Takedaite, a new mineral from Fuka, Okayama Prefecture, Japan

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Abstract

Takedaite, $Ca_3B_2O_6$, has been found in crystalline limestone near gehlenite–spurrite skarns at Fuka, Okayama Prefecture. It occurs as aggregates of granular crystals up to 0.8 mm long and 0.3 mm wide. The mineral is associated with nifontovite, olshanskyite, pentahydroborite, frolovite, sibirskite, calcite and an unidentified mineral, is white or pale gray, and has a vitreous luster. Takedaite is trigonal with space group of $R\bar{3}c$, $a = 8.638(1)$, $c = 11.850(2)$Å, $Z = 6$. The strongest lines in the X-ray powder pattern [d in Å (I) (hkl)] are 2.915(100) (113), 1.895(75)(223), 2.756(61)(104), 2.493(44)(300), 2.044(21) (214,131), 2.160(19)(220), 1.976(18)(006), 1.549(12)(306). The Vickers microhardness is 478 kg mm^{-2} and the Mohs hardness 4.5. The density is 3.10(2) g cm^{-3} (meas.) and 3.11 g cm^{-3} (calc.). Wet chemical analyses give the values CaO 71.13%, B_2O_3 28.41%, ig. loss 0.14%, and total 99.68%. The empirical formula calculated on the basis of O = 6 is $Ca_{3.053}B_{1.965}O_6$, with the simplified formula of $Ca_3B_2O_6$.

KEYWORDS: takedaite, new mineral, borate, Fuka, Japan.

Introduction

DURING a mineralogical survey of the gehlenite–spurrite skarns at Fuka, Okayama Prefecture, Japan, Kusachi and Henmi (1994) reported the occurrence of an unidentified anhydrous borate mineral closely associated with nifontovite, olshanskyite and calcite. Subsequent study has proved the mineral to be a natural analogue of synthetic $Ca_3B_2O_6$ reported by Schäfer (1968), Fletcher et al. (1970), Suzuki and Hira (1970), Tulgar (1972), Majling et al. (1974), etc.

Orthoborates with the general formula of $M_3B_2O_6$ (M = Ca, Sr, Ni, Mg, Mn, Ba, Cd ,Co, etc.) have been synthesized as an interesting subject of study by many workers (e.g. Weir and Schroeder, 1964; van der Voort et al., 1992). Among this borate group, to date only $Mg_3B_2O_6$ and $Mn_3B_2O_6$ have been identified in nature, namely kotoite (Watanabe, 1939) and jimboite (Watanabe et al., 1963), respectively. $Ca_3B_2O_6$ is therefore the third.

The new mineral has been named takedaite, after Prof. Hiroshi Takeda (1934–), Mineralogical Institute, Faculty of Science, The University of Tokyo, in recognition of his outstanding contributions to the field of mineralogy. The mineral species and its name have been approved by the Commission on New Minerals and Mineral Names, International Mineralogical Association. The type mineral of takedaite is deposited at the National Science Museum, Tokyo, Japan.

The present paper deals with the mineralogical properties and mode of occurrence of takedaite.

TABLE 1. Optical and physical properties of takedaite

	1	2
ω	1.726	1.698*
ε	1.630	1.657*
$\omega - \varepsilon$	0.096	0.041
Sign	uniaxial negative	uniaxial* negative
$D_{obs.}$	3.10	3.10[†]
$D_{calc.}$	3.12	3.09[†]
VHN_{25}	478	—
MHN	4.5	—

1. Fuka, Okayama Prefecture, Japan. The present work.
2. Synthetic $Ca_3B_2O_6$.
* After Suzuki and Hira (1970),
[†] After Majling *et al.* (1974).

Occurrence

Takedaite was found at Fuka, Okayama Prefecture. In this area, many skarn minerals occur such as gehlenite, spurrite, bicchulite (Henmi *et al.*, 1973), rankinite, kilchoanite (Henmi *et al.*, 1975), fukalite (Henmi *et al.*, 1977), oyelite (Kusachi *et al.*, 1984), etc.

A vein consisting of borate minerals developed along the boundary between crystalline limestone and the skarns. The vein was approximately 10 cm in thickness, although in one part expanded to 2 m. At the centre of the expanded area, almost 3 m in length, takedaite occurred as aggregates of granular crystals up to 0.8 mm long and 0.3 mm wide, in association with frolovite, calcite and an, as yet, unidentified mineral. At the circumference of the expanded area, hydrous borates such as nifontovite, olshanskyite (Kusachi and Henmi, 1994), sibirskite and penta-hydroborite occurred 20 cm to 50 cm in thickness.

Physical and optical properties

Takedaite was white or pale gray with a vitreous luster in hand specimen, and colourless in thin-section. Optically, the mineral was uniaxial negative with refractive indices $\omega = 1.726$, $\varepsilon = 1.630$, and the Vickers microhardness was 478(429−503) kg mm^{-2} (25 g load). The density measured by heavy liquids was 3.10(2) g cm^{-3}, the calculated density being 3.11 g cm^{-3}. In Table 1, the properties are compared with those of synthetic $Ca_3B_2O_6$ reported by Suzuki and Hira (1970), and Majling *et al.* (1974). The value of the birefringence of takedaite was larger than that of synthetic $Ca_3B_2O_6$. The other properties, however, closely resembled each other.

The infrared absorption spectrum of takedaite was measured by the KBr method for the region 4000 to 250 cm^{-1}, as shown in Fig. 1. The absorption bands at 907, 795, 710 and 618 cm^{-1} were in close agreement with those of synthetic $3CaO \cdot B_2O_3$ reported by Weir and Schroeder (1964). The absorption bands at 1275 and 1230 cm^{-1} for takedaite, however, were sharper.
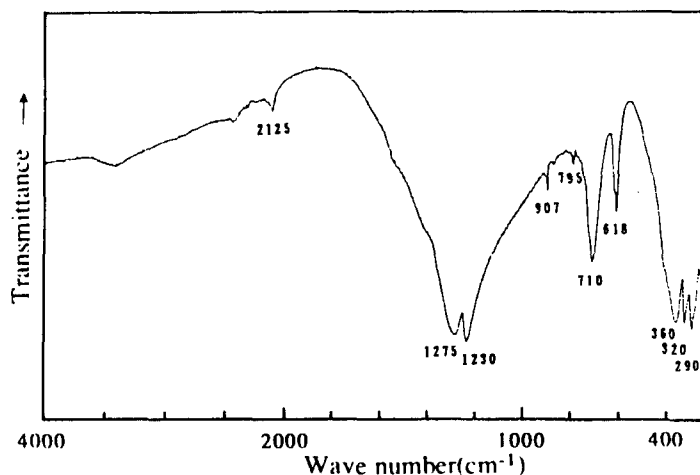

FIG. 1. Infrared absorption spectra of takedaite.

TABLE 2. X-ray powder data for takedaite

1						2		3	
I	$d_{obs.}$	$d_{calc.}$	h	k	l	I	d	I	d
10	4.645	4.6446	0	1	2	5	4.64	15	4.643
7	4.320	4.3190	1	1	0	5	4.32	15	4.316
		3.1629	2	0	2	<5	3.16		
100	2.915	2.9148	1	1	3	100	2.912	100	2.916
61	2.756	2.7544	1	0	4	30	2.754	65	2.756
4	2.551	2.5518	1	2	2			1	2.553
44	2.493	2.4936	3	0	0	30	2.491	50	2.493
19	2.160	2.1595	2	2	0	20	2.159	25	2.1596
		2.0454	2	1	4	20	2.044	25	2.0444
21	2.044 {	2.0437	1	3	1				
18	1.976	1.9750	0	0	6	40	1.976	20	1.9770
5	1.958	1.9582	3	1	2	<5b	1.957	10	1.9580
75	1.895	1.8948	2	2	3	90	1.893	90	1.8949
7	1.817	1.8163	1	2	5	10	1.817	10	1.8169
6	1.796	1.7961	1	1	6	10	1.797	10	1.7968
		1.6994	1	3	4	10	1.699	7	1.6987
5	1.698 {	1.6985	3	2	1				
5	1.648	1.6484	2	3	2	20	1.648	5	1.6480
3	1.633	1.6324	4	1	0	<5b	1.632	3	1.6329
		1.5814	4	0	4	<5	1. 581		
12	1.549	1.5482	3	0	6	20	1.548	20	1.5489
10	1.509	1.5087	4	1	3	10	1.508		
4	1.485	1.4850	3	2	4	<5	1.484	20	1.4854
		1.4681	0	4	5	<5	1.467		
5	1.457	1.4574	2	2	6			7	1.4575
4	1.440	1.4397	3	3	0	5	1.439	5	1.4396
a (Å) =		8.638(1)					8.631(3)		8.640(1)
c (Å) =		11.850(2)					11.855(4)		11.854(1)

1. Takedaite from Fuka, Okayama Prefecture, Japan. The present work.
2. Synthetic $Ca_3B_2O_6$. After Schäfer (1968).
3. Synthetic $Ca_3B_2O_6$. After Majling et al. (1974).

Chemical composition

Chemical analysis using an electron microprobe and Ion Micro Analyzer revealed the presence of Ca, B and O, and the absence of any other element. The concentration of Ca and B were determined by wet-chemical analyses, and the H_2O content was determined by ignition loss at 900°C. Chemical analysis gave CaO 71.13%, B_2O_3 28.41%, ig. loss 0.14% and total 99.68%. The empirical formula calculated on the basis of O = 6 is therefore $Ca_{3.053}B_{1.965}O_6$, which gave the ideal formula $Ca_3B_2O_6$. Takedaite was also easily soluble in dilute hydrochloric acid.

X-ray studies

The X-ray powder data for takedaite was obtained by an X-ray diffractometer using Ni-filtered Cu-$K\alpha$ radiation. Single crystals were also studied using the precession and Weissenberg methods. The diffraction photographs showed takedaite to be trigonal with the possible space group of $R\bar{3}c$ or $R3c$. The unit cell dimensions, refined by least

squares from the X-ray powder diffraction data of takedaite, were $a = 8.638(1)$ and $c = 11.850(2)$Å. The X-ray powder data are given in Table 2, and compared with that of synthetic $Ca_3B_2O_6$ reported by Schäfer (1968) and Majling *et al.*(1974).

Discussion

Orthoborates, with the general formula of $M_3B_2O_6$, have been structurally classified into two groups, i.e. trigonal and orthorhombic. The trigonal group, containing takedaite, consists of Ca-, Sr- and Ba-members. The orthorhombic group consists of Mn-, Mg-, Co-, Ni- and Cd- members. Large cations in the eight-fold M site of $M_3B_2O_6$ appear to favour the forming of a trigonal structure.

The present X-ray studies show that takedaite is trigonal with the possible space group of $R\bar{3}c$ or $R3c$. Schuckmann (1969), Vegas *et al.* (1975) and Vegas (1985) determined that the structure of synthetic $Ca_3B_2O_6$ is $R\bar{3}c$, and so the space group of takedaite is likely to be $R\bar{3}c$.

Schäfer (1968) synthesized the single crystals of $Ca_3B_2O_6$ from $Ca(OH)_2$ and H_3BO_3 at temperatures between 220 and 300°C under saturated water pressure. In view of his experimental result, takedaite from Fuka would therefore appear to be formed at a temperature around 250°C.

A borate vein containing takedaite occurs along the boundary between crystalline limestone and skarns. Takedaite was found at the centre of an expanded area in the borate vein. The crystals of takedaite have partially altered to frolovite and an unidentified mineral by a post-hydrothermal solution. Hydrous borates such as nifontovite, olshanskyite, pentahydroborite and sibirskite occur at the circumference of the expanded area, and appear to be formed by the hydration of takedaite. From the modes of occurrence, it is very likely that takedaite from Fuka was primarily formed by a reaction of boron-bearing fluids with limestone.

Acknowledgements

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