Plagionite, Heteromorphite and Semseyite as Members of a Natural Group of Minerals.

By L. J. SPENCER, M.A., F.G.S.,

With Analyses by G. T. PRIOR, M.A., F.G.S.,

Assistants in the Mineral Department of the British Museum.

[Read November 15th, 1898.]

IN a recent number of this Magazine (1897, XI. p. 192) a paper by me on "The Crystallography of Plagionite" gives the results of goniometric measurements and specific gravity determinations made on crystals of plagionite from Wolfsberg in the Harz; it was also suggested on crystallographic grounds that the mineral from Arnsberg in Westphalia described by Pisani as heteromorphite was identical with plagionite : but as no quantitative chemical analyses were made on the material measured, these results were not altogether satisfactory.

Three specimens, which on account of their crystalline form and qualitative chemical composition were at that time considered to be plagionite, were therefore selected for further examination, with the result that only one of them was found to agree also in quantitative chemical composition and specific gravity with the original plagionite : of the two others, one agreed in these respects with Pisani's determinations for heteromorphite, and the other with semseyite.

F

These three minerals, therefore, although apparently the same, or nearly the same, in crystalline form, differ considerably in the proportions of lead to antimony which they contain.

In the first three sections below, each of the three specimens is described in detail, and in a fourth section the relations between them are discussed.

I. PLAGIONITE FROM WOLFSBERG IN THE HARZ.

This specimen is a small confused group of bright crystals, without matrix; it has already been mentioned in the Magazine (XI. p. 194) as weighing 2·6642 grams and having a specific gravity of 5·57. On the surface are a little reddish-brown " tinder ore " and one or two very minute brittle needles, possibly of stibnite.

The colour of the mineral is iron-black, with perhaps a tendency to lead-grey; bright metallic lustre; opaque. The streak is black and in part shining (or, on unglazed paper, dull). The fracture is uneven, and there is a good cleavage parallel to n {111}. Brittle; hardness = $2\frac{3}{4}$.

The crystals are well developed, and the largest is about 7 mm. across. They are tabular in habit (Fig. 1), being flattened parallel to the basal plane c {001}; other important forms are the large negative pyramids {hhl}, and the smaller orthopinacoid a {100}, all of which are deeply striated and rounded parallel to their intersections with the basal plane, as is invariably the case in plagionite. These crystals were, therefore,
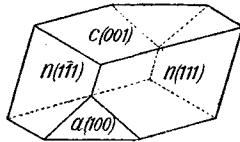

Fig. 1

badly adapted for measurement, but they were the best that could be sacrificed for combined crystallographic and chemical examination; they were comparatively large, apparently pure, and free from any drusy surfaces. The forms on the best crystal were determined by the approximate measurements to be: c {001}, a {100}, e {112}, l {223}, n {111}, x {221}, m {110}, also, narrow, badly defined, positive pyramids {hhl}, rounded orthodomes near the positions of {$\bar{7}01$}, {$\bar{7}02$} and {$\bar{7}03$}, and small indeterminable positive pyramids {$\bar{h}kl$}.

In collecting material for analysis, the cleavage and the striation of the faces were important guides. It was examined with a lens and under

the microscope, but no other mineral was detected. Attempts were made to measure each fragment which showed crystal faces; the following rather unsatisfactory angles were obtained from five fragments :—

		Calculated.[1]	Measured.
$c\,e$	$= 001 : 11\overline{2}$	25° 40′	24½°, 26½°.
$c\,n$	$= 001 : 111$	41° 8′	40°, 40½°, 42°, 42°, 42½°, 43°.
$c\,x$	$= 001 : 221$	55° 54′	54½°, 56°, 56°, 56°, 56°.
$c\,m$	$= 001 : 110$	78° 12½′	80°, 80°.
$c\,a$	$= 001 : 100$	72° 28′	72°, 74°.

The specific gravity (weight of 1 cc.) of the material analysed was 5·50 at 22° C. The method of analysis was as previously used for andorite (this Magazine, 1897, XI. p. 290), the mineral being decomposed in a current of dry chlorine. The following results[2] were obtained by Mr. Prior on 0·6002 gram :—

		Atomic ratios.		Calcd. for $9PbS.7Sb_2S$.
Pb	41·24	·2008	9	41·29
Sb	37·35	·3125	14·01	37·38
S	21·10	·6629	29·7	21·33
	99·69			100·00

These results agree closely with the formula $9PbS.7Sb_2S_3 = Pb_9Sb_{14}S_{30}$. This is midway between the original formula $4PbS.3Sb_2S_3$, given by H. Rose in 1833 for plagionite, and that now usually accepted, namely, $5PbS.4Sb_2S_3$, which was proposed by Rammelsberg in 1860 (*Min -chem.*, p. 68). The previous analyses of Wolfsberg plagionite are quoted on p. 65, where the calculated percentage compositions are also given.

II. HETEROMORPHITE FROM ARNSBERG IN WESTPHALIA.

This mineral has already been mentioned in the Magazine (1897, XI. pp. 194-5), where it is stated that "the curved, indistinct crystals were found on measurement to be plagionite. One of the three crystals measured showed the forms $c\,a\,p\,e\,n$." Pisani,[3] who first described the mineral, stated that the crystals, from their appearance and qualitative chemical composition, were at first considered to be plagionite ; but when

---

[1] G. Rose, *Pogg. Ann.* 1833, XXVIII, 421.

[2] The atomic weights used in this paper are those given by F. W. Clarke (*Smithsonian Miscell. Collections*, 1897, No. 1075). Here Sb = 119·52 and Pb = 205·36, these being slightly lower than the values usually adopted. Previous to 1855, Sb was taken as 129, which accounts for some of the differences in the old formulæ.

[3] *Comptes Rendus*, 1876, LXXXIII. 747,

his quantitative analyses gave the formula $7PbS.4Sb_2S_3$, he concluded that the mineral could not be plagionite, and he then considered it to be crystallised heteromorphite, as forming probably a species distinct from jamesonite.

Here, owing to confusion of terms, it will be well to give a short historical review of jamesonite and heteromorphite. The prismatic Cornish mineral with a perfect end-cleavage was first noticed by Mohs in 1820; Haidinger in 1825 measured the prism angle, and gave the name jamesonite; and H. Rose in 1826 found the formula to be $3PbS.2Sb_2S_3$. In 1829 Rose found the federerz (feather ore) of Wolfsberg, which had previously been considered as stibnite, to have the formula $2PbS.Sb_2S_3$. This he established as a new species distinct from jamesonite. Twenty years later (1849) Zincken and Rammelsberg described a compact mineral from Wolfsberg also having the formula $2PbS.Sb_2S_3$, which they considered to be identical with Rose's federerz, but this name being inappropriate for their compact variety, they proposed the new name heteromorphite. Jamesonite and heteromorphite (=federerz) remained as distinct species until 1860, when Rammelsberg united them under the name jamesonite with the formula $2PbS.Sb_2S_3$; Rose's original formula, $3PbS.2Sb_2S_3$, being explained as due to the presence of admixed stibnite. This has since been followed in all the text-books.[1]

Zincken and Rammelsberg gave no reasons, beyond the similarity in chemical composition, for the statement that their compact mineral was identical with federerz, and indeed it may really have belonged to the plagionite-semseyite group rather than to the dimorphous group of acicular minerals into which zinckenite, jamesonite, plumosite (=federerz), boulangerite, and possibly meneghinite, may be provisionally brought together. The compact nature with platy separation, and the absence of iron (which is always present in plumosite and jamesonite to the extent of $2 - 3$ per cent.) perhaps favour the latter view. If this be correct, then Pisani was justified in applying the name heteromorphite to the plagionite-like mineral from Arnsberg; and under the circumstances it seems best to follow him in the use of the name, even although it cannot be definitely proved that the heteromorphite of Pisani is identical with the heteromorphite of Zincken and Rammelsberg.

---

[1] As a result of this the old jamesonite formula $3PbS.2Sb_2S_3$ has been forgotten, but has turned up again under the later names warrenite and domingite! We are at present examining these minerals, and have already made an analysis of measured crystals of Bolivian jamesonite, which, as in previous cases with crystallised and cleavable jamesonite, does *not* give the formula $2PbS.Sb_2S_3$.

It therefore seemed necessary to make an analysis on material of which the crystallographic data had been determined. The Arnsberg specimen selected for this purpose was one of the two previously examined. It consists of a fairly large mass of compact material, the cavernous surface of which is covered with numerous small crystals in crystallographic continuity with the massive material below. The massive material is crystalline throughout, as shown by the numerous cleavages on the fractured surfaces, and to all appearance it is the same substance as the crystals. The only other minerals on the specimen are one or two small isolated crystals of black blende and an embedded angular fragment of black quartzite.

The plagionite-like mineral is dull iron-black, but crystals in freshly opened cavities have a bright metallic lustre; the streak is black, and in part shining; $H. = 2\frac{3}{4}$.

Although the crystals are small (about 1 mm. across) and indistinct, yet there is no mistaking the peculiar habit, striation of the faces, and good cleavage, so characteristic of plagionite. Few if any are tabular parallel to the basal plane, as is often the case in the Wolfsberg plagionite,
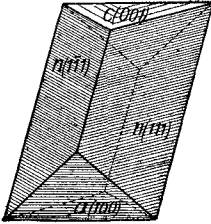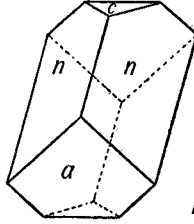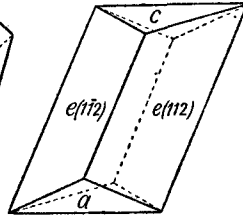

| FIG. 2. | FIG. 3. | FIG. 4. |

but they are elongated in the direction of the pyramid edges $[hhl, h\bar{h}l]$ as shown in Figs. 2—4.[1] The striations and roundings are the same as before, but much more pronounced; and, owing to the grouping of the crystals in more or less parallel position, the zone of pyramids and the orthopinacoid are more often twisted than simply rounded, as in the saddle-shaped crystals of dolomite. The basal plane is usually smoother, but is often represented by different areas which are inclined at several

---

[1] Pisani (*loc. cit.*) describes the habit of the crystals as resembling that of mispickel, with an obtuse dome, or of adularia with $c\{001\}$ and $x\{\bar{1}01\}$. with deeply striated summits and oblique striations on the prism faces. He also mentions that the system is probably monosymmetric.

degrees to each other. It was therefore very difficult to obtain any satis-
factory measurements; only eight of the numerous fragments placed on
the goniometer gave any results at all.

		Calculated.		Measured.
	Plagionite.	Semseyite.		
001 : 114	$cp = 14° 12'$	$17° 50\frac{1}{2}'$	14°.	
001 : 112	$ce = 25° 40'$	$30° 58'$	28°5', 32°1', 32°31', 32°51',	
			$32\frac{1}{2}°$ (or 34° 0').	
001 : 111	$cn = 41° 8'$	$cp = 46° 35'$	40°50' or 43°3$\frac{1}{2}$' (cleavage;	
			c gives a double image),	
			41°12' or 46°18', 40°57',	
			44°56', 44° or 45°.	
001 : 100	$ca = 72° 28'$	$ca = 71° 4'$	71°27', 72°.	
111 : 1$\bar{1}$1	$nn' = 59° 11'$	$pp' = 66° 19'$	65°, 65° (cleavage).	

Although these measurements are very bad, varying in some cases
more than 5°, still they show that the angles of the Arnsberg mineral are
of the same general character as the angles of plagionite; and on this
account the mineral was previously referred to plagionite.

The material collected for analysis consisted only of crystals and the
crystalline material directly in contact with them, and was all taken from
the free surface of the specimen. The results obtained by Mr. Prior
with 0·5677 gram are given below. Iron and arsenic were absent. Spe-
cific gravity of the material analysed = 5·73 at 23° C.

		Atomic ratios.	Calc$^{d.}$ for $11PbS.6Sb_2S_3$.	
Pb	48·89	·2381	11	48·93
Sb	31·08	·2600	12·02	31·07
S	19·36	·6082	28·1	20·00
Zn	0·18			
Cu	0·10			100·00
	99·61			

This analysis agrees with Pisani's determinations (see p. 65), though
the lead is one per cent. higher than found by him. Pisani gave the
ormula $7PbS.4Sb_2S_3$; as shown by Rammelsberg (*Min.-chem.* 1886,
p. 138), his analysis agrees better with $9PbS.5Sb_2S_3$. The above analysis
gives $11PbS.6Sb_2S_3 = Pb_{11}Sb_{12}S_{29}$, but the sulphur is rather low.

III. Semseyite from Wolfsberg in the Harz.

The specimen described in this section was selected for analysis on
account of the high specific gravity 5·99 (as determined with the

hydrostatic balance for the group of crystals weighing 10·6430 grams). This also had been catalogued with the plagionites ; the high specific gravity being, at the time, thought to be possibly due to a kernel of some heavier mineral, such as galena.

No matrix is present, but there is a little reddish " tinder ore " and " feather ore "[1] on the surface, and in a few small crevices in the interior. Although the mass was broken open and submitted to very careful examination, these were the only minerals found.

The crystals of the plagionite-like mineral are much larger (averaging 1 cm. long) than observed on any of the other specimens which have been catalogued as Wolfsberg plagionite. They are grouped for the most part in more or less parallel position, and are of the habits shown in Figs. 2 — 4 (p. 59). The crystals, although very distinct in form and habit, are sometimes distorted and twisted, even more so than in the Arnsberg mineral ; further, the surfaces are rough and drusy, and the whole appearance of some of the crystals points to their being built up of smaller individuals in radiated rather than in parallel position. Of the forms which can be distinguished : $c\{001\}$ is the most even, but is usually small and sometimes absent ; $a\{100\}$ is very rough, and often rounded in two directions ; the pyramids are sometimes fairly even, and the thicker and the flatter prismatic habits shown in Figs. 2 and 4 respectively are easily to be distinguished. At other times the pyramids merge into each other and the basal plane, forming a twisted surface. The striations are the same as before.

Attempts were made to measure several crystals and fragments, but variations of over 10° were obtained, and no definite angle can be given. The most satisfactory measurements were obtained from the pyramids across the plane of symmetry. This angle $(hhl):(h\bar{h}l)$ gave various values between the extremes 33° and 82°.

The colour of the mineral is iron-black, with dull metallic lustre, which however is brighter on fresh fractures ; the streak is black and in part shining. The mineral is brittle ; H.=2¾. The pyramidal cleavage is good, and the fracture uneven, with sometimes a more or less granular appearance. The difference between the more or less even cleavage surfaces and the uneven fractures with the granular appearance is more marked when fragments, illuminated with the aid of a Lieberkuhn, are examined under the microscope. Beyond this difference there was

---

[1] In matted fibres, which are straight and not flexible ; it contains lead, antimony and sulphur.

nothing that suggested the presence of more than one kind of mineral, and this is not inconsistent with the material being all of one kind, since the cleavage does not give a closed form.

The material collected for analysis gave sp. gr. $=5\cdot92$ at 22° C. for the fine powder. In the following analysis by Mr. Prior, the antimony and lead were determined by decomposing $0\cdot6953$ gram of the mineral in chlorine, and the sulphur by fusing another portion weighing $0\cdot3278$ gram with sodium carbonate and potassium nitrate.

		Atomic ratios.		Calc$^{d.}$ for $21PbS.10Sb_2S_3$.
Pb	51·84	·2524	21·06	51·79
Sb	28·62	·2395	20	28·71
S	19·42	·6100	50·94	19·50
	99·88			100·00

This agrees closely with the formula $21PbS.10Sb_2S_3=Pb_{21}Sb_{20}S_{51}$. Both the lead and the antimony differ by about one per cent. from the amounts required by the formula $2PbS.Sb_2S_3$ (see p. 65).

This mineral, then, although closely resembling plagionite and the Arnsberg mineral in appearance and crystalline form, contains $10-11$ per cent. more lead than the former, and 3 per cent. more than the latter, whilst it contains only 1·3 per cent. less lead than semseyite.

The name semseyite was given by Prof. J. A. Krenner[1] to small, grey, tabular crystals from Felsőbánya in Hungary, which are strikingly similar to the Wolfsberg plagionite[2] in appearance, habit and cleavage, but differ from it in the proportion of lead to antimony, the specific gravity, and also slightly in the crystal angles. Analysis by L. Sipőcz gave the formula $7PbS.3Sb_2S_3 = Pb_7Sb_6S_{16}$; sp. gr. $=5\cdot9518$. Only three measured angles are given, but these do not agree with the parameters[3] as given by Krenner, and it is difficult to know exactly what value to attach to them.

The crystals described in this section may then be called semseyite, since they agree with this in chemical composition, specific gravity, and in the habit and cleavage. Also the approximate measurements, 33° and

[1] *A Magyar tudományos Akadémia Értesitöje*, Budapest, 1881, XV. 111-3. German abstracts are given in *Zeits. Kryst. Min.* 1884, VIII. 532-3, and *Ungarische Revue*, 1881, p. 367.

[2] In fact, the specimens appear at one time to have been labelled as plagionite, since M. Tóth (*Minerals of Hungary*, Budapest, 1882, p. 385) gives plagionite from Felsőbánya, on the authority of the Hungarian National Museum.

[3] The parameters and angles calculated by Dana from Krenner's three measured angles are here adopted.

82°, given above, are near to $ss'(113 : 1\bar{1}3) = 33°50'$ and qq' $(221 : 2\bar{2}1)$ $= 81°2'$ of semseyite.   The corresponding extreme plagionite angles are : pp' $(114 : 1\bar{1}4) = 21°14'$ and yy' $(331 : 3\bar{3}1) = 83°29'$; also ee' $(112 : 1\bar{1}2) = 37\cdot57'$.

Another specimen of Wolfsberg " plagionite " consists of numerous small crystals of the same habit as the above : they are, however, much more distorted and less distinct, and form globular aggregates,[1] the surfaces of which are defined by the rounded and striated orthopinacoids $a\{100\}$.   Penetrating the whole group are one large, and several smaller, thin-tabular crystals of bournonite.   On the surface of the specimen are small quantities of " tinder ore " and a few minute crystals of copper pyrites and calcite.   The specific gravity of the whole group (weighing 29·4529 grams) is 5·99.   Since all the accompanying minerals have specific gravities lower than this, the plagionite-like mineral must have a specific gravity slightly higher.[2]   Qualitative analysis showed the presence of only lead, antimony and sulphur.   On one small fragment the angle from the basal plane to the cleavage was measured as 46°49', also for the natural faces $cp = 47°$.   This specimen is therefore semseyite. Curiously enough, this specimen, and another with isolated crystals of the same prismatic habit on a matrix of quartz, were acquired by the British Museum (from Dr. Fischer in 1864) labelled as crystallised heteromorphite of Rammelsberg.

IV.   The Relations of the Plagionite-Semseyite Group.

As already stated, both Pisani and Krenner had remarked on the great similarity of the crystals of the Arnsberg heteromorphite and of semseyite with those of the Wolfsberg plagionite.   The form, striation of the faces, and cleavage are the same for all three minerals, and the approximate measurements which could be obtained from the material described above are not sufficient to distinguish between them.   Pisani gave no measurements, and the data given by Krenner for semseyite only differ essentially from the plagionite constants in the greater length of the vertical axis, in the ratio of 4 : 3.

---

[1] Such globular aggregates of " plagionite " from Wolfsberg have already been described by Kenngott (*Sitz.-ber. Akad. Wien*, 1855, XV. 236 ; XVI. 160).   He also gives figures illustrating the prismatic habit.

[2] Taking the sp. gr. of bournonite to be 5·8, and estimating its volume (about 1cc.) by measuring the size of the crystals, the sp. gr. of the semseyite is calculated as about 6·0.

	a	$: b :$	c	β	$c : 111$ (cleavage).
Plagionite[1] ...	1·1361	: 1	: 0·8410	72°28'	41° 8'
Semseyite ...	1·1442	: 1	: 1·1051	71° 4'	46°35'

Since the chemical composition and specific gravity of the Arnsberg heteromorphite are between those of plagionite and semseyite, it might be expected that the vertical axis should also have some intermediate value. The measurements given above (p. 60) are however too unsatisfactory to show whether this is the case or not, but some of these angles lie between the corresponding plagionite and semseyite values.

The corresponding forms occurring on the three minerals are compared in the following table. All the observed heteromorphite and semseyite forms, but not all the plagionite forms, are given. The parametral plane is the direction of good cleavage for all.

Plagionite	c001	a100	p114	—	112	n111	x221	—	s112
Heteromorphite	c001	a100	p114	—	e112	n111	—	—	—
Semseyite	c001	a100	—	s113	—	p111	q221	$t\bar{1}$13	—

The crystals of plagionite, heteromorphite and semseyite described above show a difference in habit, in the first being tabular (Fig. 1), and in the last two prismatic (Figs. 2—4). The plagionite crystals measured by Rose and Luedecke, and most of the crystals of which measurements have previously been given in this Magazine, were also tabular in habit. But it is doubtful whether this difference in habit is sufficient for purposes of discrimination. Most crystals are unsuitable for accurate measurement, so that the only methods of determination are quantitative analysis or to take the specific gravity. The crystals are, however, usually small and scattered over a matrix of quartz, &c., and to collect sufficient material for their determination would mean the destruction of the rare specimens.

In order to compare the chemical composition of members of the group, all the published analyses are brought together and arranged below according to the percentage of lead. Zincken and Rammelsberg's heteromorphite from Wolfsberg has also been added for the reasons stated above (p. 58).

---

[1] G. Rose's parameters (*Pogg. Ann.* 1833, XXVIII. 421) are here given, since they were presumably determined on the same material as analysed by his brother, H. Rose. Luedecke's (1883) measurements were not made on analysed material.

		Pb.	Sb.	S.	Total.	Sp. gr.
Plagionite	Schultz (1860)	Wolfsberg	39·36	37·84	21·10 Cu 1·27	99·57	—
	Rose (1833)[1]	,,	{40·52	37·94	21·53	99·99	(5·4)
			{40·62	—	21·89		
	Kudernatsch (1836)	,,	{40·81				
	Crystals		{40·98	[37·53]	21·49	100·00	
	Prior (p. 57)	,,	41·24	37·35	21·10	99·69	5·50
Heteromorphite	Pisani 1876)[2]	Arnsberg	{47·86	31·20	19·90 Zn 0·60	99·56	{5·59 to 5·73
			48·1				
	Poselger (1847)[3]	Wolfsberg	48·48	32·98	20·32	101·78	5·68
	Prior (p. 60)	Arnsberg	48·89	31·08	19·36 {Cu 0·10 Zn 0·18}	99·61	5·73
Semseyite	Prior (p. 62)	Wolfsberg	51·84	28·62	19·42	99·88	5·92
	Sipőcz (1881)[4]	Felsőbánya	53·16	26·90	19·42 Fe 0·10	99·58	5·95

Although these analyses fall into three well-marked groups, yet they are all different, and none of them give simple formulæ. The calculated percentage compositions corresponding with the various formulæ are added for comparison with the analyses. $2PbS.Sb_2S_3$ is also given, but it agrees with none of the analyses.

		Pb.	Sb.	S.	Pb. : Sb.
Plagionite	$5PbS.4Sb_2S_3 = Pb_5Sb_8S_{17}$ ...	40·68	37·88	21·44	1 : 1·60
	$9PbS.7Sb_2S_3 = Pb_9Sb_{14}S_{30}$ ·	41·29	37·38	21·33	1 : 1·55
	$4PbS.3Sb_2S_3 = Pb_4Sb_6S_{13}$ ...	42·07	36·73	21·20	1 . 1·50
Heteromorphite	$7PbS.4Sb_2S_3 = Pb_7Sb_8S_{19}$ ...	47·94	31·89	20·17	1 : 1·14
	$9PbS.5Sb_2S_3 = Pb_9Sb_{10}S_{24}$...	48·54	31·39	20·07	1 : 1·11
	$11PbS.6Sb_2S_3 = Pb_{11}Sb_{12}S_{29}$	48·93	31·07	20·00	1 : 1·09
	$2PbS.Sb_2S_3 = Pb_2Sb_2S_5$ ...	50·77	29·55	19·68	1 : 1
Semseyite	$21PbS.10Sb_2S_3 = Pb_{21}Sb_{20}S_{51}$	51·79	28·71	19·50	1 : 0·95
	$9PbS.4Sb_2S_3 = Pb_9Sb_8S_{21}$ ...	53·22	27·53	19·25	1 : 0·89
	$7PbS.3Sb_2S_3 = Pb_7Sb_6S_{16}$ ...	53·96	26·92	19·12	1 : 0·86

[1] *Pogg. Ann.* XXVIII. 422. The two analyses were made on crystals from different specimens (Berzelius' *Jahresber.* 1835, XIV. 173; *Pogg. Ann.* 1835, XXXV. 362).

[2] *Loc. cit.* (a) Mean of three analyses on selected crystalline material; (b) on massive material, after deducting 7 per cent. of blende.

[3] Rammelsberg's *Handwörterb. chem. Min.* 1847, 3rd Suppl., p. 44. This is the massive heteromorphite described by Zincken and Rammelsberg, *Pogg. Ann.* 1849, LXXVII. 240. Compare Rammelsberg's *Handb. Min.-chem.* 1860, p. 71, where different figures are given: a second analysis is given here, which agrees more closely with $2PbS.Sb_2S_3$.

[4] On crystals: Krenner (*loc. cit.*). A more detailed account of this analysis is given by Sipőcz in *Tscherm. Min. Mitth.* 1886, VII. 283.

In attempting to explain the relation between these minerals, three suggestions present themselves :

(1). That the crystals may enclose galena.

(2). That there may be isomorphous mixing of two end members, as in the plagioclase and scapolite groups.

(3). That the three minerals may be members of a morphotropic series, in which the vertical crystallographic axis increases in length with an increase in the amount of lead.

While examining and selecting material for the three analyses, the first suggestion was kept constantly in view, but no indications of the presence of galena could be found. Unless it were very finely disseminated, it would, on account of the lead-grey colour and perfect cleavage, be easily detected under a microscope fitted with accessories for illuminating opaque objects; further, all the British Museum specimens from Wolfsberg and Arnsberg were carefully examined, but no galena could be found on any of them ; moreover, galena is not a mineral recorded from the antimony (stibnite) mines at Wolfsberg and Arnsberg. The semseyite from Felsőbánya (and Rodna), however, occurs as small crystals coating corroded galena, and in this case it would not be easy to collect material entirely free from galena. The presence of any galena might be detected by the action of suitable solvents ; hydrochloric acid, however, would not do, since it decomposes both plagionite and galena. Also if the variation in composition were due to enclosed galena, there would then be no variation in the crystalline form, as is shown (but perhaps not absolutely proved) to be the case by Krenner's measurements.
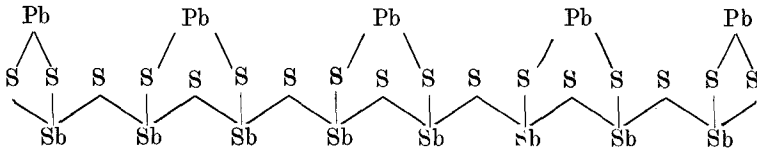
The second suggestion is rather supported by the gradual variation in composition and by the absence of any simple formula, but it would not explain why the analyses fall into three fairly well-marked groups. The two unknown end members would presumably have more simple formulæ than the extremes given above, and they would probably show a wider variation in the parameter c than now shown. But the difference in the angles of the members already known is greater than is the rule in isomorphous substances, and certainly considerably greater than in the plagioclase and scapolite groups.

On the whole, the third suggestion, that of a morphotropic series, seems the most probable. Amongst minerals, the only morphotropic series yet established is that of the humite group[1]; it has also been
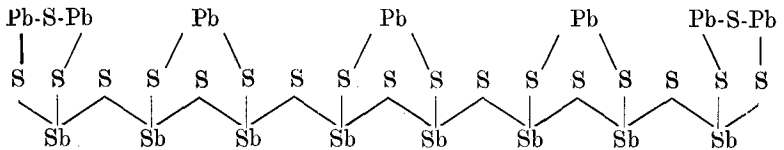
---

[1] *Min. Mag.* 1896, XI. 137, 161.

suggested that andorite, diaphorite and freieslebenite form such a series.[1] In both these cases the crystals of members of each group are so similar in appearance that they cannot be distinguished by mere inspection, and the only essential difference between them is in the greater length of the vertical axis, which varies regularly with the chemical composition, while the parameters $a : b$ remain practically constant. This is exactly the relation existing between plagionite and semseyite.
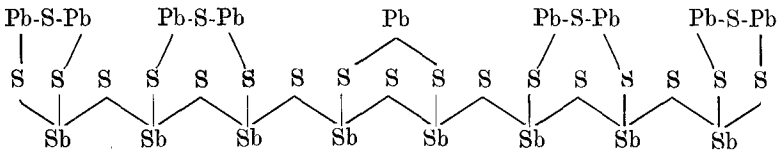
In these cases the comparison of structural formulæ is suggestive, and such formulæ have been given for chondrodite, humite and clinohumite by Sjögren and F. W. Clarke. The following structural formula for plagionite ($5PbS.4Sb_2S_3$) has recently been given by V. C. Butureanu[2] :

```
 Pb        Pb         Pb         Pb        Pb
 /\       / \        / \        / \       /\
S  S  S  S   S  S  S   S  S   S  S  S   S  S  S  S  S
 \ |/\ |   | /\ |   | /\ |   | /\ |   | /\ |  /
  Sb     Sb     Sb     Sb     Sb     Sb     Sb     Sb
```

Replacing two of the —Pb— atoms by the groups —Pb—S—Pb—, the heteromorphite formula $7PbS.4Sb_2S_3$ is obtained :

```
Pb-S-Pb        Pb          Pb         Pb      Pb-S-Pb
 |   / \       / \        / \        / \       \   |
 S  S   S  S  S   S  S  S   S  S   S  S  S   S  S   S
  \  |/\ |   | /\ |   | /\ |   | /\ |   | /\ |   |/
   Sb     Sb     Sb     Sb     Sb     Sb     Sb     Sb
```

Introducing four such groups, we get the formula $9PbS.4Sb_2S_3$, and this agrees better with the analysis of the original semseyite than does the formula $7PbS.3Sb_2S_3$ given by Krenner.

```
Pb-S-Pb    Pb-S-Pb           Pb        Pb-S-Pb    Pb-S-Pb
 |   /     /    \           /\          /    \      \   |
 S  S   S  S   S  S  S  S   S  S   S  S   S  S  S   S   S
  \  |/\ |   | /\ |   | /\ |   | /\ |   | /\ |   |/
   Sb     Sb     Sb     Sb     Sb     Sb     Sb     Sb
```

These formulæ are symmetrical, and the manner in which new atoms of lead are introduced suggests a relation with the increase in the vertical axis of the monosymmetric crystals. Two other possible formulæ in the same series are $8PbS.4Sb_2S_3 = 2PbS.Sb_2S_3$ and $10PbS.4Sb_2S_3$.

---

[1] L. J. Spencer, "Diaphorite from Washington and Mexico," *Amer. J. Sci.* 1898, VI. 316.

[2] *Bult. Soc. Sci.* Bucarest, 1897, VI. 179.

An objection to this is that only a few of the analyses agree exactly with the three formulæ, $5PbS.4Sb_2S_3$, $7PbS.4Sb_2S_3$ and $9PbS.4Sb_2S_3$, and, in fact, almost every analysis requires a different formula.   Since iso-morphous mixture has been provisionally rejected, another explanation must be given for this variation in composition.

The only crystals which have as yet given satisfactory measured angles are those of the extreme members with the formulæ $5PbS.4Sb_2S_3$ and $9PbS.4Sb_2S_3$.   Other crystals are very imperfect, and opposite planes of the same form are never quite parallel; they appear, in fact, to be built up of smaller crystals whose crystallographic elements are not quite the same, so that the compound crystals, although having the same habit as the smaller crystals, are distorted and twisted.   The smaller crystals may be supposed to have definite compositions, as given by the three formulæ above ; the bulk analysis of a compound crystal would then give an indefinite formula, e.g. the formula $21PbS.10Sb_2S_3$ in section III.   This is perhaps supported by the specific gravity deter-minations in sections I and III; in both cases the sp. gr. of the material analysed was slightly less than for the whole group.   Pisani also found variations in the specific gravity.

It is possible that other twisted crystals may be explained in the same way : e.g. the saddle-shaped crystals of dolomite may be built up of smaller crystals containing different proportions of $CaCO_3$ and $MgCO_3$, and consequently with different crystal angles.

Besides the three localities mentioned above, viz. Wolfsberg, Arnsberg and Felsőbánya, plagionite-like minerals have been recorded from seven other localities; but as none of these have been properly determined, it is impos-sible to say whether they are plagionite, heteromorphite or semseyite.

Previous crystallographic determinations made on material not analysed now become of little value.   The parameters given by me (Min. Mag. 1897, XI. 194) were calculated from the mean angles measured on the seven best crystals (from four specimens), and these, it is now seen, may have varied considerably in chemical composition.   On these crystals the angle $cn = 001 : 111$ varied by 3°, and by more than 2° on one and the same crystal; the extreme means of the several readings for each crystal were $41°5' - 41°45'$.   Although it still seems probable that these crystals were plagionite, and that the variations in the measured angles were due to the imperfections of the crystals rather than to differences in com-position, it is nevertheless quite possible that some of the " new " forms (all determined on these seven crystals) may be reduced to forms already known when referred to the heteromorphite or semseyite axes.