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MAWSONITE, A NEW COPPER-IRON-TIN SULFIDE FROM MT. LYELL, TASMANIA AND TINGHA, NEW SOUTH WALES

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Abstract

Mawsonite, a new copper-iron-tin sulfide, occurs in bornite-rich ores from Mt. Lyell, Tasmania and Tingha, New South Wales. The chemical composition, using electron probe analysis, is Cu 44.3, 45.0; Fe 12.5, 11.8; Sn 10.4, 11.8; S 33.0, 30.3; yielding a formula $Cu_7Fe_2SnS_{10}$. Mawsonite is body centred pseudocubic with $a = 10.74 \pm .01$ Å and is essentially isostructural with reniérite. Optically, mawsonite is orange in colour, strongly pleochroic and very strongly anisotropic. The mineral is magnetic, has a hardness $\approx 3\frac{1}{2}$ and is negative to standard etch reagents. Mawsonite is the tin analogue of reniérite and corresponds, in part, to the material described originally by Murdoch as "orange bornite."

Introduction

Recent microscopic examination of bornite-rich ore samples from Mt. Lyell, Tasmania and from Tingha, north eastern New South Wales has revealed the presence of an orange colored mineral with properties in polished section corresponding closely to those of a group of minerals originally described by Murdoch (1916) under the name "orange bornite." The precise nature of the material described as "orange bornite" by Murdoch (1916) has long been in doubt. "Orange bornites" have been regarded variously as equivalent to cubanite or a cubanite solid solution (Legraye, 1933; Edwards, 1939), to the synthetic compounds Cu_5FeS_6 (Orcel, 1943) and $Cu_3Fe_4S_6$ (Edwards, 1954), whereas the investigations of Vaes (1948), Murdoch (1953) and Sclar and Geier (1957) have clearly shown that "orange bornites" from the Prince Leopold mine, Kipushi, Congo and the Tsumeb mine, South West Africa correspond to the germanium mineral reniérite $Cu_3(Ge, Fe, Sn, Zn)S_4$. The latter authors have suggested that other reported occurrences of "orange bornite," *viz.* San Expedito mine, Cerro de Pasco, Peru (Orcel and Plaza, 1928), Morococha, Peru (Harcourt, 1942) and Vaulry, France (Orcel, 1943) might also be occurrences of reniérite. There is, however, a good deal of evidence to suggest that tin, rather than germanium, is an essential constituent of many "orange bornites." Thus, Harcourt (1942) reported tin in material from Morococha, while the close association of this mineral with cassiterite, stannite, hexastannite (?) and bornite at Vaulry, France (Orcel, 1943) and the Ashio mine, Japan (Nakamura, 1961) together with the experimental evidence of Moh (1960) and Moh and Otteman (1962) that extensive diadochy exists between germanium and tin in stannite-type compounds, tend to support this view. It is of interest to note that Ramdohr (1960) records two orange colored minerals occurring characteristically as inclusions in bornite, the one being moderately anisotropic and "fast sicher identisch mit Renierit." The other, which shows stronger pleochroism and anisotropism and previously thought by Ramdohr to correspond to luzonite-enargite, could not be correlated with any known mineral.

Our investigations have shown that the "orange bornite" from Mt. Lyell and from Tingha is a new copper-iron-tin sulfide of formula $Cu_7Fe_2SnS_{10}$. It is clearly the tin analogue of reniérite and, accordingly, a valid mineral species. We propose the name mawsonite[1], in honour of the late Sir Douglas Mawson (1882–1958), noted Australian geologist and Antarctic explorer. Type specimens of mawsonite from Mt. Lyell have been deposited in the British Museum of Natural History, London; the U. S. National Museum in Washington and the Mineralogical Museum, Harvard University, Cambridge, Mass., U.S.A.

OCCURRENCE

Mt. Lyell, Tasmania. The well known copper deposits of the Mt. Lyell district, Queenstown, Tasmania occur as massive to disseminated ore bodies within highly altered volcanic rocks of Cambrian age (Wade and Solomon, 1958). The main ore minerals present include pyrite, chalcopyrite, bornite, chalcocite, digenite, tetrahedrite-tennantite, enargite, sphalerite and galena (Edwards, 1939; Markham, 1963). The presence of an orange, strongly pleochroic and strongly anisotropic mineral was first noted by Edwards (1939) who suggested that it was probably cubanite or chalcopyrite containing cubanite in solid solution. Later (1954), he correlated this mineral with the synthetic phase $Cu_3Fe_4S_6$ produced by Merwin and Lombard (1937) in their investigations of the Cu-Fe-S system. More recently, Ramdohr (1960) referred to the presence of reniérite at Mt. Lyell and the same mineral had been referred to by Markham (1963) as "orange stannite."

Material examined in the present study comes from the North Lyell and Crown Lyell mines, two ore bodies locally rich in bornite. The mawsonite occurs typically as rounded to irregular inclusions in bornite (Fig. 1), generally in the size range 0.05–0.2 mm and to a maximum observed grain size of 1.3 mm. The most common assemblages are bornite-chalcocite, bornite-chalcopyrite-tetrahedrite and bornite-chalcopyrite-pyrite. Other associated minerals include galena, tennantite and an enargite-type phase.

Tingha, New South Wales. Samples from Tingha, New England district

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[1] Name approved by the Commission of New Minerals and Mineral Names, I.M.A.

of New South Wales, come from the Royal George mine, a small copper-tin prospect some $1\frac{1}{2}$ miles E.N.E. of Tingha on the Tingha—Elsmore road. No recorded description of this deposit is extant but the mineralization occurs in a narrow quartz vein along shears in granite of late Permian age. The paragenesis includes cassiterite, bornite, hexastannite, mawsonite, chalcocite, enargite and arsenopyrite. Under the microscope replacement of cassiterite by bornite has formed characteristic reaction rims, similar to those previously noted by Nakamura (1961) from the Ashio mine, Japan. The reaction rims consist largely of hexastannite with mawsonite occurring around the outer margins (Figs. 2a, b). Mawsonite also occurs rarely within chalcocite rims surrounding bornite. The grain size of mawsonite from Tingha is rarely in excess of .03 mm.

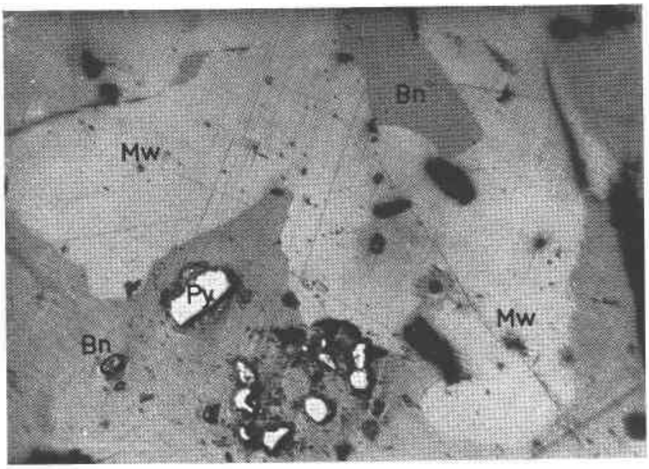


FIG. 1. Mawsonite (Mw) in bornite (Bn) with associated pyrite (Py). Mt. Lyell, Tasmania. ×100.

PHYSICAL PROPERTIES

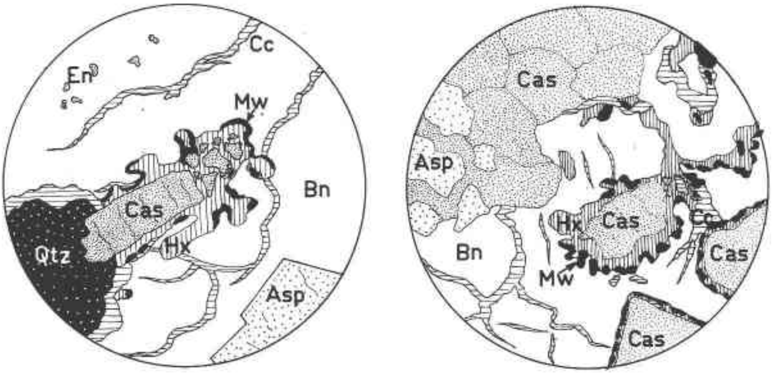
Because of the fine grain size and intimate intergrowths of mawsonite with other sulfide minerals, all measurements of physical properties are those obtained from polished surfaces.

Optical properties. In polished section mawsonite has a characteristic brownish orange color relative to that of freshly polished bornite. It shows strong reflection pleochroism from orange to brown with a slight orange tint, in the latter position it is almost identical in color to hexastannite. Mawsonite is very strongly anisotropic with polarization colors ranging from bright straw yellow to bright royal blue and to dark gray-blue near extinction. Extinction is generally sharp and complete.

Twinning has not been observed but local lamellar twinning was noted by Edwards (1939) in his earlier description of the Mt. Lyell "orange bornite."

Measurement of rotation of the plane of polarization (A_r) in monochromatic light (590 $\mu\mu$), in air, corrected for rotation due to reflector glass, gave 3.2°.

Dispersion phenomena observed conoscopically showed very strong *dispersion of anisotropy* with distinct black isogyres, distinct crimson fringes in the concave, which is otherwise pink in color and distinct greenish-blue fringes on the convex, remainder of field pale green-blue. Dispersion due to *surface reflection* extremely weak though isogyres black and distinct, very faint bluish tint on concave side, remainder of field uncolored.



(a) (b)

FIG. 2a, b. Mawsonite (Mw) forming an outer rim around hexastannite (Hx) which results from reaction between cassiterite (Cas) and bornite (Bn); associated minerals include enargite grains (En), arsenopyrite (Asp), chalcocite (Cc) and quartz (Qtz). Tingha, N.S.W. ×72.

Reflectivity. A series of reflectivity measurements with photo-electric cell and Kodak "Wratten" filters (Nos. 58, 22, 29) gave the following results:

R%	Green	25.5–27.3
	orange	26.1–37.1
	red	27.3–38.3
	white light (air)	27.2–30.5
	(oil)	21.3–25.2

The wide range in reflectivity values are to be ascribed to its strong bireflection. These reflectance values are in the same general range as those of the germanium mineral reniérite (Lévy and Prouvost, 1957).

Microhardness. A series of quantitative hardness determinations using a Leitz Durimet tester was kindly carried out by Mr. H. Brinkies, School of Metallurgy, University of New South Wales. These gave a range in Vickers Hardness Number (V.H.N.) of 166–210 with a mean of 184. This corresponds to a hardness of $\approx 3\frac{1}{2}$–4 on Moh's scale. This figure agrees well with the polishing hardness of mawsonite for it shows slight positive relief relative to bornite (H = 3).

Etch reactions. Mawsonite is negative to the following etch reagents: 1:1 HNO_3, 1:1 HCl, NaCN, KOH, $HgCl_2$ and $FeCl_3$. However, NaCN produces a very slight darkening of certain mawsonite grains.

Cleavage, density, magnetism. No cleavage is visible on polished surfaces but fractures resulting from hardness indentation tests suggest two imperfect cleavages at approximately right angles. No measurements of density have been possible because of the fine grain size. Mawsonite is magnetic.

CRYSTALLOGRAPHY

X-ray powder photographs of mawsonite from Mt. Lyell have been taken using Co Kα radiation. The sample was obtained by carefully drilling out a small amount of powder from a polished surface. Table 1 lists the d values, intensities and hkl values for all reflections obtained.

The resulting powder pattern can be indexed completely on a cubic, body-centered cell of dimensions $a = 10.74 \pm .01$ Å. Because of its anisotropic properties, however, mawsonite must be regarded as pseudocubic. The lattice is clearly of the sphalerite type with the pattern very similar to that given by Harcourt (1942) for "orange bornite" from Morococha, Peru and by Murdoch (1953) for reniérite from the Prince Leopold mine, Congo and Tsumeb, South West Africa. Murdoch's (1953) indexing of his reniérite pattern is based on a primitive, pseudocubic cell with $a = 10.583$ Å. The close similarity between the powder patterns of mawsonite and reniérite, however, indicate that the two minerals are essentially isostructural.

CHEMICAL COMPOSITION

Dr. J. F. Lovering of the Australian National University, Canberra has kindly carried out electron probe analyses of mawsonite from both Mt. Lyell and Tingha and the results are listed in Table 2.

The Mount Lyell analysis corresponds approximately to the formula $Cu_7Fe_2SnS_{10}$ and, apart from a somewhat lower sulfur content, the Tingha analysis is very similar and yields a formula $Cu_7Fe_2SnS_{9.5}$. An analysis of the associated hexastannite phase from Tingha is also pre-

TABLE 1. X-RAY POWDER DIFFRACTION DATA FOR MAWSONITE, MT. LYELL CoKα RADIATION $\lambda = 1.791$ Å

d (obs.)	I (est.)	hkl
5.37	2	002
4.37	2	112
3.80	1	022
3.34	1	013
3.09	10	222
2.875	2	123
2.680	5	004
2.395	1	024
2.287	1	233
2.185	½	224
2.098	½	015, 134
1.959	½	125
1.895	8	044
1.788	½	006, 244
1.739	½	116, 235
1.618	6	226
1.547	1	444
1.460	½	127, 336, 255
1.343	2	008
1.232	3	266
1.201	½	048
1.065	5	1, 1, 10, 277
1.034	2	2, 2, 10, 666
0.950	2	088
0.908	2	2, 6, 10

TABLE 2. CHEMICAL COMPOSITION OF MAWSONITE

	1	2	3
Cu	44.3	45.0	38.0
Fe	12.5	11.8	11.1
Sn	10.4	11.8	15.6
Zn	—	< 0.1	4.1
S	33.0	30.3	29.2
	100.2	98.9	98.0

1. Mawsonite, North Lyell mine, Mt. Lyell, Tasmania.
2. Mawsonite, Tingha, New South Wales.
3. Hexastannite, Tingha, New South Wales.

All analyses by Dr. J. F. Lovering.

sented in Table 2. Of interest is the zinc content of 4.1%, yielding an approximate formula $Cu_{4.5}(FeZn)_2SnS_7$.

DISCUSSION

The *x*-ray and chemical data presented indicate mawsonite to be the stannian analogue of reniérite. This is borne out by the essentially isostructural relationship between these two minerals, their similarity in optical properties, together with their close correspondence in chemical composition as indicated in Table 3 and Fig. 3.

In both minerals the atomic proportions Cu+Fe+Sn+Zn+Ge: S+As are close to the ratio 1:1 as suggested by the structure type, a complex derivative of sphalerite (Ross, 1957). In Fig. 3, the compositions of all minerals discussed are plotted in terms of the theoretical end-member components CuS, (Fe, Zn)S and (Sn, Ge)S. Their compositional relationships to chalcopyrite and stannite are also shown. This plot is not completely satisfactory because both mawsonite and hexastannite from Tingha and the Kipushi reniérites show a slight sulfur deficiency relative to the ideal metal:sulfur ratio of 1:1. Following Moh (1960), zinc is assumed to occupy the iron structural positions of the lattice and tin the germanium positions. A close chemical similarity between reniérite and mawsonite is indicated by Fig. 3.

TABLE 3. COMPARISON OF COMPOSITIONS OF MAWSONITE AND RENIÉRITE

	1		2		3	
Cu	44.3		45.0		41.0–42.05	
Fe	12.5	22.9	11.8	23.6	13.73–13.84	23.63–25.69
Sn	10.4		11.8		0–0.16	
Zn	—		<0.1		3.53– 3.94	
Ge	—		—		6.37– 7.75	
S	33.0		30.3		31.51–31.69	32.30–32.69
As	—		—		0.79– 1.00	

1. Mawsonite, North Lyell mine, Tasmania.
2. Mawsonite, Royal George mine, Tingha, New South Wales.
3. Range of four chemical analyses of reniérite from the Prince Leopold mine, Congo (Sclar and Geier, 1957).

Mawsonite is clearly distinct from stannite and the other modifications of stannite previously noted by Ramdohr (1960) and by Moh and Otteman (1962). Normal stannite shows tetragonal symmetry and is markedly different in chemical composition and optical properties, hexastannite has a wurtzite-type lattice whereas isostannite is a truly cubic polymorph of stannite showing isotropic optics.

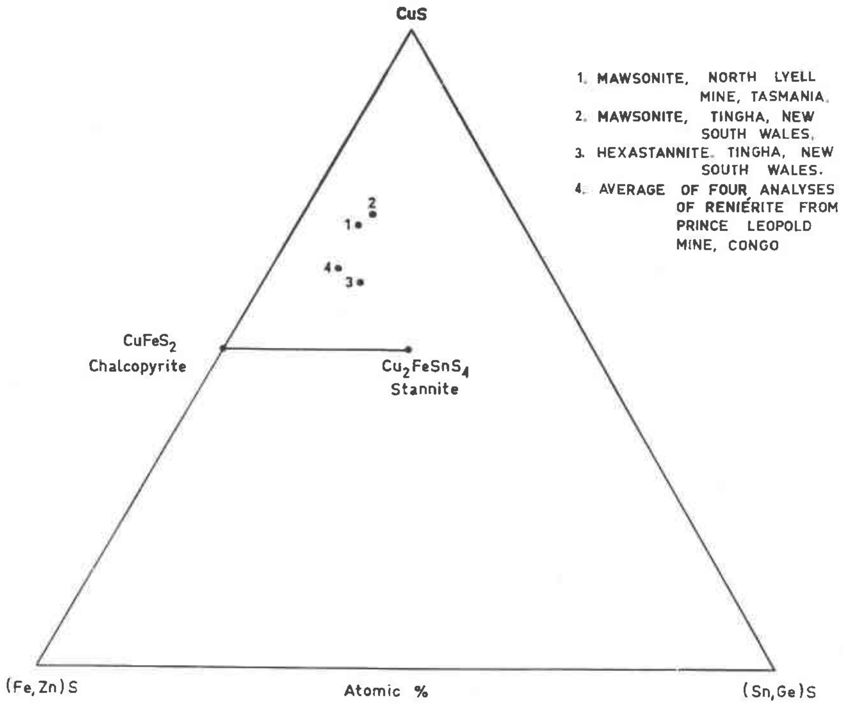


FIG. 3. Composition of mawsonite (1, 2) plotted in relation to reniérite (4), hexastannite (3), stannite and chalcopyrite.

It is concluded that most occurrences of "orange bornite" can be correlated either with the germanium mineral reniérite or the tin analogue mawsonite described in this paper. Mawsonite is to be anticipated, however, in those deposits where the paragenesis includes such tin-bearing minerals as cassiterite, stannite or hexastannite in association with bornite.

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