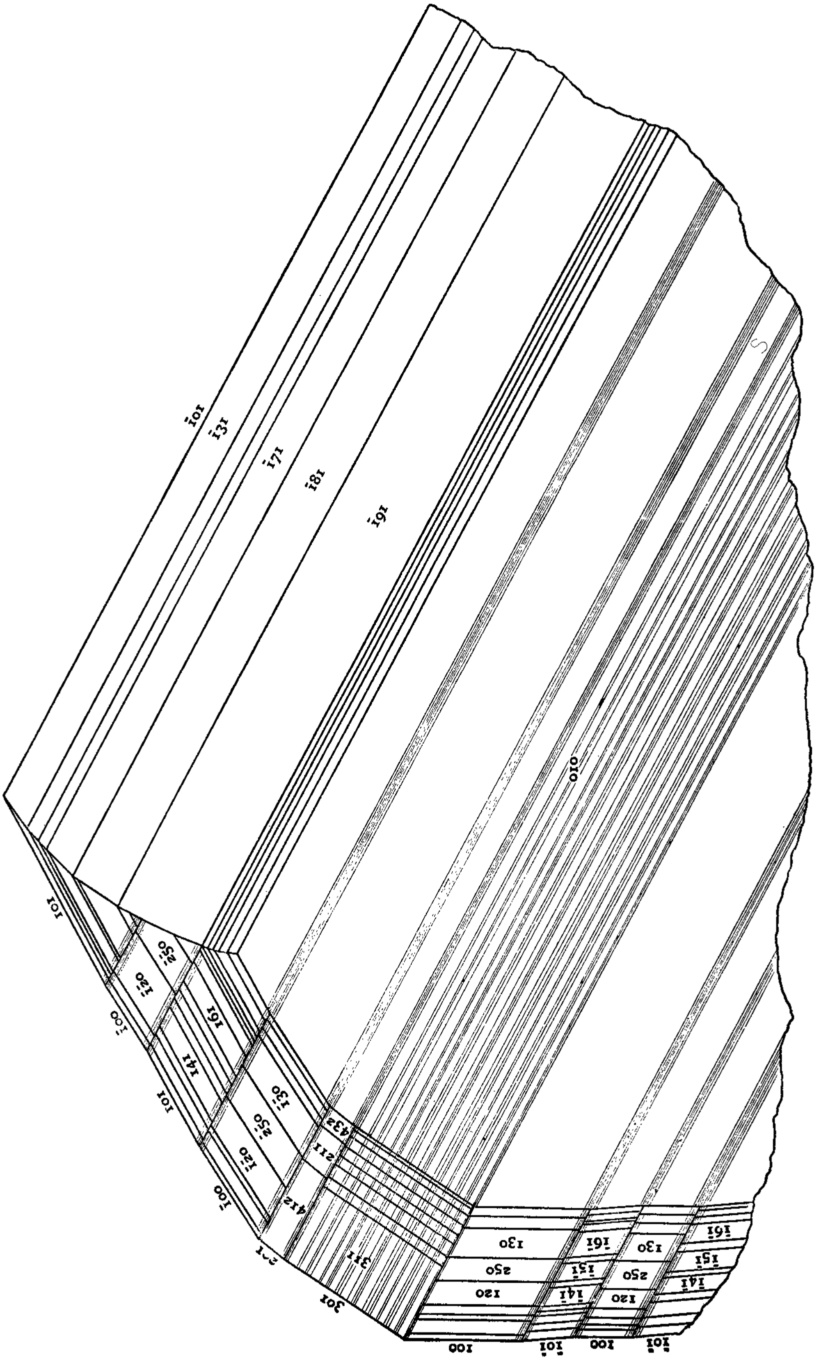
$\bar{1}01$
$\bar{1}31$
$\bar{1}71$
$\bar{1}81$
$\bar{1}91$
S
010
101
$\bar{1}00$
$1\bar{2}0$
$2\bar{5}0$
$16\bar{1}$
101
141
$1\bar{3}0$
$2\bar{5}0$
120
$\bar{1}00$
$\bar{4}3\bar{2}$
$\bar{2}11$
$41\bar{2}$
$\bar{2}\bar{1}1$
$\bar{3}11$
$30\bar{1}$
100
120
250
130
$\bar{1}0\bar{1}$
$\bar{1}4\bar{1}$
$\bar{1}5\bar{1}$
$\bar{1}6\bar{1}$
100
120
250
130
$\bar{1}0\bar{1}$
$\bar{1}4\bar{1}$
$\bar{1}5\bar{1}$
$\bar{1}6\bar{1}$

Fig. 3.