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Fukalite, a new calcium carbonate silicate hydrate mineral*

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ABSTRACT

Fukalite occurs in spurrite-gehlenite skarns at Fuka, and Mihara, Okayama Prefecture, and at Kushiro, Hiroshima Prefecture. It is an alteration product of spurrite and is associated with calcite and/or xonotlite. It is found as pale brown to white crystals up to 0.2 mm long.

The crystals are orthorhombic a 5.48(1), b 3.78(1), c 23.42(3) Å, $Z=2$. They are optically biaxial, 2V about 90°, refractive indices α 1.595, β 1.605, γ 1.626 for the Fuka materials, elongation negative. The wet chemical analyses give an ideal formula $Ca_4Si_2O_6(OH)_2(CO_3)$. The density is 2.770 g/cm^3 (observed) and 2.77 g/cm^3 (calculated). The strong lines of the X-ray powder pattern are 2.854, 3.084, 2.926, 2.388, 1.756 and 5.86 Å.

The mineral is named after the first locality, Fuka, Okayama Prefecture, Japan.

Introduction

Three localities of gehlenite-spurrite skarns are known in the district of Chugoku, Japan. Two of them, Fuka and Mihara, are in

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Okayama Prefecture, and the other, Kushiro, is in Hiroshima Prefecture.

There were found various rare minerals, among which gehlenite, hydrogrossular (K. Henmi *et al.*, 1971), spurrite, tilleyite (Kusachi *et al.*, 1971a), foshagite, hillebrandite, scawtite (Kusachi *et al.*, 1971b), xonotlite (Kusachi, 1972), bicchulite (C. Henmi *et al.*, 1973), rankinite, kilchoanite (K. Henmi *et al.*, 1975), cuspidine (Kusachi *et al.*, 1977) and some others (K. Henmi *et al.*, 1976) were described already.

The present paper deals with fukalite, a new mineral with the composition approximated by the formula $Ca_4Si_2O_6(OH)_2(CO_3)$, from the three localities. As calcium carbonate silicate hydrates only scawtite, $Ca_7(CO_3)(Si_6O_{18})\cdot 2H_2O$, had been known. Fukalite was found as an additional phase of them.

The species and name have been approved by the Commission on New Minerals and Mineral Names, IMA.

Occurrences

Fukalite was first found at Fuka where skarn minerals such as spurrite, gehlenite, perovskite and rankinite were formed as pyrometasomatic products of limestone. The skarns contain various amounts of retrograde minerals such as tilleyite, kilchoanite, bicchulite and others. Fukalite occurs as one of the retrograde minerals of spurrite.

At Fuka, aggregates of spurrite are sometimes surrounded by fukalite-containing aggregates up to 20 cm wide. The following zonal arrangement was observed between spurrite zone and fluorite-bearing zones. Each zone is 2 cm or more in width and contains small amounts of gehlenite, idocrase, grossular and sometimes perovskite.

spurrite zone
fukalite - scawtite zone
fukalite zone
xonotlite - calcite zone
wollastonite - calcite - fluorite (- prehnite) zone

fluorite - quartz zone

The fukalite zone is mainly composed of flaky crystals of fukalite up to 0.2 mm long with minor amounts of calcite and xonotlite, and cuspidine is frequently scattered in spots. Fukalite is also found in some hillebrandite veinlets.

At Kushiro and Mihara, fukalite is found also as an alteration product in gehlenite-spurrite skarns. In these localities the mineral assemblages are nearly the same as those at Fuka, except that monticellite is found with fukalite at Kushiro. The mineral assemblages at the three localities are compared in Table 1.

Table 1. Minerals coexisting with fukalite.

	Fuka	Mihara	Kushiro
minerals mixed with fukalite			
cuspidine	○	○	
xonotlite	○	○	○
calcite	○	○	○
minerals occurring in vicinities of fukalite			
spurrite	○		○
hillebrandite	○		
scawtite	○	○	○
foshagite	○		
wollastonite	○		○
fluorite	○		
gehlenite	○	○	○
perovskite	○		
grossular	○	○	○
hydrogrossular	○	○	
idocrase	○	○	○
monticellite			○

Physical properties

The color of fukalite is white to pale brown. The Mohs hardness of aggregate is about 4. The density measured by pycnometer is 2.770±0.005 g/cm^3 and that calculated is 2.77 g/cm^3. Under the microscope the mineral is colorless and is optically biaxial, 2V about 90°, and optic sign could not be determined. Refractive indices of fukalite from the type locality are α 1.59_5, β 1.60_5, γ 1.62_6, and from Mihara are α 1.59_2, β 1.60_6, γ 162_9. Although under the microscope fukalite looks like muscovite in shape and retardation, fukalite is easily distinguished from muscovite by its negative elongation.

Chemical analyses

The chemical compositions of fukalite from Fuka and Mihara were determined by wet chemical analysis and are given in Table 2. On the basis of $O+OH+F=11$, the analyses yield the formulae $(Ca_{3.97}Mg_{0.01}Fe_{0.01}Na_{0.02})_{4.01}(Si_{1.98}Al_{0.04})_{2.02}O_{6.03}(OH_{2.02}F_{0.07})_{2.09}(CO_3)_{0.96}$ for

Table 2. Chemical analyses of fukalite.

weight percent			numbers of ions on the basis of $O+OH+F=11$				
	Fuka	Mihara		Fuka		Mihara	
SiO_2	29.09	28.98	Si	1.982	2.026	1.990	2.011
TiO_2	0.00	0.00					
Al_2O_3	0.55	0.27	Al	0.044		0.021	
Fe_2O_3	0.10	0.14	Fe	0.005	4.013	0.007	4.051
MnO	0.00	0.00					
MgO	0.14	0.02	Mg	0.014		0.002	
CaO	54.40	54.81	Ca	3.971		4.033	
Na_2O	0.17	0.05	Na	0.022		0.007	
K_2O	0.01	0.02	K	0.001		0.002	
$H_2O(+)$	4.45	4.26	OH	2.022	2.091	1.951	2.044
$H_2O(-)$	0.23	0.39					
P_2O_5	0.01	0.07					
F	0.32	0.43	F	0.069		0.093	
CO_2	10.32	10.22	CO_3	0.960		0.958	
$-O=F_2$	−0.13	−0.18					
Total	99.66	99.38					

the Fuka material, and $(Ca_{4.03}Mg_{0.00}Fe_{0.01}Na_{0.01})_{4.05}(Si_{1.99}Al_{0.02})_{2.01}O_{6.08}(OH_{1.95}F_{0.09})_{2.04}(CO_3)_{0.96}$ for the Mihara material. The analyses compare well with the ideal composition $Ca_4Si_2O_6(OH)_2(CO_3)$. Although small amounts of calcite and xonotlite are present in the analyzed materials, influences of these two minerals on compositions are compensative each other, and the resulting compositions are near to that of pure fukalite. Observed density (2.770) agrees well with the density (2.77) calculated from this formula. Fukalite is decomposed by acids with effervescence.

X-ray studies

Weissenberg and precession photographs showed that fukalite is orthorhombic and its diffraction symbol is *mmmB--b*, which allows the following space groups as possibilities; $Bm2_1b$, *Bmmb* and *B2mb*.

The cell dimensions for the Fuka material refined by the indexed powder pattern are a 5.48±0.01, b 3.78±0.01, c 23.42±0.03 Å and $Z=2$. The X-ray powder patterns of this mineral from the three localities are shown in Table 3. The specimens contain small amounts of calcite and xonotlite.

Thermal properties

X-ray diffraction patterns of fukalite on heating in the atmosphere show that decarbonation and dehydration occur almost simultaneously at about 600°C and larnite is formed.

The hydrothermal behavior of fukalite and related minerals is shown in Table 4. At 1 kb water pressure, fukalite does not change at the temperatures lower than 500°C and decomposes to a mixture of calcite, foshagite and dellaite above 550°C. This change was irreversible in an experiment (No. 6). The attempts to synthesize fukalite were unsuccessful.

Table 3. X-ray powder data for fukalite.

Fuka		Kushiro		Mihara		calculated*		impurities
d	*I*	*d*	*I*	*d*	*I*	*hkl*	*d*	
7.02	15	6.99	30					xon
5.86	25	5.82	40			004	5.855	
4.26	5	4.26	13					xon
3.904	20	3.899	20	3.910	6	006	3.903	
3.598	20b	3.610	20b	3.594	13b	012	3.597	+xon
3.256	20	3.243	30					xon
3.187	15	3.178	15	3.175	25	014	3.176	
3.084	90	3.083	80	3.081	100	111	3.084	+xon
3.033	60	3.020	20	2.029	30			cal
2.926	65	2.923	50	2.927	25	008	2.028	
2.888	10			2.887	25	113	2.890	
2.854	100	2.850	100	2.854	90	107	2.856	
2.733	20b	2.722	30b	2.718	30b	200	2.740	
		2.693	50			016	2.715	+xon
2.592	10b	2.587	13b	2.595	13	115	2.592	+xon
2.481	15	2.485	20	2.486	20	204	2.482	
2.338	30	2.338	30	2.339	13	0.0.10	2.342	
2.314	20	2.310	13	2.314	13	018	2.315	
2.278	8			2.283	6	117	2.278	+cal
2.094	10			2.101	6			cal
2.075	13	2.069	13	2.071	13	214	2.075	
1.996	10b	1.993	10b	1.999	6b	208	2.001	
						119	1.996	
						0.1.10	1.991	
1.948	10b	1.949	13b	1.956	6	0.0.12	1.952	+xon
1.927	10	1.923	6	1.929	13	216	1.929	
1.889	15	1.891	13	1.888	13	020	1.890	
1.756	30b	1.756	30b	1.756	30b	1.1.11	1.757	
						+		

xon : xonotlite, cal : calcite.

* calculated from *a* 5.48, *b* 3.78, *c* 23.42 Å.

Table 4. The results of hydrothermal treatments at 1 kb water pressure.

No.	Starting Materials	Temp. °C	Duration days	Products
1	Fuk*	350	7	Fuk
2	〃	450	8	Fuk
3	〃	500	5	Fuk
4	〃	550	9	Cal+Fos+Del
5	〃	600	4	Cal+Fos+Del
6	Cal+Fos+Del (product of No. 4)	450	8	Cal+Fos+Del
7	2Spu*+SiO_2	350	5	Cal+Xon (+Spu)
8	〃	450	9	Cal+Xon+Del
9	4Lar**+$H_2C_2O_4 \cdot 2H_2O$	350	5	Cal+Xon+Del
10	〃	400	7	Cal+Xon+Del
11	〃	450	7	Cal+Kil
12	〃	450	10	Cal+Fos+Del
13	〃	500	6	Cal+Kil

Abbreviations—Cal: calcite, Del: dellaite, Fos: foshagite, Fuk: fukalite, Kil: kilchoanite, Lar: larnite, Spu: spurrite.

* Natural specimens from Fuka.

** Synthesized with reagent grade $CaCO_3$ and silicagel.

Name and type mineral

The mineral is named after the first locality, Fuka, and should be pronounced as [fukɑlɑit]. Type specimens from the three localities have been deposited at Department of Earth Sciences, Faculty of Science, Okayama University, Okayama, Japan.

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