On Teallite, a new sulphostannite of lead from Bolivia; and its relations to Franckeite and Cylindrite.

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AMONGST the specimens recently selected for the British Museum from the collection of South American minerals brought together by the late Theodor Hohmann, are two on which occurs a mineral in thin laminae resembling graphite. From the locality and associations, the mineral was at first presumed to be either franckeite or cylindrite, the two sulphantimonite-sulphostannates of lead from Bolivia, which were described in 1893 by Stelzner and Frenzel respectively[1]. Qualitative analysis, however, soon showed that, although similar to them in physical characters, it differed chemically from both franckeite and cylindrite in containing no antimony, but only lead, tin, and sulphur.

Of the two specimens from the Hohmann collection, one was labelled 'sulphoselenide of lead from Bolivia,' and the other 'selenide of lead from Atacama,' so that unfortunately the precise locality of the mineral is at present unknown. In all probability both specimens came from the same district in Bolivia, since in appearance they are very similar.

The new mineral occurs in thin graphite-like folia embedded in glistening kaolin, upon a dark grey matrix impregnated with iron-pyrites; on one specimen it is associated with a little wurtzite in thin plates, and on the other with a little galena.

Crystallographic Characters:—The teallite on the two specimens occurs for the most part in very thin folia with irregular boundaries. A few somewhat thicker plates, however, were found which had a nearly square outline and showed two zones of narrow faces replacing the edges. In each of these zones two sets of narrow pyramid-faces, making angles of $62\frac{1}{2}°$ and $75°$ with the broad cleavage-face, were measured on the three-circle goniometer[2]. Owing to the flexible nature of the plates, the measured angles differed rather widely—from $61°\ 42'$ to

[1] Neues Jahrb. Min., 1893, vol. ii, pp. 114 and 125.

[2] For kind initiation into the manipulation of this instrument I am indebted to Mr. Herbert Smith.

63° 16′, and from 74° 33′ to 75° 58′ respectively—and 62½° and 75° are taken as roughly the mean values. The angle between the two zones measured on the goniometer was 86°. The mineral is therefore in all probability orthorhombic, and not tetragonal as at first supposed. This result was supported by measurement of the angle between two sets of striae, which were observed on some of the plates, running parallel to the edges, and also by observation of the etched figures produced on the cleavage-face by dilute nitric acid. These consisted of two sets of fine striations, like the natural ones, parallel to the edges, and a third set equally inclined to them and occurring only in two opposite (obtuse) corners of the parallelogram formed by the nearly rectangular sets.

Forms observed:—

c {001}, a broad face showing two sets of striations inclined at angles of 86° and 94° and parallel to the intersections with the pyramid-planes.

o {111}, narrow faces often broken up and irregular owing to the cleavage.

p {221}, bright, narrow faces.

Other somewhat doubtful and imperfect narrow faces observed are: *a* (100), *d* (101), *e* (201), and *t*′ ($\bar{2}$11).

Angles measured:—

		Measured.			Calculated.
c : *o*	...	62½°	...	...	—
c : *p*	...	75°	...	...	75° 25′
c : *a*	...	about 90°	...	...	90° 0′
c : *d*	...	„ 57°	...	...	54° 33′
c : *e*	...	„ 74°	...	...	70° 25′
c : *t*′	...	„ 79°	...	...	79° 39′

Angle between the zones [*co*] and [*co*‴] = 86° (i.e. (110):(1$\bar{1}$0) = 86°).

Crystal-system, orthorhombic. Axial ratios,

$$a : b : c = 0{\cdot}93 : 1 : 1{\cdot}31.$$

Crystallographically and in physical characters, teallite shows some relations with nagyagite in which *b* (010) is a perfect cleavage and *ε* (101) : *ε*′ (10$\bar{1}$) = 88° 59½′; *b* (010) : *s* (343) = 75° 17½′.

Other Physical Characters:—Cleavage, *c* (001) perfect. Folia flexible, but not elastic. Hardness, 1–2. Teallite does not scratch gypsum, and is thus readily distinguished from franckeite and cylindrite, which scratch gypsum easily. Somewhat malleable, and makes a mark on paper. Like graphite and cylindrite it is difficult to pulverize. Specific gravity (weight of 1 cc.), 6·36. Lustre, metallic. Colour, blackish-grey. Opaque. Streak, black.

Chemical Composition:—The only impurity associated with the mineral was kaolin, a thin film of which was often found partially coating the cleavage surfaces. This was easily detachable, so that it was possible to obtain very pure material for analysis.

Heated in the closed tube, the mineral gives off a little sulphur and does not fuse. It is readily decomposed by hot, concentrated hydrochloric acid, as well as by nitric acid.

In the quantitative analysis the mineral was decomposed by fusion with sodium carbonate and sulphur, the tin being precipitated as sulphide from the aqueous extract, and the lead as sulphate from the nitric acid solution of the residue. The sulphur was estimated in a separate portion by fusing with sodium carbonate and nitre. The results of two analyses[1], I and II, were as follows:—

	I.	II.	Mean.	Atomic ratios.	Calculated for $PbSnS_2$.
Pb	53·00	52·95	52·98	0·256	53·05
Sn	30·89	29·89	30·39[2]	0·255	30·51
Fe	0·20	not det.	0·20	—	—
S	16·28	16·30	16·29	0·508	16·44
			99·86		100·00

The numbers obtained correspond very closely with the simple formula $PbSnS_2 = PbS{\cdot}SnS$.

The name *teallite* is given to the new mineral in honour of Dr. J. J. Harris Teall, F.R.S., Director-General of the Geological Survey of Great Britain and Ireland.

Relations of Teallite, Franckeite, and Cylindrite.

In view of the above results and the close similarity in physical characters between the new mineral and franckeite and cylindrite, it seemed desirable to make further analyses of the latter minerals in

[1] The atomic weights used throughout this paper are the 'International Atomic Weights' for 1904, with O = 16. Weights used in analyses, 0·6343 gram in I, and 0.3929 gram in II; for sulphur determinations, 0·2752 gram in I, and 0.2658 gram in II.

[2] In I the tin was determined as oxide by the direct ignition of the sulphide and is possibly a little too high; in II, in order to test for traces of antimony, the sulphide was converted into oxide by means of nitric acid and a slight loss may have occurred. The mean value given above is therefore probably not far from the truth.

order to discover if any closer chemical relationship could be formulated between them and teallite than the mere fact that they all contained lead, tin, and sulphur.

Franckeite from Poopó, Bolivia.

Two specimens were analysed. One was selected as being the most crystalline and homogeneous, since it resembled teallite in showing thin plates with striae. In this case, measurement under the microscope showed that the striae were accurately at right angles and not at 86° or 94° as with teallite. Some of the plates also showed striae inclined at 45° to the rectangular sets, and on one plate occurred a narrow face inclined to the cleavage-face at an angle of 47° 46′. Crystallographically franckeite is probably very similar to teallite, but tetragonal instead of orthorhombic.

The franckeite on this specimen occurs as a vein about one inch in thickness in a porous quartz-rock impregnated with 'feather-ore': it was covered by a patch of brown wurtzite and blende with some iron-pyrites. In picking out material for analysis the chief impurity to be removed was the brown sulphide of zinc. No mechanically intermixed 'feather-ore' could be detected.

The mineral was decomposed by fusion with sodium carbonate and sulphur, as in the case of teallite. The mixed sulphides of tin and antimony were oxidized by nitric acid, and the resulting oxides weighed together: they were then separated by a double fusion with caustic soda. The result of the analysis of carefully selected material, consisting of thin plates, is given under III:—

	III[1].	Atomic ratios.	Calculated for $Pb_5FeSn_3Sb_2S_{14}$.
Pb	46·23	0·224	48·42
Fe	2·69	0·048	2·61
Zn	0·57	0·009	—
Ag	0·97	0·009	—
Sn	17·05	0·143	16·71
Sb	11·56	0·096	11·25
S	21·12	0·659	21·01
	100·19		100·00

Specific gravity (weight of 1 cc.) = 5·88.

[1] Weight used in analysis III, 0·5494 gram; for sulphur determination, 0·2179 gram.

The numbers obtained correspond fairly closely to a formula $Pb_5FeSn_3Sb_2S_{14}$, which may be written $3PbSnS_2 + Pb_2FeSb_2S_8$, i. e. as a molecular compound of a sulphostannite of lead (teallite) with a sulphantimonate of lead and iron.

Another analysis was made on more massive material from a specimen of franckeite from the Trinacria mine, near Poopó. In this specimen no impurity of 'feather-ore' could be detected, but the material did not appear to be absolutely homogeneous, parts being readily cleavable into thin flakes, and parts less easily split up. The analysis was made on material consisting mainly of the more massive and less readily cleavable material, in order to see how it might vary in chemical composition from the more crystalline material used in the preceding analysis. The result of the analysis is given under IV, and that of Winkler's original analysis of franckeite, from Chocaya, Bolivia, under V:—

	IV[1].	Atomic ratios.	V. (Winkler.)	Calculated for $Pb_{4\frac{1}{2}}FeSn_{2\frac{1}{2}}Sb_2S_{13}$.
Pb	48·02	0·232	50·57	47·95
Fe	2·74	0·049	2·48	2·88
Ag	0·99	0·009	Zn 1·22	—
Sn	13·89	0·117	12·34	15·32
Sb	13·06	0·109	10·51	12·38
S	20·82	0·650	21·04	21·47
			Gangue 0·71	—
	99·52		98·87	100·00

Sp. gr. ... 5·92.

The numbers obtained in this analysis approximate to a formula $Pb_{4\frac{1}{2}}FeSn_{2\frac{1}{2}}Sb_2S_{13} = 2\frac{1}{2}PbSnS_2 + Pb_2FeSb_2S_8$, midway between the formula $Pb_5Sn_2Sb_2S_{12}$ ($= 2PbSnS_2 + Pb_3Sb_2S_8$) of Winkler and the formula $3PbSnS_2 + Pb_2FeSb_2S_8$ given by analysis III. The latter formula is taken as representing the chemical composition of the pure mineral, since the material used in the second analysis was less crystalline and apparently less homogeneous.

Cylindrite from Poopó, Bolivia.

Two specimens, consisting of well-defined cylinders made up of apparently quite homogeneous material, were analysed. The material

[1] Weight used in analysis IV, 0·7185 gram; for sulphur determination, 0·2557 gram.

readily broke up into cleavage-flakes, showing a brilliant metallic lustre but no well-marked striations.

The results of these analyses[1] are given under VI and VII, while under VIII is added that of Frenzel's original analysis of cylindrite:—

	VI.	Atomic ratios.	VII.	Atomic ratios.	VIII. (Frenzel.)	Calculated for $Pb_3FeSn_4Sb_2S_{14}$.
Pb	35·24	0·170	34·58	0·167	35·41	33·70
Fe	2·81	0·050	2·77	0·050	3·00	3·03
Ag	0·50	0·005	0·28	0·003	0·62	—
Sn	25·65	0·215	25·10	0·211	26·37	25·85
Sb	12·31	0·102	12·98	0·108	8·73	13·05
S	23·83	0·743	23·88	0·745	24·50	24·37
	100·34		99·59		98·63	100·00
Sp. gr.	5·46	...	5·49	...	5·42	

The numbers agree fairly closely with the formula $Pb_3FeSn_4Sb_2S_{14}$, which may be written $3PbSnS_2 + SnFeSb_2S_8$, corresponding to the formula $3PbSnS_2 + Pb_2FeSb_2S_8$ of franckeite, with Sn in place of Pb_2.

The above formulae of franckeite and cylindrite, like most of those, not simply empirical, applied to minerals, admit of no real experimental proof; but it may be urged on their behalf that, without doing violence to the analytical results, they serve to suggest a chemical connexion corresponding to the close similarity in physical characters, not only between franckeite and cylindrite themselves, but also between these minerals and teallite.

As regards cylindrite, the close similarity, both in specific gravities and in the analytical results, of the three specimens at present analysed, appears to be good proof that the mineral which occurs in this peculiar cylindrical form has a definite chemical composition. In the case of franckeite the evidence on this point is not so conclusive. Owing to the mode of occurrence of this opaque mineral in radiated or spherulitic aggregates, it is difficult to be assured of its homogeneity. The results of the three analyses at present made certainly show variations in composition, though they all approximate to formulae which can be expressed as mixtures of $PbSnS_2$ with $Pb_2FeSb_2S_8$. The formula, $3PbSnS_2 + Pb_2FeSb_2S_8$, is adopted for franckeite as representing the chemical composition of material which had the appearance of being the most crystalline and homogeneous of the specimens in the British Museum collection.

[1] Weights used in analyses, 0·5684 gram in VI, and 0·6659 gram in VII; for sulphur determination, 0·2446 gram in VI, and 0·2289 gram in VII.

SUMMARY.

Characters of Teallite:—

Grey-black colour, metallic lustre, soils paper like graphite, occurs in flexible folia with nearly square outline, perfect basal cleavage, hardness, 1–2, does not scratch gypsum, density, 6·36. Orthorhombic, $a:b:c = 0{\cdot}93:1:1{\cdot}31$. Chemical formula, $PbSnS_2$.

Probable chemical formula of franckeite:—

$$Pb_5FeSn_3Sb_2S_{14} = 3PbSnS_2 + Pb_2FeSb_2S_8.$$

Probable chemical formula of cylindrite:—

$$Pb_3FeSn_4Sb_2S_{14} = 3PbSnS_2 + SnFeSb_2S_8.$$