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## An occurrence of bavenite, $\text{Ca}_4\text{Be}_2\text{Al}_2(\text{SiO}_3)_9 \cdot x\text{H}_2\text{O}$ , in Thailand

BAVENITE is a rare beryllium mineral reported as a constituent of pegmatitic druses in granitic rocks (Claringbull, 1940; Raade, 1968), often in association with or replacing beryl (Neumann and Sverdrup, 1959; Schaller and Fairchild, 1932). The purpose of this note is to report the first occurrence of bavenite to be recognized in Thailand.

The bavenite occurs as large white crystals with a platy habit, up to 1 mm in thickness and 50 mm in length and breadth, within a skarn at the shallowly dipping contact between granite and calcareous sediments at Doi Mok scheelite mine, Wiang Pa Pao, north Thailand (Times Atlas of the World, 4th edn.). The geology of the mine has been described by Suensilpong and Jungyusuk (1981); only essential features will be repeated here. The bavenite-bearing skarn forms the top of a small hill separated from more extensive hills by a deep fault gulley and marble cliffs. Gradation from the skarn into the country rocks is consequently not seen because of the faulting, but the skarn-granite contact is well exposed in mine workings.

The mineralogy of the skarn and immediately adjacent granite is complex. In thin section, the bavenite occurs as euhedral laths with rectangular cross-sections, showing moderately high relief ( $\alpha = 1.586$ ;  $\beta = \gamma = 1.590$ ; Switzer and Reichen, 1960) and set in massive hydrogrossular and interstitial calcite. Individual crystals of bavenite are fractured and cemented by calcite. Epidote occurs as needles within calcite, and scheelite is present. Although

not observed in the bavenite-bearing material, idocrase, chlorite, plagioclase, diopside, and quartz are also reported to be present within the skarn (Suensilpong and Jungyusuk, 1981).

Two facies of granite are exposed in the mine workings: an early biotite granite, which is cut by veins of a later tourmaline leucogranite. Both varieties show varying degrees of hydrothermal alteration in irregularly spaced zones cut by the mine levels. Where the alteration is relatively slight, sericitization of both alkali feldspar and plagioclase is observed, and biotite (if present) is altered to chlorite containing needles of rutile. The tourmaline leucogranite shows recrystallization of tourmaline as small needles as well as sericitization of the feldspars. Both granite varieties show more severe effects of alteration within approximately 10 m of the contact, where calcite and fluorite occur as cross-cutting veins and as matrix to altered silicate minerals (which include sericitic pseudomorphs after feldspar). In this contact zone the rutile inclusions within chlorite pseudomorphs after biotite are replaced by sphene. The presence of sphene, and calcite veining, is also observed in alteration zones further from the contact; these may not be far below the roof of the granite.

Standard X-ray diffraction methods (scanning goniometer, with Al as an internal standard and monochromator-resolved  $\text{Cu-K}\alpha_1$  radiation) were used to characterize the bavenite from Doi Mok. The orthorhombic cell parameters are:  $a = 9.72$

TABLE I. Powder diffraction data for bavenite from Doi Mok, Thailand

<i>I</i>	<i>h k l</i>	<i>d</i> <sub>calc.</sub>	<i>d</i> <sub>obs.</sub>	<i>d</i> <sub>JCPDS</sub>	<i>I</i>	<i>h k l</i>	<i>d</i> <sub>calc.</sub>	<i>d</i> <sub>obs.</sub>	<i>d</i> <sub>JCPDS</sub>
10	0 1 0	11.651	11.6	11.6	30	0 1 2	2.416	2.416	2.42
5	1 0 0	9.720	9.7	9.83	10	4 1 0	2.379	2.378	2.37
10	1 1 0	7.464	7.44	7.44	30	0 2 2	2.273	2.292	2.29
10	1 2 0	4.997	4.97	4.98	20	1 5 0	2.266	2.256	2.29
80	2 0 0	4.860	4.86	4.85	10	2 4 1	2.229	2.228	2.23
5	1 0 1	4.402	4.39	4.35	5	4 1 1	2.143	2.151	2.16
35	1 1 1	4.118	4.20	4.21	15	{ 0 5 1	2.107 }	2.102	2.09
15	0 3 0	3.884	3.86	3.85		{ 2 5 0	2.101 }		
80	2 2 0	3.732	3.72	3.71	20	0 3 2	2.084	2.074	2.09
45	2 0 1	3.463	3.40	3.40	25	3 4 1	1.984	1.978	1.97
100	2 1 1	3.320	3.35	3.35	85	5 0 0	1.944	1.943	1.95
100	3 0 0	3.240	3.23	3.22	10	5 1 0	1.917	1.916	
80	3 1 0	3.122	3.118	3.12	15	4 4 0	1.866	1.872	1.87
55	0 3 1	3.052	3.040	3.03	20	5 0 1	1.809	1.823	1.82
35	2 3 0	3.034	3.030	3.03	20	3 5 1	1.767	1.765	
20	3 2 0	2.832	2.827	2.83		{ 4 0 2	1.732 }	1.737	
5	1 4 0	2.790	2.787	2.79	45	{ 5 3 0	1.738 }		
5	3 0 1	2.709	2.736	2.73		{ 5 2 1	1.727 }		
5	3 1 1	2.638	2.660	2.65	10	4 5 0	1.682	1.677	
40	2 3 1	2.585	2.584	2.56	20	4 2 2	1.660	1.660	
15	3 3 0	2.488	2.488	2.48	5	0 1 3	1.630	1.635	
45	{ 4 0 0	2.430 }	2.428	2.42	45	6 0 0	1.620	1.619	
	{ 1 4 1	2.429 }							

*d*<sub>calc.</sub> is *d* spacing calculated using *a* = 9.72, *b* = 11.65, *c* = 4.94 Å. *d*<sub>JCPDS</sub> is *d* spacing given in JCPDS powder diffraction file 13-535. Cu-Kα<sub>1</sub> radiation, λ = 1.54051 Å.

± 0.01 Å, *b* = 11.65 ± 0.02 Å, *c* = 4.94 ± 0.01 Å, *V* = 559.1 ± 1.2 Å<sup>3</sup>. A full list of the reflections obtained and their *d*-spacings is given in Table I. These data represent an improvement on those given in earlier descriptions of bavenite (Fleischer and Switzer, 1953; Switzer and Reichen, 1960), which were used to compile the JCPDS reference file, in that some indices have been corrected and newly observed reflections indexed. However, until the structure is more precisely determined, perhaps by a single crystal X-ray study, the data in Table I should be regarded as provisional.

A partial chemical analysis of the bavenite has been determined by energy-dispersive electron microprobe analysis, and is given in Table II. Be and H could not be determined; the electron beam current was adjusted to give a total of 100% on an albite standard, and so the analysis gives an appropriate total. The analysis is very similar to that given by Switzer and Reichen (1960), also presented in Table II, and is consistent with the general formula H<sub>n</sub>Ca<sub>4</sub>Be<sub>2+n</sub>Al<sub>2-n</sub>(SiO<sub>3</sub>)<sub>9</sub> · xH<sub>2</sub>O. There is no evidence, from the Ca : Al : Si ratio, that any substitution of Be + H for Al has taken place, and so the formula for the Doi Mok bavenite may be simplified to Ca<sub>4</sub>Be<sub>2</sub>Al<sub>2</sub>(SiO<sub>3</sub>)<sub>9</sub> · xH<sub>2</sub>O.

There are two features in particular that make the Thai bavenite occurrence unusual. First, this is possibly the first recording of bavenite from a skarn—most descriptions in the western literature

TABLE II. Analyses of bavenite

	1	2
CaO	23.44	23.95
BeO	5.52	n.d.
Al <sub>2</sub> O <sub>3</sub>	9.62	10.52
SiO <sub>2</sub>	57.04	57.35
H <sub>2</sub> O <sup>+</sup>	2.86	n.d.
H <sub>2</sub> O <sup>-</sup>	0.14	n.d.
Total	98.62	91.82
	27(O)	25(O)
Ca	4.001	4.036
Be	2.113	n.d.
Al	1.826	1.950
Si	9.088	9.020

(1) Taken from Switzer and Reichen (1960). (2) Partial electron microprobe analysis of bavenite from Doi Mok.

are of bavenite occurrences from pegmatitic vugs within granitic rocks. Secondly, the material from Doi Mok occurs as remarkably large crystals, many times the size of those described previously. It is quite possible that other similar occurrences of bavenite may be found, as it is relatively easy on cursory examination to confuse the large crystals of bavenite with, for example, wollastonite. Furthermore, the reported association of bavenite with beryl and other beryllium minerals suggests that these may also occur at Doi Mok; however, they have not yet been recorded.

The origin of the bavenite at Doi Mok lies in the evidently extensive, possibly multistage, chemical exchange between the granite and the calcareous country rocks during the formation of the skarn. Some of this exchange may post-date the consolidation of both the biotite granite and the tourmaline leucogranite as both are altered in a complementary fashion. The chemical changes probably involve: addition of Ca to the granite (to give calcite, fluorite, sphene); addition of Be (at least) to the country rock (bavenite); and addition of F and W, along the contact zone in particular (fluorite, scheelite). This alteration may be related to the continued crystallization of granite magma, with exsolution of a hydrous fluid phase as the transporting agent, at deeper levels than those exposed in the vicinity of the mine, in addition to subsequent hydrothermal activity.

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## Primary scapolite from the Forland complex of Prins Karls Forland, Svalbard

PRINS KARLS FORLAND, Svalbard, consists largely of pre-Carboniferous rocks forming the Forland complex (Harland *et al.*, 1979) which have been subjected to Caledonian (S<sub>1</sub>) deformation and metamorphism. Detailed accounts of the stratigraphy, structure, and metamorphism of the Forland complex are given by Harland *et al.* (1979), Manby (1978), and Morris (1979). This paper

describes for the first time the occurrence of scapolite in the Pinkie Group of the Forland complex. Based on textural and mineralogical evidence Manby (1978) and Morris (1979) show that metamorphism was initiated prior to, and continued with the main penetrative D<sub>1</sub> deformation. Metamorphism was of greenschist-facies grade and D<sub>1</sub> deformation produced a large scale SW-verging