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## *On Schwartzembergite.*<sup>1</sup>

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THE mineral schwartzembergite was first described by Domeyko<sup>2</sup> in 1864 as an oxychloriodide of lead from the Desert of Atacama. The specimens, which are said to have been collected about ten leagues<sup>3</sup> from Paposo in the Desert of Atacama, at a mine worked for argenteriferous galena, were brought to his notice by Dr. Schwartzemberg, an assayer at Copiapo, who had recognized the material as being an iodide of lead. Domeyko made a chemical analysis (see p. 82) of the mineral, a yellowish crust, 1 to 2 mm. in thickness, upon galena, and obtained the formula,<sup>4</sup>  $2\text{Pb}(\text{Cl},\text{I})_2 \cdot 3\text{PbO}$ , the specific gravity being 5.7; no crystal measurements were obtainable, neither were any optical observations made. The investigation could not be continued because most of the specimens were stolen on their way down from the mine, since it was supposed that they must, because of the care bestowed upon them, contain silver iodide, which also is found at the same mine. A little later, an analysis (see p. 82) was made by Liebe,<sup>5</sup> who had received some specimens

<sup>1</sup> Communicated by permission of the Trustees of the British Museum.

<sup>2</sup> I. Domeyko, *Annales des Mines*, 1864, ser. 6, vol. v, p. 453.

<sup>3</sup> One Spanish league is nearly equal to four English miles.

<sup>4</sup> This is the modern form; Domeyko wrote the formula as  $2\text{Pb}(\text{Cl}_2, \text{I})3\text{PbO}$ .

<sup>5</sup> K. T. Liebe, *Neues Jahrb. Min.*, 1867, pp. 159-164.

from H. Ferber, a mining engineer, to whom they had been given by Schwartzemberg, and he deduced the formula,<sup>1</sup>  $PbI_2 \cdot 2PbO$ . His material, which was a little denser, the specific gravity being 6.2, was not very pure, and contained both the sulphate and the carbonate of lead; it was mostly amorphous, but appeared in parts in the form of small rhombohedral crystals resembling chalybite. In the fifth edition of his 'System of Mineralogy', published in 1868, J. D. Dana assigned to the new mineral the name, schwartzembergite, by which it is now known. Domeyko, in the third edition of his book on mineralogy,<sup>2</sup> published in 1879, brings together all that is known of the mineral, its localities and paragenesis. Bertrand<sup>3</sup> a little later examined under the microscope some fragments of the mineral from San Rafael and found them to yield a negative uniaxial interference-figure, but he gives no other details.

In 1903, several specimens formerly belonging to the collection of Theodor Hohmann (1843-1897), a mining engineer in Chili, were acquired by the Trustees of the British Museum. Among them were three labelled schwartzembergite, San Rafael mine, Sierra Gorda, Caracoles, Chili, which displayed numerous yellow and brownish crystals, some of them being comparatively large. The form of these crystals is obviously tetragonal,<sup>4</sup> and not rhombohedral as had been previously described.

*Morphological and Optical Characters.* (G. F. H. S.)

On the first specimen (86453 of the Museum Register) the crystals are large, being as much as 6 mm. across, and are honey-yellow to reddish-brown in colour. They occur in groups associated with gypsum, perclite, and corroded quartz. On the second specimen (86454) the crystals are much smaller, never exceeding 1 mm. across; the colour does not consequently reach so deep a brown. Besides gypsum and perclite, the specimen has on it tiny crystals of paralaurionite (rafaelite). On the third specimen (86455) the crystals are also small, and are intimately associated with gypsum, perclite, and quartz.

The colour of the crystals depends upon their size. When they are quite small, the colour is honey-yellow, but with increasing thickness it

<sup>1</sup> The formula was given in the old form  $PbI \cdot 2PbO$ .

<sup>2</sup> I. Domeyko, 'Mineralojia,' 3rd edit., Santiago, 1879, pp. 319-321.

<sup>3</sup> É. Bertrand, 'Étude optique de différents minéraux,' Bull. Soc. Min. de France, 1881, vol. iv, p. 87.

<sup>4</sup> In an editorial note it is stated, '... the last-named [schwartzembergite] being in well-developed tetragonal crystals.' Mineralogical Magazine, 1903, vol. xiii, p. 382.

becomes brownish and finally reddish; the powder, on the other hand, is always straw-yellow in colour. The crystals are very flat, and their contour is square with more or less rounded corners. They are formed of eight low pyramids, four above and four below, directly above one another in pairs. The pyramids are so much rounded that the shape of the crystals approximates to a very flat cone. A small secondary pyramidal form (*q*) is occasionally seen which is very steep and makes equal angles with the contiguous large pyramids; each face has another lying below it. The crystals are usually attached at the side, and complete development is very rare.

If a crystal be mounted upon a two- or three-circle goniometer and revolved, it is at once perceived that ordinary measurements are quite out of the question. A continuous band of light is given by the pyramidal faces on each half of the crystal, and no distinct images of the object-slit from which readings can be taken are visible. The images given by the small pyramidal faces are better defined; the faces are double, the two parts being mutually inclined at a small re-entrant angle. A form of camera lucida<sup>1</sup> was devised for attachment to the goniometer, by means of which the 'light-figures' given when a pin-hole signal was used could be drawn immediately upon a stereographic projection. These figures are of the type shown in fig. 1. The connecting bands lie very nearly in zones intersecting at right angles. At the poles of intersection, *p*, which represent a considerable area in the centre of each of the large faces, there is an increase of intensity of the light and often some frilling of the figure in the zone [*cp*] away from the pole *c*. The distance *cp* is about  $23\frac{1}{2}^{\circ}$ , but values as low as  $16^{\circ}$  have been observed. The azimuthal angles at the pole *c* approximate to  $90^{\circ}$ , but values as low as  $71^{\circ}$  have been observed. The other form *q* is planer, and better readings of the distance have been obtained; *cq* is about  $67^{\circ} 40'$ . If *p* be given the indices (011), *q* becomes (441), and the calculated value of *cp* is  $23^{\circ} 17'$ : the axial ratio  $a : c = 1 : 0.430$ . A distinct cleavage parallel to *c* (001) was noticed.

That the symmetry of schwartzembergite, however, is pseudo-tetragonal in character is shown by a study of the optical properties as revealed in polarized light. Owing to the high refractivity, immersion in oil is necessary for a satisfactory observation. Through each of the faces of the form *p* a biaxial interference-figure, of negative birefringence,

<sup>1</sup> G. F. H. Smith, 'A camera lucida attachment for the goniometer,' *Mineralogical Magazine*, 1910, vol. xv, pp. 388-389.

is visible; the plane of the optic axes is parallel to the corresponding horizontal edge of the contour (fig. 2), the centre of the figure being about  $36^\circ$  from the centre of the field of the microscope, and the angle in air between the optic axes about  $38^\circ$ . Between the large faces lie smaller sectors through which also a biaxial interference-figure is visible, with negative birefringence, but much larger axial angle, about  $84^\circ$  in air. The plane of the optic axes is now perpendicular to the horizontal contour, and bisects the planes of the optic axes visible through the contiguous faces,  $p$ ; one of the optic axes is in the centre of the field of the microscope, while the centre of the figure lies about  $42^\circ$  away towards the pole  $c$ . The figures are distinct only near the horizontal contour of the crystals; farther inwards they are distorted owing to the wedge

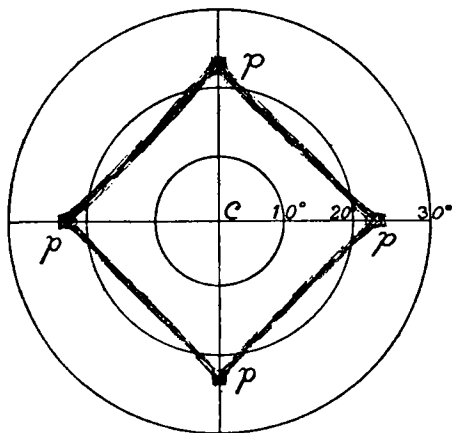


FIG. 1.—Stereographic projection of the 'light-figure' of Schwartzbergite.

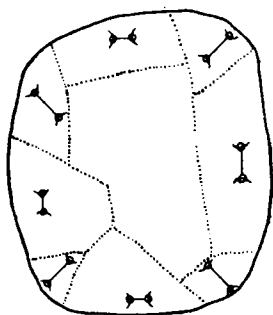


FIG. 2.—Crystal of Schwartzbergite showing division into sectors of different optical orientation.

shape of the section traversed and to the overlapping of different sectors. In the centre no figure is visible, and little variation in the intensity of the transmitted light is noticeable on rotation of the nicols. An approximate determination of the refractivity was obtained, viz. 2.35, by noting the deviation experienced by light traversing the prism formed by a pair of large faces meeting in the horizontal edge.

It is surprising that the same crystal should in different sectors show biaxial interference-figures of such widely different angular width. Inside the crystal the angles reduce to about  $16^\circ$  and  $28^\circ$ . These observations are not in accord with Bertrand's, and it may be questioned whether he

really examined schwartzembergite; his observations agree with the characters of matlockite.

The curious nature of the morphological characters indicates that in these crystals the intermolecular repulsive forces which prevail in liquids and appear as surface tension are comparable with the intermolecular attractive forces which are responsible for the growth of rigid crystals. Schwartzembergite is therefore one of the links connecting liquid crystals with plane-faced crystals.

*Chemical Composition.* (G. T. P.)

The material used in the analysis consisted of clear transparent fragments of large crystals from the specimen (86453) from San Rafael, Chili. It was carefully picked over under the lens and separated as far as possible from adhering gypsum, traces of which, however, doubtless remained, as shown by the fractional percentages of lime and sulphuric acid obtained in the analysis.

The results of the analyses are as follows:—

	I.	II.	III.	IV.	V.	Mean.
Pb . . .	75.15	75.07	74.98	—	—	75.07
Cu . . .	—	—	—	—	trace	trace
CaO . . .	—	—	—	—	0.67	0.67
Cl . . .	—	—	—	8.02	7.91	7.96
I . . .	—	—	—	8.54	8.73	8.64
SO <sub>3</sub> . . .	—	—	—	—	0.47	0.47
O and loss .	—	—	—	—	—	(7.19)
						<hr/> 100.00

The weights used in the analyses were 0.4189, 0.4411, 0.5671, 0.6631, and 0.7336 gram respectively. The specific gravity, as determined with the pycnometer on 0.8851 gram of material, is 7.39.

For one of the determinations of lead the mineral was decomposed with sulphuric acid: in the other analyses it was fused with sodium carbonate. The iodine in the water-extract was determined in the usual way by liberating with nitrose, absorbing in carbon bisulphide, and titrating with sodium thiosulphate.

If, as in the previous analyses of Domeyko and Liebe, the iodine and chlorine be considered to be present as iodide and chloride of lead, the above result of the analyses may be interpreted as follows under I, for

comparison with which are given under II and III respectively the results of the previous analyses of Domeyko and Liebe:—

	I.	II.	III.
	(Prior.)	(Domeyko.)	(Liebe.)
PbCl <sub>2</sub> . . . .	31.17 . . . .	22.8 . . . .	11.40
PbI <sub>2</sub> . . . .	15.68 . . . .	18.7 . . . .	30.89
PbO . . . .	48.29 . . . .	47.1 . . . .	48.92
CaO . . . .	0.67 . . . .	— . . . .	PbSO <sub>4</sub> 5.51
SO <sub>3</sub> . . . .	0.47 . . . .	2.5 . . . .	PbCO <sub>3</sub> 1.88
—	CaCO <sub>3</sub>	1.7 . . . .	Sb <sub>2</sub> O <sub>3</sub> 0.91
96.28	Fe <sub>2</sub> O <sub>3</sub> + Al <sub>2</sub> O <sub>3</sub>	1.6 . . . .	—
	Silica, &c.	3.7 . . . .	99.51
		98.1	

The loss of nearly four per cent. could not be accounted for by the detection of any other constituent of the material analysed. It was for this purpose that so many determinations of lead, &c., were made. The conclusion was finally arrived at that the loss must be due to oxygen and that the iodine was present as iodate and not iodide. This idea was strongly supported by the behaviour of the mineral when heated with hydrochloric acid. It was found that abundant chlorine was given off, easily recognizable by its odour and bleaching effects, even when quite small fragments of the mineral were treated with the acid. Moreover, when the mineral was dissolved in cold nitric acid, there was evidence to show that in the solution the iodine was in the form of iodate and not iodide, for the precipitate produced by silver nitrate was pure white in colour and was easily soluble in dilute ammonia, from which solution, on heating, sulphurous acid precipitated silver iodide insoluble in ammonia.

When the iodine is reckoned as iodate of lead the result of the analyses may be written as follows:—

		Molecular ratios.
PbI <sub>2</sub> O <sub>6</sub> . . . .	18.95 . . . .	0.034
PbCl <sub>2</sub> . . . .	31.17 . . . .	0.112
PbO . . . .	48.29 . . . .	0.216
CaO . . . .	0.67 . . . .	
SO <sub>3</sub> . . . .	0.47 . . . .	
	99.55	

By the fusion with sodium carbonate it would appear that all iodate

was converted into iodide, for no increase of iodine was obtained by treating the water-extract with sulphurous acid before separating the iodine.

The numbers obtained in the analyses correspond fairly closely to the formula  $3(\text{PbCl}_2 \cdot 2\text{PbO}) \cdot \text{PbI}_2\text{O}_6$ , representing a molecular compound of iodate of lead with an oxychloride of lead having the composition of mendipite.

It would seem as if the anomalous morphological and optical characters of the mineral had a direct connexion with its abnormal chemical composition.

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