

and thin sections. The reyerite formed the subject of an enquiry by Sir Fred Stewart and I am grateful to him for permission to work on the material, and for providing additional field samples.

### References

- Bell, B. R. (1984) *Scott. J. Geol.* **20**, 73–86.  
 Cann, J. R. (1965) *Mineral. Mag.* **35**, 1–4.  
 Chalmers, R. A., Farmer, V. C., Harker, R. I., Kelly, S., and Taylor, H. F. W. (1964) *Ibid.* **33**, 821–40.  
 Claringbull, G. F. and Hey, M. H. (1952) *Ibid.* **29**, 960–2.

- Clement, S. C. and Ribbe, P. H. (1973) *Am. Mineral.* **58**, 517–22.  
 Heddle, M. F. (1893) *Trans. Geol. Soc. Glasgow*, **9**, 241–55.  
 Merlino, S. (1972) *Nat. Phys. Sci.* **238**, 124–5.  
 — (1988) *Mineral. Mag.* **52**, 247–55.  
 Sweet, J. M. (1961) *Ibid.* **32**, 745–53.  
 Walker, G. P. L. (1971) *West. Commem. Vol.* (Univ. Saugar, India) 181–94.

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## Szaibelyite and fluorborite from the St Dizier Sn-borate skarn deposit, NW Tasmania, Australia

THE rare borate minerals szaibelyite ( $\text{MgBO}_2\text{OH}$ ) and fluorborite ( $\text{Mg}_3\text{BO}_3(\text{F},\text{OH})_3$ ) occur abundantly in a proximal magnesian ore skarn deposit in NW Tasmania, Australia. They have not been reported from Australia before, probably both because the set of geological circumstances necessary for their genesis are rarely met and their identification is difficult. In other areas outside Australia the minerals typically occur where dolomite marbles have been replaced by ore skarn assemblages, or where dolomite-silicate assemblages have been metamorphosed. They have been reported with such minerals as clinohumite (e.g. Minakawa, 1977); vonsenite, nordenskiöldine harkerite, pyroxene, monticellite, etc. (Wang, 1983; Tilley, 1951) and commonly in proximal magnesian Sn skarns (e.g. Alexandrov, 1974, 1975; Wang, 1983; Zhao, 1984; Zhiji, 1984; Shufeng, 1984; Kwak, 1987).

In NW Tasmania the minerals occur within a relatively large ore skarn deposit, the St Dizier deposit, which represents a possible resource of 1.75 million tons of Sn ore averaging 0.75 wt. %  $\text{SnO}_2$ . Additional economic elements include minor amounts of Cu, Zn, W, and rare Be. The deposit occurs within an indented keel-shaped block of country rock marginal to the northern

contact of the Devonian Heemskirk granite batholith, 20 km NW of the town of Zeehan. The keel consists mainly of Precambrian Oonah formation quartzite and dolomite, with minor limestone and graphitic shale. These dip almost vertically and strike normal to the granite's contact. The dolomite, shale, and (to a lesser extent) the limestone have been first altered by contact metamorphism yielding various types of rocks including predazitic marble, andalusite-phengitic hornfels and calc-silicate-bearing marble. Later Fe-Si-Sn-B-Mn-Zn(-etc.)-bearing ore solutions, superimposed upon some of the above marbles, have yielded a complex ore skarn deposit consisting of at least 43 minerals with a large variation of skarn assemblages (Nicholson, 1985, for full descriptions of the deposit).

As in most proximal (near-to-contact) magnesian skarns, there is an early, largely anhydrous assemblage of forsterite-diopsidic pyroxene + magnetite ± cassiterite assemblage with superimposed (a) early F-bearing silicate phases (humite-group minerals) followed by (b) a magnetite-borate phase [magnetite + hulsite + szaibelyite + fluorborite ± Sn-bearing ludwigite ± warwickite(?)], (c) a hydrous 'retrograde' skarn phase (e.g. serpentine + talc + greenalite + tremolite), (d) a

later chlorite-sulphide phase (pyrrhotite, arsenopyrite, sphalerite, chalcopyrite, etc.) and a very late carbonate phase (dolomite + siderite + calcite  $\pm$  fluorite).

The minor calc-silicate marble units have been replaced by grossularitic and very minor goldmanitic (to 26 wt. %  $V_2O_3$ ) garnet, magnetite, diopside-hedenbergite pyroxene, and vesuvianite with overprinted axinite, actinolitic amphibole, epidote, etc. but, of course, no Mg-borates. Nearest the greisenized granitic pluton and granitic dykes, the skarn has been greisenized to a (Fe)-phlogopite-quartz-tourmaline  $\pm$  fluorite assemblage. The magnetite-borate phase occurs spatially in the core of the deposit and contains essentially all the unusual borates and high Sn-values.

Both szaibelyite and fluoborite occur as microcrystalline, haystack-like mats of short fibres, ragged splinters and wisps of grains ( $< 40 \mu\text{m}$  long and  $< 8 \mu\text{m}$  wide) which are often locally aligned. Szaibelyite may extend into carbonate grains (Fig. 1A) and is commonly closely associated with hulsite, magnetite and fluoborite. Sza-

belyite is colourless to pale yellow-brown with moderate relief, birefringence up to mid second order, straight extinction and length-fast orientation (thus it is optically negative). Its occurrence has been confirmed by X-ray and electron microprobe analyses (see next section).

Fluoborite (Fig. 1B) occurrences are similar to szaibelyite; it was first noticed by the unusually high fluorine values in electron microprobe analyses. It occurs as a fine-grained felty mass of colourless to dull grey-brown crystals exhibiting straight extinction, low relief and moderate birefringence. It is commonly found with hulsite, szaibelyite, Sn-bearing ludwigite and magnetite. In some instances it is intergrown with szaibelyite; in others it occurs in a zone nearest a vein and marginal to szaibelyite-rich material, while elsewhere it occurs in fractures in or apparently replacing hulsite. Fluoborite's occurrence is confirmed by electron microprobe and X-ray analysis.

The textural data imply that fluoborite post-dates both szaibelyite and hulsite, with its occurrence commonly being related to permeability (fractures) developed in the ore skarn at this time.

#### Compositions of szaibelyite and fluoborite

The analyses were performed using a JEOL JX5A electron microprobe housed at the Geology Department, the University of Melbourne, Vic. The accelerating voltage was 20 kV, specimen current was 0.02 to 0.03  $\mu\text{A}$  and the beam diameter was 5 to 10  $\mu\text{m}$ . The analysis of the two minerals by the electron microprobe was difficult due to (a) their relative instability under the electron beam and (b) the small size of crystals in relation to the electron beam diameter. Analytical problems associated with these fine grained minerals which commonly occur intergrown with other minerals are well known (e.g. Schaller, 1942). Consequently although the analyses in Table 1 are somewhat low (98-99 wt. % totals), they are probably as accurate as possible under the circumstances.

Although a large number of analyses were carried out, only those having totals near 100%, with low Si and Ca were accepted as being representative. Minor amounts of carbonate were often present and in cases where Ca values were appreciable ( $> 0.5$  wt. %), the totals were often low ( $< 98$  wt. %), implying carbonate impurities. High Si values implied that silicates such as serpentine were present. Another difficulty was the fact that fluorine is difficult to analyse for accurately using the electron microprobe and it was not possible to analyse for boron. In the latter case an ideal calculated  $B_2O_3$  content of between 18.45% (= OH-free fluoborite) and 19.05%

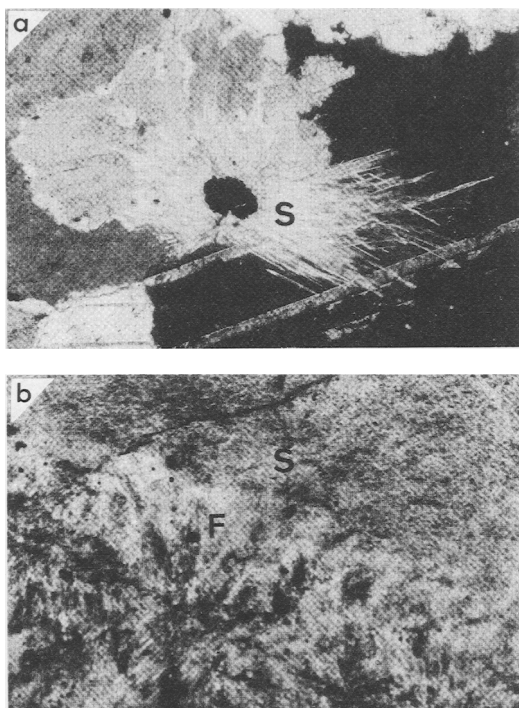


FIG. 1. (a) Photomicrograph of szaibelyite fibres (S) within twinned carbonate (field of view is approx. 0.25 cm wide, crossed nicols). (b) Photomicrograph of intergrown szaibelyite (S) and fluoborite (F) rich areas (field of view is approx. 0.5 cm wide, crossed nicols).

TABLE 1 COMPOSITIONS OF SZAIBELYITE AND FLUORBORITE

	1	2	3	4	5	6	7	8	9
	1.00	2.00	3.00	4.00	5.00	6.00	7.00	8.00	9.00
SiO <sub>2</sub>	-	0.00	0.00	0.00	-	-	0.08	-	0.02
Al <sub>2</sub> O <sub>3</sub>	-	0.33	0.34	0.30	-	-	0.00	-	0.00
FeO	-	3.50	3.39	3.48	-	-	0.83	-	0.88
MnO	-	1.50	1.36	1.02	-	-	0.05	0.57	0.05
MgO	47.92	40.90	41.78	41.09	66.18	64.06	63.12	0.05	62.31
F	-	0.06	0.05	0.12	-	30.21	12.04	62.85	14.68
TOTAL	47.92	46.29	46.92	46.01	66.18	94.27	76.12	77.16	77.92
H <sub>2</sub> O *	10.80	10.80	10.80	10.80	14.77 +	-	10.20	9.85	9.51
B <sub>2</sub> O <sub>3</sub>	41.38	41.38	41.38	41.38	19.05 **	18.45	18.75	18.75	18.75
TOTAL	100.00	98.47	99.10	98.19	-	112.72	105.07	105.76	106.18
F O						100.00	100.00	100.00	100.00
Fe		0.08 }	0.08 }	0.08 }			0.04 }	0.03 }	0.04 }
Mn		0.04 }	0.03 }	0.02 }	2.01		0.00 }	5.79 }	5.73 }
Mg	2.00	1.76 }	1.78 }	1.91 }	3.00	3.00	5.75 }	5.70 }	5.65 }
OH	2.00	2.08	2.06	2.10	6.00	6.00	4.16 }	4.00 }	3.86 }
F							2.33 }	2.64 }	2.83 }
B	2.00	2.06	2.04	2.06	2.00	2.00	1.98 }	1.97 }	1.96 }

\* = calculated from the ideal formula of szaibelyite

1 = ideal szaibelyite formula calculation

5 = ideal fluorborite, OH - end member

6 = ideal fluorborite, F - end member

\*\* = assumed B<sub>2</sub>O<sub>3</sub> wt% (-18.75) for F:OH fluorborite of 1:1

+ = calculation for H<sub>2</sub>O content as follows: Total of ideal F-fluorborite (e.g. 112.72) minus 100 (-12.72) multiplied by the proportion of F weight (e.g. 12.04 analysis 7) over F by weight of ideal F-fluorite (30.21). (e.g.  $12.04 \times 12.72 = 5.06$ ). Thus the H<sub>2</sub>O content is assumed to be 105.06 minus total of all other components including ideal values of B<sub>2</sub>O<sub>3</sub>.

(= F-free fluorborite) was used, depending on the fluorine content. The extrapolation for B<sub>2</sub>O<sub>3</sub> between the two end members was assumed to be linear and a value of 18.75 wt. % B<sub>2</sub>O<sub>3</sub> was used.

As can be seen in Table 1 the analyses are relatively close to 100, and there is measurable FeO and lesser MnO substitution into both minerals. The MnO and Fe contents of fluorborite are quite low but those of szaibelyite are up to 1.50 and 3.50 wt. % respectively. Szaibelyite forms an isomorphous series with sussexite 2(Mn,Mg)O.B<sub>2</sub>O<sub>3</sub>.H<sub>2</sub>O and possibly an as yet unknown mineral, 2FeO.B<sub>2</sub>O<sub>3</sub>.H<sub>2</sub>O, but these have not been found in the deposit.

Fluorborite is essentially pure, with appreciable quantities of F and OH. The minor SiO<sub>2</sub> values recorded may well relate to minor serpentine inclusions or inter-crystal impurities encountered during analysis. SiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> were not included in the formula calculations. This and the low totals may account for the fact that Mg + Mn + Fe is less than 6 per formula unit (5.69-5.79, Table 1). F + OH is generally higher than 6 per formula unit possibly because of the method of H<sub>2</sub>O calculation.

Szaibelyite in B-Sn ore skarn deposits commonly replaces earlier anhydrous borates such as kotoite (Mg<sub>2</sub>B<sub>2</sub>O<sub>6</sub>) and suanite (Mg<sub>2</sub>B<sub>2</sub>O<sub>5</sub>), as has been noted in the Seward Peninsula, Alaska, USA (Alexandrov, 1975). Fluorborite, however, predates rather than post-dates szaibelyite there. At St Dizier a fluorine-rich ('acid' phase; Alexandrov, 1975) period of skarn genesis postdates the

szaibelyite (which Alexandrov, 1975, refers to as late alkaline phase). No kotoite or suanite has been identified at St Dizier but hulsite and, to a lesser extent, ludwigite are extremely common. Texturally, the replacement of these by fluorborite appears to have occurred.

## References

- Alexandrov, S. M. (1974) Geochemistry of B-Sn mineralization in the magnesian skarns of Eastern Chukota. *Geochem. Internat.* **11**, 532-9.
- (1975) Geochemical aspects of B-Sn ore formation in Alaskan deposits. *Ibid.* **12**, 139-50.
- Kwak, T. A. P. (1987) *W-Sn skarn deposits*. Elsevier, p. 466.
- Minakawa, T. (1977) Szaibelyite and clinohumite from Irazuyama, Ehime Prefecture. *Geosci. Mag.* **28**, 51-4 (in Japanese).
- Nicholson, M. (1985) *Aspects of the St. Dizier Creek skarn, N.W. Tasmania*. Unpubl. BSc thesis, La Trobe Univ., p. 74.
- Schaller, W. T. (1942) The identity of ascharite, camselite, and B-ascharite with szaibelyite; and some relations of the magnesium borate minerals. *Am. Mineral.* **27**, 467-86.
- Shufeng, W. (1984) The main characteristics of tin-mineralization of the Dading ore deposits. *International symposium on the geology of tin deposits, Abstracts*, 31-2.
- Tilley, C. E. (1951) The zoned contact-skarns of the Broadford area, Skye: a study of boron-fluorine metasomatism in dolomites. *Mineral. Mag.* **29**, 621-66.

Wang, S. (1983) Some problems concerning geochemistry of the Dading tin-iron ore deposits. *Bull. Inst. Min. Deposits, Chinese Acad. Geol. Sci.* **9**, 72.

Zhao, Y. (1984) The characteristics of volatile components and alkaline metasomatism in main skarn-type iron deposits in China and their role in ore formation. *Geochem.* **3**, 14-23.

Zhiji, R. (1984) Geochemical characteristics of tin-bearing magnetite-skarns. *Ibid.* **3**, 115-27.

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## The crystallography of munitrite, $\text{NaVO}_3 \cdot (2-x)\text{H}_2\text{O}$

RECENTLY in these pages a new vanadium mineral from Pakistan was described by Butt and Mahmood (1983), which they referred to as 'partially dehydrated'  $\text{NaVO}_3 \cdot 2\text{H}_2\text{O}$ , and which they named 'munitrite' (name was approved by the International Commission on New Minerals and Mineral Names). The key defining data offered was a set of X-ray powder data, which they could not identify with any known phase. Butt and Mahmood found that their data fit those of Lukács and Strusievici (1962), given unindexed for synthetic  $\text{NaVO}_3 \cdot 1.9\text{H}_2\text{O}$ . In fact, the X-ray data of Butt and Mahmood match closely those for synthetic  $\text{NaVO}_3 \cdot 1.89\text{H}_2\text{O}$ , for which the crystal structure has been refined with high precision by Björnberg and Hedman (1977). The latter authors found a monoclinic unit cell in space group  $P2_1/a$ , with  $a = 16.756(2)$ ,  $b = 3.6391(3)$ ,  $c = 8.023(a)\text{Å}$ , and  $\beta = 111.18(1)^\circ$ , as measured from Guinier-Hägg powder data (unpublished). The orthorhombic unit cell found by Butt and Mahmood using Ito's method for indexing unknown powder patterns has 2.7 times the volume of the true cell, and there is no apparent relationship between the two cells. A least-squares refinement using the  $d$  spacings of Butt and Mahmood leads to  $a = 16.72(2)$ ,  $b = 3.636(3)$ ,  $c = 8.015(6)\text{Å}$ , and  $\beta = 111.0(1)^\circ$ , in good agreement with Björnberg and Hedman. The  $\sigma(2\theta)$  value for 22 reflections is  $0.072^\circ$  for this calculation.

Butt and Mahmood report a chemical analysis in which the Na/V ratio is close to unity, but the water content corresponds to about  $0.8\text{H}_2\text{O}$  instead of  $2\text{H}_2\text{O}$  or  $1.9\text{H}_2\text{O}$ . Yet the unit cell

volume for their X-ray data is  $455.0(6)\text{Å}^3$ , only slightly smaller than  $456.17(8)\text{Å}^3$  found by Björnberg and Hedman. As this difference corresponds to about  $0.05\text{H}_2\text{O}$ , it is apparent that the sample analysed by Butt and Mahmood was not pure. None of the prominent reflections for  $\alpha\text{-NaVO}_3$  or  $\beta\text{-NaVO}_3$  (Morris *et al.*, 1981) correspond to those given for munitrite.

A set of powder data attributed to Björnberg are recorded on Card No. 32-1201 of the JCPDS Powder Data Files, which, together with powder data calculated from the crystal structure, establishes the identity of the compound studied by Björnberg and Hedman (1977) and munitrite. In this laboratory, powder data for synthetic  $\text{NaVO}_3 \cdot 1.9\text{H}_2\text{O}$  have been obtained by the Guinier-Hägg method. These data are listed in Table 1, along with those of Butt and Mahmood (1983), Lukács and Strusievici (1962), and the JCPDS data for comparison. Least-squares refinement of the unit cell parameters based on the data obtained in this laboratory (Table 1) led to values in close agreement with those of Björnberg and Hedman. Some recrystallized preparations have been found to give X-ray patterns of inferior quality with some lines broadened or missing, presumably because of partial loss of water from the structure. It is not known how much water can be lost while the structure is retained. It is best to define the composition of munitrite as  $\text{NaVO}_3 \cdot (2-x)\text{H}_2\text{O}$ , where  $x$  may vary from 0 to about 0.2.

The structure consists of a monoclinic arrangement of metavanadate  $(\text{VO}_3)_n$  chains whose ele-