

Several elements not detected by other methods were found, the most important being the tentative identification of tin in the Chorolque fluid, and the presence of boron in the samples from both the Chorolque and Bostraze tin deposits.

In comparison with the data of Tsui and Holland (1979), the relatively strong response for Cu is notable. They studied material from a variety of moderate temperature vein ores and found extremely low Cu concentrations in the inclusion fluids (< 100 ppm). Some of the quartz sample material used in the study reported here contains solid microinclusions in addition to fluid inclusions, so some degree of contamination is possible. The strong Cu response in our Liruei and Bostraze samples could be partly a result of contamination; however, the other deposits belong to the porphyry class and the fluids had very high temperatures and salinities when trapped. They would have been capable of carrying high Cu concentrations. In the case of the Panguna deposit, Cu values exceeding 2000 ppm have been independently determined in fluid inclusions (Eastoe, 1979), which tends to support the validity of the strong response for Cu observed in the laser experiments.

*Conclusions.* Qualitative laser microprobe analysis is a rapid and simple technique. In fluid inclusion analysis, however, there are several problems, including poor absorption of ruby laser light by transparent host minerals, dilute inclusions, and vapourization of solid microinclusions. In the experiments described here, the best results were obtained on inclusions containing daughter salts.

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## Additional data on sugilite

SUGILITE, a member of the milarite group, was described by Murakami *et al.* (1976) from the Iwagi Islet, Ehime Pref., south-west Japan where it occurs as aggregates of small crystals in an aegirine-syenite associated with pectolite, albite, and aegirine. The violet mineral from the Wessels mine, South Africa, recorded as sogdianite (another member of the milarite group) by Bank *et al.* (1978) and Dillmann (1978), has been shown by Dunn *et al.* (1980) to be a manganoan sugilite. This note records a third

occurrence of this mineral, rather richer in manganese than the material from the Wessels mine with which it is compared. Chemical and X-ray data for both occurrences are presented.

Some years ago Mr E. H. Shackleton, of the former United Steel Companies Ltd., sent a number of manganese mineral specimens to the British Museum (Natural History) for identification. He had picked them out from shipments made to the ore processing plant at Workington in Cumbria,

and as the ore was often a mixture of the produce of several mines, precise localization of the samples has proved difficult. Most of the minerals were identified fairly readily. However, one specimen (BM 1955, 169), a dark red-black ore from the area then known as the Central Provinces of India (now Madhya Pradesh), had scattered across its surface a few rather small, deep pink prismatic crystals which did not, at the time, readily identify with any of the minerals known to occur in the association. It is only comparatively recently that, through X-ray and electron probe studies, the mineral has been found to be a manganooan sugilite. Murakami *et al.* (1976) showed that sugilite has a hexagonal unit cell and they proposed the chemical formulation  $(K,Na)([H_2O],Na)_2(Fe^{3+},Na,Ti,Fe^{2+})_2(Li,Al,Fe^{3+})_3(Si_{12}O_{30})$ .

Four examples of the Wessels mine sugilite are currently represented in the mineral collection at the British Museum (Natural History), BM 1979, 180-2 and BM 1979, 207. Two of the specimens are cut stones and the others contain the mineral in massive form.

**Optical properties.** The Indian sugilite occurs in a massive form and rarely in small anhedral grains of a deep amethystine pink colour on the manganese ore. It is uniaxial negative  $\omega$  1.595,  $\epsilon$  1.590; not dichroic, or if so, only very weakly. In thin section the mineral is pink, anisotropic, with no visible dichroism, but grades into a rather drab light brown colour. Its hardness is 4½. The associated minerals are braunite, a manganese amphibole, and quartz. The properties of the South African sugilite have been described by Dunn *et al.* (1980). Our determination of the refractive indices of this material gave  $\omega$  1.610 and  $\epsilon$  1.606, very close to their figures. Some inclusions of amphibole and a little pectolite were noted with our Wessels mine sugilite.

**Chemical analysis.** Sugilite specimens from both localities were analysed in a Cambridge Instrument Co. Geoscan electron probe microanalyser equipped with an EDAX energy-dispersive system. The standards used in the correction programme were wollastonite (Si), jadeite (Na), orthoclase (K),  $Al_2O_3$ , and pure Fe, Mn, and Ti. The analyses set out in Table I have been supplemented by an atomic absorption determination for lithium and duplicate wet-chemical determinations of iron and manganese. Also shown in Table I is the analysis of type sugilite (3) given in Murakami *et al.* (1976).

The general chemical similarity of the two minerals is immediately apparent; so is the absence of Zr and Ti, both essential if either mineral were to be equated with sodgianite. Based on their substantial contents of iron and lithium and the

absence of quadrivalent metals, there are two minerals in the milarite group to which both samples can be related chemically, namely emeleusite (Upton *et al.*, 1978) and sugilite (Murakami *et al.*, 1976). The X-ray data (following section) rule out emeleusite and point to their identity with sugilite in a manganese-bearing form. The Indian specimen contains the greater concentration of manganese and an  $Al_2O_3$  content very similar to the Japanese type material. Our

TABLE I. *Sugilite: chemical and unit-cell data*

	1	2	3
SiO <sub>2</sub>	70.38	68.22	71.38
TiO <sub>2</sub>	0.19	—	0.51
Al <sub>2</sub> O <sub>3</sub>	2.98	0.48	2.97
Fe <sub>2</sub> O <sub>3</sub>	8.03	13.14	12.76
FeO	—	—	0.19
Mn <sub>2</sub> O <sub>3</sub>	3.61	2.03	—
Li <sub>2</sub> O	2.54	4.10	3.14
Na <sub>2</sub> O	5.29	5.47	4.37
K <sub>2</sub> O	4.53	4.50	3.76
H <sub>2</sub> O	—	—	0.93
Total	97.55	97.94	100.01

  

Recalculated to 30 oxygens			
Si	12.23	11.98	12.15
Ti	0.03	—	0.06
Al	0.61	0.10	0.60
Fe <sup>3+</sup>	1.05	1.74	1.63
Fe <sup>2+</sup>	—	—	0.03
Mn <sup>3+</sup>	0.48	0.27	—
Li	1.78	2.90	2.15
Na	1.78	1.86	1.44
K	1.00	1.01	0.82
H <sub>2</sub> O	—	—	0.92

  

Milarite group site occupancies based on Forbes <i>et al.</i> (1972)			
T(1) Si	12.23	11.98	12.15
T(2) Li	1.78	2.90	2.15
Al	0.61	0.10	0.60
Fe <sup>3+</sup>	0.61	—	0.25
A Fe <sup>3+</sup>	0.44	1.74	1.38
Mn <sup>3+</sup>	0.48	0.27	—
Na	1.05	—	0.53
Ti	0.03	—	0.06
Fe <sup>2+</sup>	—	—	0.03
B Na	0.73	1.86	0.73
H <sub>2</sub> O	—	—	0.92
C K	1.00	1.01	0.82
Na	—	—	0.18
a Å	10.002 ± 7	10.040 ± 5	10.007 ± 2
c Å	13.959 ± 5	14.062 ± 3	14.000 ± 2

- BM 1955, 169. Manganooan sugilite. Central Provinces, India. Average of three analyses by energy-dispersive electron probe microanalysis.
- BM 1979, 180. Manganooan sugilite. Wessels mine, Hotazel, South Africa. Average of four energy-dispersive analyses.
- Sugilite. Iwagi Islet, south-west Japan. Data from Murakami *et al.* (1976).

analysis (2) of the Wessels mine sugilite is very close to that published by Dunn *et al.* (1980) and is reproduced here as it contains a determination of lithium, the major alkali metal in the mineral. The very clean X-ray film we obtained indicated that our material was sufficiently free from inclusions for such a determination to be worthwhile.

The analyses in Table I have been recalculated to 30 oxygens and site allocations made according to Forbes *et al.* (1972). A new study of the crystal chemistry of the milarite group has recently been published by Černý and Hawthorne (1980).

A portion of the  $\text{Fe}^{3+}$  is placed in the  $T(2)$  site to complete its three-atom occupancy, the remainder being allocated to the  $A$  site. In the Japanese and Indian sugilites the iron has to be divided in this way but in the South African specimen the  $T(2)$  site is filled by lithium and aluminium, so all the iron is allocated to the  $A$  site. This allocation results in the Indian sugilite having slightly more manganese than iron in the  $A$  site and also rather high sodium in this position. It is not thought, however, that there is any justification at this stage for introducing a new name into the group on this basis. The slightly low totals for both samples suggest the presence of some water, although Černý and Hawthorne (1980) suggest that molecular water is not an essential constituent of milarite. Our water determinations, obtained using an elemental analyser for the measurement of H, were a little high and have been omitted from the summation. Some organic contamination introduced during the mineral separation and, possibly, incomplete separation of the amphibole from the Indian sugilite are possible explanations.

In view of the earlier confusion between sogdianite and the Wessels mine sugilite we examined a specimen supposed to be sogdianite (BM 1973, 53(a)) from the Alai Range type locality, supplied by Professor A. S. Povarennykh. The white massive appearance of his specimen differs from that described by Dusmatov *et al.* (1968) as violet platy masses and the electron probe analyses (the average of four determinations gave  $\text{K}_2\text{O}$  15.27,  $\text{Na}_2\text{O}$  0.49,  $\text{Al}_2\text{O}_3$  17.02,  $\text{SiO}_2$  60.28%) bear little resemblance to their published analysis of sogdianite. The X-ray powder patterns, though related, do not match. We have not been able to obtain any material fitting the sogdianite description more closely.

*X-ray diffraction study.* The distinction between emeleusite and sugilite can be made through a determination of their respective unit cells.

Emeleusite is reported as orthorhombic (pseudohexagonal) with  $a$  10.073,  $b$  17.350, and  $c$  14.010 Å, while sugilite is hexagonal  $a$  10.007 and  $c$  14.000 Å. We have taken 11.46 cm diameter X-ray powder patterns of both emeleusite and sugilite specimens from their respective type localities and can confirm that, within the general similarity imposed on minerals of the milarite group, the two patterns are distinguishable.

The powder patterns obtained from the Indian and South African specimens match that of type sugilite very closely indeed and have been indexed on the same hexagonal cell with the dimensions given at the foot of Table I. The figures were refined by a graphical high-angle extrapolation method as well as by a least-squares method.

*Conclusion.* There are several minerals, in addition to those already mentioned, which may be included within the milarite group of double-chain silicates. Tuhualite and zektzerite can be included within the orthorhombic (pseudohexagonal) subgroup along with emeleusite. To the hexagonal members may be added osumilite, merrihueite, roedderite, yagiite, brannockite, darapiosite, and armenite. The possibility of further chemical substitutions in the group has been emphasized by Marr and Glasser (1979) in their syntheses of zektzerite and a number of its isotypes. There is therefore a good chance of further examples of manganese-enriched sugilites coming to light.

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