

Aramayoite, a new mineral, from Bolivia.

By L. J. SPENCER, M.A., Sc.D., F.R.S.

With a chemical analysis by E. D. MOUNTAIN, M.A.

Mineral Department, British Museum (Natural History).

[Read November 2, 1926.]

BOLIVIAN minerals have been sent for examination and preservation in the British Museum collection at various times since 1894 by my old school-fellow Mr. Malcolm Roberts, A.R.S.M., now General Manager of the Compagnie Aramayo de Mines en Bolivie. Several of these have been described in the pages of this magazine (see vol. 14, p. 309). Although he has industriously collected Bolivian minerals for over thirty years he is only now rewarded by the discovery of a species new to science. The material which he has been good enough to entrust to me for description was recognized by him as being probably something new, and this was confirmed by a chemical analysis made by Mr. T. Burns McGhie in the assay office at Quechisla in Bolivia.

Following the wish of Mr. Roberts and also that of Don Carlos Victor Aramayo, the present Bolivian Minister in London, the new mineral is here named aramayoite, in honour of Señor Don Felix Avelino Aramayo, who until last year was the Managing Director of the Compagnie Aramayo de Mines en Bolivie, and formerly the Bolivian Minister in London and afterwards in Paris.

The mineral was found in 1925 in a wide lode carrying abundant silver-tin ore in the company's Animas mine at Chocaya,¹ province

¹ This locality is mentioned by A. A. Barba, 'Arte de los Metales', Madrid, 1689; English translation by the Earl of Sandwich, London, 1674, Book I, p. 115: 'And in the rich Mine of *Chocaya*, in the Province of the *Chichas*, in the richest Stones of that Oar they have found much Silver, like wyre woven together as aforesaid.'

Sud-Chichas, department Potosi, Bolivia. Only a single piece was found, one-half of which was sent by Mr. Roberts for the British Museum collection, the counterpart being kept in the collection at the mine offices in Bolivia. The specimen received shows an irregular pocket of aramayoite, about 8×6 cm., surrounded by a zone of pyrite, in massive tetrahedrite.

The aramayoite shows an irregular and confused aggregate of bright cleavage surfaces with striated areas at the edges, in much the same fashion as 'books' of mica. The colour is iron-black with brilliant metallic lustre on the perfect cleavage, and the mineral presents a certain resemblance to tetradymite and franckeite.¹ The cleavage surfaces are about a centimetre across, and the 'books' are $\frac{1}{4}$ — $\frac{1}{2}$ cm. measured in a direction perpendicular to the cleavage. Thin cleavage flakes are pliable but not elastic. They break up with square or rectangular outlines, and on the surface they are marked by striae and steps in two directions at right angles. Occasionally there are also sharp lines of fracture at 45° (as measured under the microscope) to the first set. The crystals therefore appear to be tetragonal with perfect basal cleavage $c(001)$ and good cleavages at the edges in the zones $[001, 100]$ and $[001, 110]$. The mineral is somewhat sectile. When powdered in an agate mortar it breaks up into short fibres which have a tendency to clog together. The streak is black, and the hardness $2\frac{1}{2}$. The cleavage flakes are quite opaque.

Numerous fragments were placed on the goniometer, but unfortunately no satisfactory measurements could be obtained. The fibrous cleavage at the edges of the plates, which at first sight appeared to be parallel to the tetragonal prism $a(100)$ gave scattered and banded reflections. The most prominent reflections were at 73° to 80° from $c(001)$, with a mean of about 77° . No marked difference could be noticed in the two zones at right angles. The cleavages that give rise to the square outlines are therefore pyramidal. Various other readings were, however, obtained; the more frequent being about 53° and 40° , suggesting other pyramidal cleavages, while an occasional poor reflection at about 90° suggested a prismatic cleavage $a(100)$. The rarer zones at 45° to the first set gave no consistent results.

¹ Franckeite (of A. W. Stelzner, Neues Jahrb. Min., 1893, vol. ii, p. 114) was named after the brothers Carl and Ernst Francke, with whom Mr. Aramayo was formerly associated in Aramayo Francke Mines Limited, and curiously came from this same locality.

On one part of the specimen the aramayoite shows a drusy crystalline surface with a cellular or skeletal growth, and gives simultaneous reflections of light from numerous isolated spots over considerable areas. The small square basal planes, which fall approximately together to give larger areas, are bounded at the edges by pyramidal facets. These are coarsely striated parallel to their intersection with the basal plane. Fragments of this aggregate when placed on the goniometer gave scattered images from the basal planes and banded images from the pyramidal facets. The more prominent reflections gave angles of about 55° from $c(001)$; others were at about 77° and 40° .

These measurements are not reliable, and they are admittedly biased in the endeavour to arrive at some consistent results. Taking the more prominent pyramidal cleavage as $f(301)$ and at 77° from $c(001)$, this gives the calculated angle $c(001) : e(101) = 55^\circ 18'$, and the axial ratio $a : c = 1 : 1.44$. This agrees with the best angle from pyramidal facets on the drusy surfaces, but not so well with the angle 53° from the cleavages. The angle of about 40° from both facets and cleavages suggests the calculated angle $c(001) : g(305) = 40^\circ 54'$. The few poor measurements from facets and cleavages in the zone $[001, 110]$ are not consistent with these values.

The bulk of the specimen consists of massive tetrahedrite. Similar material from the lode assays up to twelve per cent. of silver. Mr. Roberts suggests that stannite is also perhaps present, but this is not distinguishable from the massive tetrahedrite. The pyrite is granular. Along a crevice it is present as small crystals with the forms $o(111)$ and $e(210)$ equally developed, giving a form bounded by twenty triangular faces. Small colourless to white crystals of quartz are present in small cavities in the tetrahedrite.

A curious change came over the aramayoite after it had been in the museum for about two months. The specimen had been kept under observation in a glazed case (facing the morning sun) in the work-room. It remained bright and shining until one morning, when it was noticed that the aramayoite on the side of the specimen towards the glass was white and dusty. This white coating was wiped off, but appeared again the next day. The specimen has since been kept in the dark, and there have been no further signs of misbehaviour. The white film was very easily wiped off, and it had quite the appearance of the well-known deposit from ammonium chloride vapour. It was the merest film, and was not examined chemically. After the film had been wiped off the underlying aramayoite, though still bright, was not quite so brilliant,

and it showed a slight iridescent tarnish. On the other side of the specimen the aramayoite was not affected, and this still shows its original brilliant lustre.

No explanation of this curious phenomenon can be given. Cleavage flakes of the mineral exposed to direct sunlight in a south window for four weeks showed not the slightest change. The only liquid in the case together with the specimen was methylene iodide. The pyrite on the specimen shows no sign of decomposition, although the specimen has a slight 'acid' or 'metallic' smell. It may sometimes be noticed, especially in damp weather, that a museum case exposed to direct sunlight and then coming into shadow will show a rapid condensation of moisture inside the glass. Cleavage flakes of aramayoite immersed in water or floating on the surface, or resting on wet blotting-paper, when exposed to direct sunlight showed no change. Others were steamed and boiled in water or dilute sulphuric acid, and in strong hydrochloric acid, but they still persisted in the display of their brilliant metallic lustre. Methylene iodide had no action. In the vapour of strong hydrochloric acid or nitric acid at the ordinary temperature the cleavage flakes became tarnished after some days; and in the nitric acid vapour a white crust was formed on portions of the surface. The powdered mineral is slowly decomposed by hot strong nitric acid with separation of a white precipitate, but hot strong hydrochloric acid has no action.

The crystallographic determinations given above (which are left as first written) are evidently incomplete and unsatisfactory. The excellent cleavage plates suggested that an X-ray Laue photograph might give some clue to the symmetry of the crystals; and, through the kindness of Sir William H. Bragg, an X-ray examination of the new mineral has been made by Miss Yardley in the Davy-Faraday Laboratory of the Royal Institution. Her results are of such importance that they are presented below in a separate paper. They afford a striking example of how X-ray methods may come to the aid of descriptive mineralogy when the usual crystallographic methods fail. Miss Yardley finds the absence of planes and axes of symmetry and has been able to completely determine the crystallographic constants of the triclinic crystal. Her results, based on internal structure, point to a pseudo-tetragonal type; and this is confirmed by the external characters, as indicated by the cleavages. The main cleavage plane is the basal plane of the pseudo-tetragonal cell.

When preparing cleavage flakes for the X-ray examination, Miss Yardley made an interesting observation which is best recorded in this place. The

main (001) cleavage surfaces sometimes showed minute (0.01—0.1 mm.) square pits with steep sloping sides, and very like etch-figures in appearance.¹ These were evidently formed by the ripping out of material along the 'pyramidal' cleavages. The pits are occasionally octagonal in outline, due, no doubt, to the second set of 'pyramidal' cleavages. Sometimes the pits completely penetrate the cleavage flake, leaving square windows; whilst at other times an extremely thin layer of the material is left at the bottom of the pit. When these pits are examined under a high magnification in sunlight or in a brilliant artificial light they sometimes show a deep blood-red colour by transmitted light. The same colour was also sometimes to be seen on the frayed edges of the cleavage fragments. The statement made above that the mineral is opaque therefore requires qualification. Fragments were again crushed in oil on a microscope slide, but under these conditions only occasionally could the red colour be seen by transmitted light. Several thin cleavage flakes mounted in Canada-balsam were rubbed down as far as possible, but they still remained quite opaque. The streak of the mineral was again examined, and it was found to be black without any indication of red.

Miss Yardley's preparations were further examined between crossed nicols, when the blood-red colour showed up much more vividly. The extinction is uniform and at about 4° to the traces of the prominent 'pyramidal' cleavage. An interference-figure in convergent polarized light could not be obtained. This observation in parallel polarized light proves at once that the mineral is not tetragonal; but from a consideration of the cleavages it may be described as pseudo-tetragonal.

The new mineral is shown by chemical analysis to be a sulph-antimonite of silver with a large part of the antimony replaced by bismuth, the formula being $\text{Ag}_2\text{S} \cdot (\text{Sb}, \text{Bi})_2\text{S}_3$ or $\text{Ag}(\text{Sb}, \text{Bi})\text{S}_2$. This suggests a bismuth-bearing variety of miargyrite (AgSbS_2). But crystallographically it is quite distinct from miargyrite; the latter being monoclinic with no prominent cleavage, a cherry-red streak, and blood-red and translucent in thin splinters. It also differs from matildite (AgBiS_2), which is described as forming striated needles, or massive, without cleavage. The characters given for plenargyrite (AgBiS_2) do not appear sufficient to distinguish it from matildite. Being pseudo-tetragonal and with perfect basal cleavage and good pyramidal cleav-

¹ Similar figures on fluorite and some other minerals have been described (in Japanese) and figured by M. Kuhara, Journ. Geol. Soc. Tokyo, 1919, vol. 26, pp. 208-214, 335-341, pls. VIII-X, XII-XIV, and called 'tear-figures'.

ages, aramayoite is quite distinct crystallographically from any other sulpho-salt, and it creates a new subdivision in the RS. (As,Sb,Bi)₂S₃ group.

Chemical Composition of Aramayoite. (By E. D. Mountain.)

The preliminary analysis made by Mr. T. B. McGhie gave the following results :

			Atomic ratios.	FeS ₂ .	Cu ₃ Sb ₂ S ₇ .	SiO ₂ .	Remainder.
S	...	25.17	0.785	28	14	—	743
Sb	...	31.00	0.259	—	4	—	255
Bi	...	10.00	0.048	—	—	—	48
Ag	...	32.12	0.298	—	—	—	298
Cu	...	1.00	0.016	—	16	—	—
Sn	...	trace	—	—	—	—	—
Pb	...	nil	—	—	—	—	—
Fe	...	0.80	0.014	14	—	—	—
SiO ₂	...	0.40	0.008	—	—	8	—
		100.49					
Weight percentages	...	—	—	1.71	1.93	0.40	—

Assuming that the iron is present as pyrite, the copper as tetrahedrite, and the silica as quartz, we obtain for the remainder the molecular ratios Ag : Sb + Bi : S = 2 : 2 : 5. The analyst himself, however, assumed the copper to be present in the form of chalcopyrite, but otherwise obtained substantially the same result.

As this analysis showed probable impurities of 4.04% and an excess of sulphur over the normal ratio to the bases, silver, antimony, and bismuth, it was considered advisable to repeat the analysis on as pure material as could be collected. For this purpose Dr. Spencer picked out about two grams of very pure cleavage flakes.

Two independent determinations of the specific gravity by the pycnometer method on 0.9047 gram and 0.9962 gram respectively gave identical results of 5.602 after correction by the Hutchinson graph. Preliminary tests showed the absence of tin and only a trace of iron. When heated in a bulb-tube, the mineral decrepitates and melts at a low temperature, with partial volatilization, to a black mass which cools to a bright metallic bead.

A quantitative analysis was carried out on 0.7613 gram of powdered material. A separation was first made by heating to a dull-red heat in a current of chlorine, thus driving off the sulphur, antimony, iron, and bismuth in that order. The sulphur was determined in a separate

portion weighing 0.5973 gram by the fusion method. The analysis gave the following results:

			Atomic			
			ratios.	$\text{Cu}_8\text{Sb}_2\text{S}_7$.	Remainder.	Calculated.
S	...	20.87	0.651	7	644	20.66
Sb	...	29.95	0.250	2	248	30.55
Bi	...	13.75	0.066	—	066	14.02
Ag	...	34.74	0.322	—	322	34.77
Cu	...	0.53	0.008	8	—	—
Fe	...	trace	—	—	—	—
		<u>99.84</u>				<u>100.00</u>

These results give $\text{Ag} : \text{Sb} + \text{Bi} : \text{S} = 1 : 1 : 2$, corresponding with the formula $\text{Ag}(\text{Sb}, \text{Bi})\text{S}_2$ or $\text{Ag}_2\text{S} \cdot (\text{Sb}, \text{Bi})_2\text{S}_3$.
