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Abuite, $CaAl_2(PO_4)_2F_2$, a new mineral from the Hinomaru–Nago mine, Yamaguchi Prefecture, Japan

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Abuite was found in hydrothermally altered rocks in the Hinomaru–Nago mine, Kiyo area, Abu, Abu County, Yamaguchi Prefecture, Japan (34°53′N 131°52′E). Abuite is often included in aluminum phosphate rich samples, embedded with quartz and augelite and/or trolleite, and is often accompanied by other phosphates especially apatite and crandallite. Abuite is transparent and colorless with white streak and vitreous luster. It is very difficult to find them in bare eyes, since the dominant phases in aluminum phosphate rich samples, augelite, trolleite, and quartz, are all also transparent and colorless. The empirical formula of abuite (based on 10 anions pfu, O = 8, F + OH = 2) is $(Ca_{0.99}Sr_{0.01})_{1.00}Al_{1.96}P_{2.03}O_8(F_{1.89}OH_{0.11})$. H_2O was calculated by stoichiometry. The simplified formula is $CaAl_2(PO_4)_2F_2$. Abuite is the calcium analogue of $SrAl_2(PO_4)_2F_2$, which was synthesized by hydrothermal methods (Le Meins and Courbion, 1998). The crystal structure is orthorhombic, with space group $P2_12_12_1$. Unit cell parameters refined from the obtained X–ray diffraction pattern are a = 11.818(2), b = 11.993(3), c = 4.6872(8) Å and V = 664.3(2) Å^3, with Z = 4.

Keywords: Abuite, Hinomaru–Nago mine, Al–phosphates, Gatumbaite, New mineral

INTRODUCTION

Various aluminum phosphates such as augelite, trolleite, scorzalite, svanbergite and florencite–(Ce) are reported from the Hinomaru–Nago mine. New mineral abuite was first reported as a 'gatumbaite–like mineral' by Matsubara and Kato (1998) from its chemical composition and lack of X–ray diffraction pattern coinciding with the original pattern. Gatumbaite was reported by von Knorring and Fransolet (1977), with the formula $CaAl_2(PO_4)_2(OH)_2 \cdot H_2O$. However, chemical and X–ray diffraction experiments indicated that the 'gatumbaite–like mineral' is a new mineral with completely different crystal structure from gatumbaite. The simplified formula of abuite $CaAl_2(PO_4)_2F_2$ is very close to gatumbaite, only differing in the amount of F and H_2O. The name is for the type locality, near the town of Abu, Abu County, Yamaguchi Prefecture, Japan. The mineral and mineral name have been approved by the International Mineralogical Association, Commission on New Minerals, Nomenclature and Classification (No. 2014–084). The type specimen is deposited in Kitakyushu Museum of Natural History and Human History, Kitakyushu, Japan, under the registered number KMNHM000003.

GEOLOGICAL SETTINGS

Abuite was found in hydrothermally altered rocks in the Hinomaru–Nago mine, Kiyo area, Abu, Abu County, Yamaguchi Prefecture, Japan (34°53′N 131°52′E). The Hinomaru–Nago mine was described in previous studies as the 'Hinomaru–Nako mine' by mistake. The name of the mine comes from the company name 'Hinomaru–Yougyou (pottery)' which had an office in the 'Nago' area. There are many hydrothermal deposits in Abu County, formed by hydrothermal alteration of acidic pyroclastic rocks belonging to the Abu Group of upper Cretaceous age, caused by the intrusion of a biotite adamellite (Kamitani, 1977). The Hinomaru–Nago mine is characterized by the presence of various aluminum phosphates, aside from the aluminum silicates widely seen in Abu County (Kamitani, 1977; Matsubara and Kato, 1998). Augelite and trolleite are the most dominant Al–phosphates in the Hinomaru–Nago mine, and include other Al–phosphates.

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ANALYTICAL METHODS

X-ray diffraction (XRD) data was collected on crystal fragments using a Rigaku RINT RAPIDII curved imaging plate microdiffractometer that used monochromatized Cu*K*α radiation generated at 40 kV and 30 mA. The fragments were randomized using a Gandolfi-like motion about two axes (oscillation on ω and rotation on φ). The XRD data of abuite was indexed with the calculated data for $CaAl_2(PO_4)_2F_2$, using the atomic coordinates for synthetic $SrAl_2(PO_4)_2F_2$, PDF card; #04-011-4811 (Le Meins and Courbion, 1998).

Chemical analyses were also performed by a JEOL JXA8530F electron probe microanalyzer (EPMA). Quantitative analyses were performed at an accelerating voltage of 15 kV, beam current of 5 nA and prove diameter of 20 μm. The standard materials were apatite (Ca*K*α, P*K*α, F*K*α), celestine (Sr*L*α), and corundum (Al*K*α). H_2O contents were calculated by stoichiometry. The ZAF method was used for data correction.

OCCURRENCE

The hydrothermally altered rocks of the Hinomaru-Nago mine can be roughly divided in to three groups as in Matsubara and Kato (1998); white fine-grained rock, light grey less fine-grained rock, and white coarser-grained rock. Fine-grained white rock is mainly composed of quartz, andalusite, and clay minerals such as pyrophyllite, kaolinite, and muscovite, and devoid of any aluminum phosphates. Light grey less fine-grained rock and white coarser-grained rock are mainly composed of quartz, andalusite, and aluminum phosphates, the latter involving more aluminum phosphates in quantity. They come in close relation, and the white coarser-grained parts are seen as small patches in out crops of light grey less fine-grained part. Not every sample of these types includes aluminum phosphates, and the blue tints of lazulite-scorzalite, or the cleavage of augelite can be the clue to determine. Abuite is often included in aluminum phosphate rich samples. Abuite is embedded with quartz and augelite and/or trolleite, and is often accompanied by other phosphates especially apatite and crandallite (Fig. 1). Abuite occurs as grains of 100-500 μm in size, and sometimes makes aggregates with other minerals, up to 2 mm in size. Abuite was probably formed during hydrothermal alteration of pre-existing minerals.

PHYSICAL AND OPTICAL PROPERTIES

Abuite is transparent and colorless with white streak and vitreous luster. Cleavage is not observed. It is very difficult to find them in bare eyes, since the dominant phases in aluminum phosphate rich samples, augelite, trolleite, and quartz, are all also transparent and colorless. No fluorescent was seen. Density could not be measured due to small amount of the mineral. The calculated density is 3.214 g cm^{-3} using the empirical formula and refined unit cell parameters.

Table 1. Chemical compositions of abuite from the Hinomaru-Nago mine

wt%	1	2	3	4	5
P_2O_5	45.04	45.38	41.87	42.78	44.08
Al_2O_3	31.26	30.81	30.26	30.28	31.67
CaO	17.29	16.28	16.24	13.60	17.42
SrO	0.22	1.78		5.39	
F*	11.24	10.17	(11.21)	(11.37)	11.80
O = F	4.73	4.28	(4.91)	(4.91)	4.97
H_2O**	0.31	0.81	0.00	0.00	
Total	100.63	100.95	(94.67)	(98.51)	100.00
10 anions pfu, O = 8, F + OH = 2					
P	2.03	2.05	2.00	2.01	2
Al	1.96	1.93	2.01	1.99	2
Ca	0.99	0.93	0.98	0.81	1
Sr	0.01	0.05	0.00	0.17	
F*	1.89	1.71	(2.00)	(2.00)	2
OH	0.11	0.29	0.00	0.00	

1, Hinomaru-Nago mine, Japan (Sample Nk007, n = 21). 2, Hinomaru-Nago mine, Japan. Most Sr-rich analysis (Sample Nk008, n = 4). 3, Hinomaru-Nago mine, Japan. An analysis, with no Sr (Matsubara and Kato, 1998). 4, Hinomaru-Nago mine, Japan. Most Sr-rich analysis (Matsubara and Kato, 1998). 5, Ideal chemical composition for abuite; $CaAl_2(PO_4)_2F_2$.

* For 3 and 4, F content was calculated on the assumption that F = 2 *apfu*, for comparison with present study, since F was not analyzed in Matsubara and Kato (1998).

** H_2O was calculated by stoichiometry.

CHEMICAL COMPOSITION

The empirical formula of abuite (based on 10 anions pfu, O = 8, F + OH = 2) is $(Ca_{0.99}Sr_{0.01})_{1.00}Al_{1.96}P_{2.03}O_8(F_{1.89}OH_{0.11})$ (Table 1). H_2O was calculated by stoichiometry. The simplified formula is $CaAl_2(PO_4)_2F_2$, which requires CaO 17.42, Al_2O_3 31.67, P_2O_5 44.08, F 11.80, O = F -4.97, total 100.00 wt%. Abuite is mostly homogeneous, and slight compositional inhomogeneity by Sr is seen in some samples (Fig. 2 and Table 1). As noted in the next section, Sr analog of abuite is already synthesized, so Sr analog of abuite may also exist in nature.

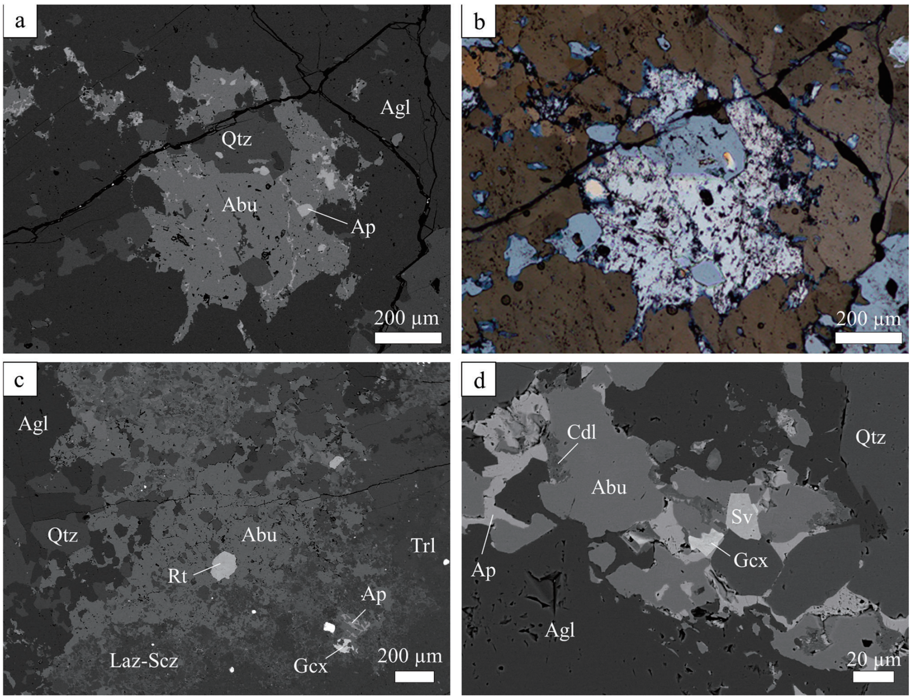

Figure 1. Occurrence of abuite from the Hinomaru-Nago mine. (a) BSE image and (b) photomicrograph (crossed nicols) of abuite. (c) BSE image of abuite occurring with lazulite-scorzalite. (d) BSE image of abuite occurring with apatite and alunite super group minerals. Abu, abuite; Agl, augelite; Ap, apatite; Cdl, crandallite, Gcx, gorceixite; Laz, lazulite; Qtz, quartz; Rt, rutile; Scz, scorzalite; Sv, svanbergite; Trl, trolleite.

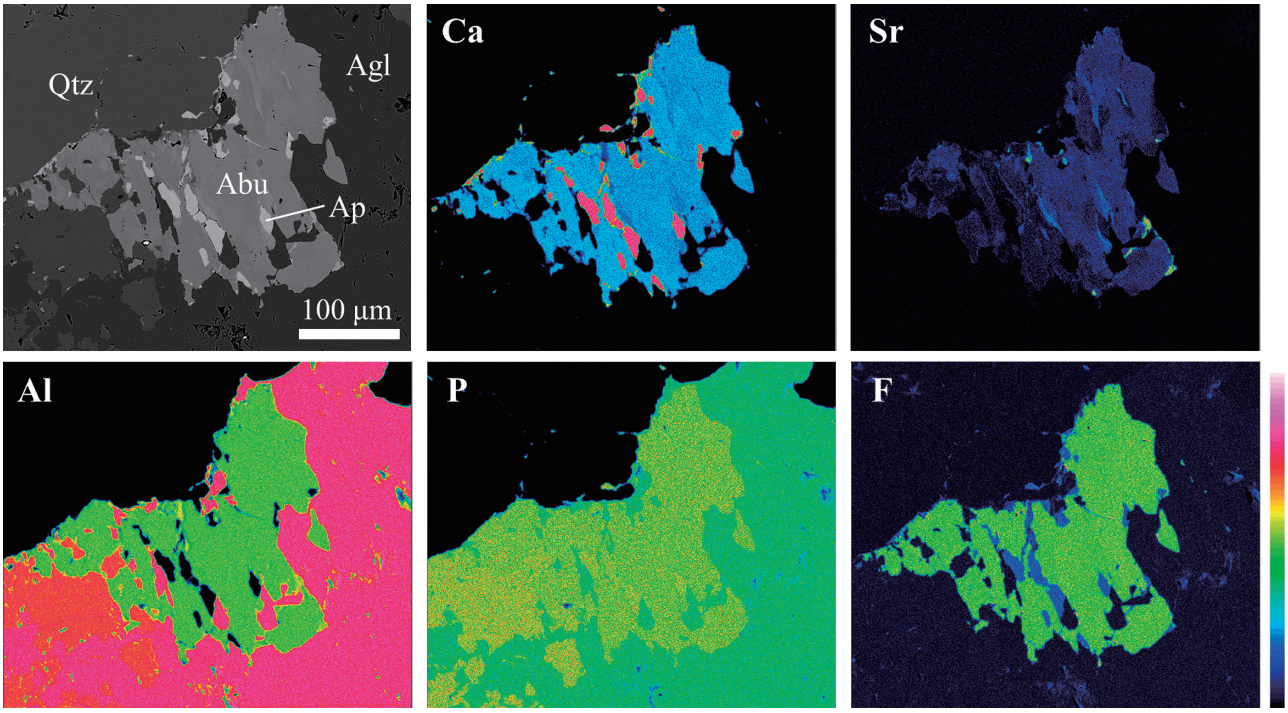

Figure 2. BSE image and X-ray mapping images (Ca*K*α, Sr*L*α, Al*K*α, P*K*α and F*K*α) of abuite including Sr. Abu, abuite; Agl, augelite; Ap, apatite; Qtz, quartz.

X-RAY CRYSTALLOGRAPY

Abuite is the calcium analogue of $SrAl_2(PO_4)_2F_2$, which was synthesized by hydrothermal methods (Le Meins and Courbion, 1998). $SrAl_2(PO_4)_2F_2$ is orthorhombic, space group $P2_12_12_1$ with unit cell parameters $a = 12.026(1)$, $b = 12.199(1)$ and $c = 4.666(1)$ Å. The Sr phase has not been found to occur in nature to date. The XRD pattern of abuite was calculated using the atomic coordinates for $SrAl_2(PO_4)_2F_2$. The calculated XRD pattern conforms closely

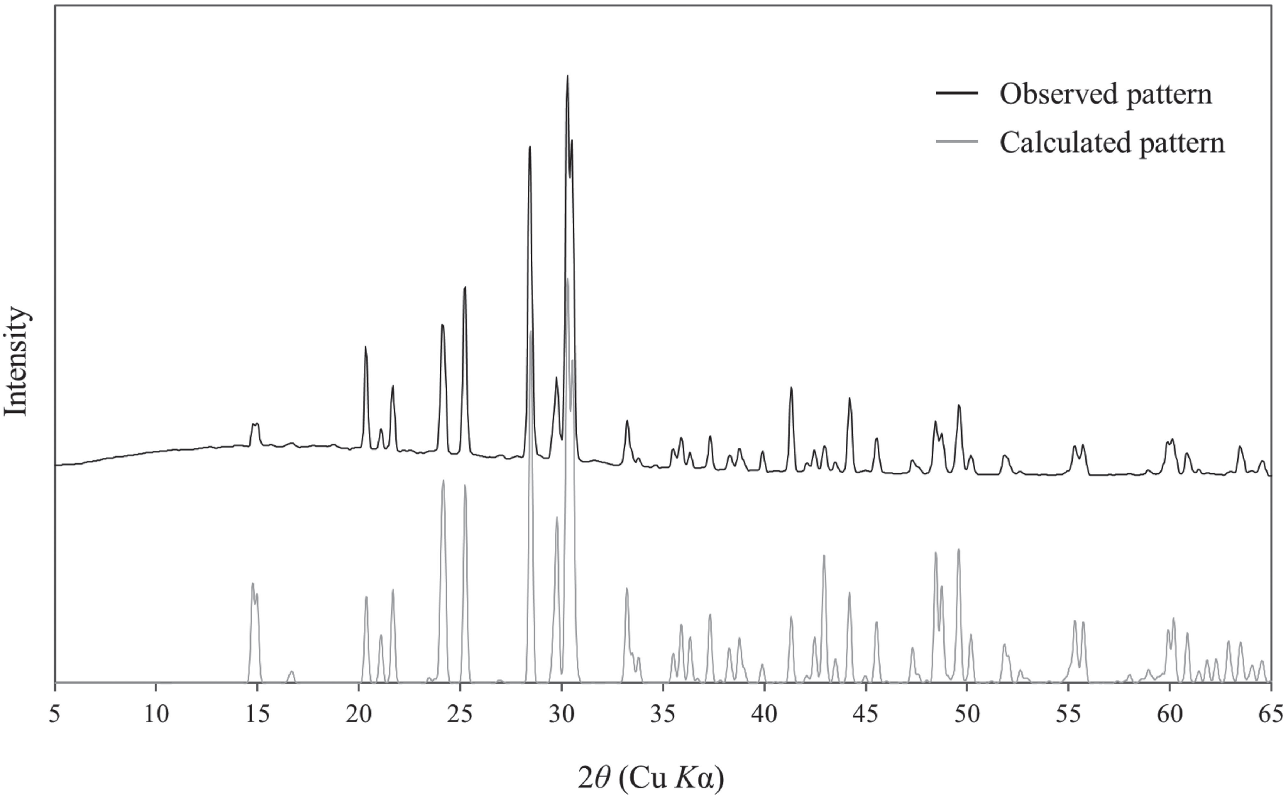

Figure 3. Observed XRD pattern and calculated XRD pattern of abuite. The XRD data for $CaAl_2(PO_4)_2F_2$ was calculated using the atomic coordinates for synthetic $SrAl_2(PO_4)_2F_2$, PDF card; #04-011-4811 (Le Meins and Courbion, 1998). The unit cell parameters and peak width was adjusted to fit the observed XRD pattern.

to the observed data (Fig. 3). Data were indexed using the calculated data for $CaAl_2(PO_4)_2F_2$ and are listed in Table 2 (in Å for Cu$K\alpha$) in comparison with $SrAl_2(PO_4)_2F_2$, PDF card; #04-011-4811 (Le Meins and Courbion, 1998). The unit cell parameters of abuite refined from the obtained XRD pattern are a = 11.818(2), b = 11.993(3), c = 4.6872(8) Å and V = 664.3(2) Å^3 with Z = 4.

Abuite have similar atomic coordinates to $SrAl_2(PO_4)_2F_2$, estimated from the resemblance of the calculated XRD pattern for $CaAl_2(PO_4)_2F_2$ to the observed XRD pattern of abuite. The crystal structure of $SrAl_2(PO_4)_2F_2$ (Le Meins and Courbion, 1998) consists of infinite chains of *cis*-linked Al octahedra along [001] by sharing two fluorine atoms. Two different chains are linked by PO_4 tetrahedra, giving rise to channels along [001] delimited by a helical distribution of oxygen anions in which the Sr cations are found.

DISCUSSION

The chemical composition of abuite is similar to gatumbaite (Table 3). The only difference is the presence of fluorine and H_2O content. Gatumbaite is a very rare mineral which is reported in only four localities (von Knorring and Fransolet, 1977; Duggan et al., 1990; Ek and Nysten, 1990; Breiter et al., 2009). However, XRD pattern is only obtained in two localities (von Knorring and Fransolet, 1977; Ek and Nysten, 1990), and data only written in type locality. Also, F is detected in the sample from Vernéřov, Bohemia, Czech Republic (Breiter et al., 2009). Though more investigation is essential, it is possible that abuite was described as gatumbaite in some localities.

Abuite occurs in hydrothermally altered rocks of the Hinomaru-Nago mine, and gatumbaite is reported from pegmatites and hydrothermal deposits (von Knorring and Fransolet, 1977; Duggan et al., 1990; Ek and Nysten, 1990; Breiter et al., 2009). Augelite occurs in all localities, with accompanying berlinite and/or trolleite. The occurring species of these Al-phosphates differ by temperatures, in the descending order; berlinite, augelite, trolleite (Wise and Loh, 1976). Augelite is stable in narrow range around 400-500°C in low pressure, which is relatively high temperature for hydrothermal deposits. In addition, Al-silicates such as andalusite or kyanite are widely found in the hydrothermal deposits, indicating the presence of large volume acidic fluids (Wise, 1975). So relatively high temperature acidic environments may

Table 2. X-ray diffraction data for abuite from the Hinomaru-Nago mine

			Abuite			$SrAl_2(PO_4)_2F_2$		
h	k	l	d_{obs}	d_{cal}	I/I_0	d_{cal}^*	I/I_0^*	
1	1	0				8.564	0.1	
0	2	0	6.00	6.00	5	6.100	0.6	
2	0	0	5.90	5.91	5	6.013	0.9	
1	2	0				5.440	4.0	
2	1	0				5.393	3.0	
0	0	1	4.73	4.69	1			
0	1	1				4.350	63.4	m
1	0	1	4.362	4.357	25	4.350		m
2	2	0	4.209	4.209	5	4.282	3.1	
1	1	1	4.099	4.095	16	4.097	13.6	
1	3	0				3.852	0.9	
3	1	0				3.808	0.8	
0	2	1	3.683	3.693	32	3.706	15.4	
2	0	1		3.672		3.686	24.5	
1	2	1	3.529	3.525	43	3.542	99.9	
2	3	0				3.368	0.8	
3	2	0				3.350	1.2	
2	2	1	3.139	3.132	86	3.155	59.2	
3	0	1	3.001	3.016	20	3.041	52.3	
0	4	0		2.998		3.050	49.4	
4	0	0	2.951	2.955	100	3.007	42.4	
1	3	1		2.946		2.971	46.5	
3	1	1	2.928	2.925	80	2.950	51.6	m
1	4	0				2.950		m
3	2	1	2.692	2.694	11	2.721	63.0	m
2	4	0	2.676	2.674	4	2.721		m
4	2	0	2.65	2.65	2	2.697	18.9	
0	4	1	2.527	2.526	5	2.553	2.0	
4	0	1	2.50	2.499	8	2.527	7.9	
1	4	1	2.47	2.47	4	2.497	26.8	
4	1	1				2.475	1.2	
3	3	1	2.407	2.408	9	2.435	11.2	
3	4	0				2.427	6.9	
1	5	0	2.352	2.351	4	2.391	4.7	
0	0	2				2.333		m
2	4	1	2.321	2.322	6	2.350	6.6	
5	1	0		2.319		2.360	4.0	
4	2	1				2.333	7.3	m
0	1	2				2.291	0.1	m
1	0	2				2.291		m
1	1	2	2.257	2.258	5	2.251	2.3	
2	5	0				2.261	0.4	
0	2	2	2.183	2.183	24	2.179	20.1	
2	0	2				2.175	13.7	
1	2	2	2.146	2.147	2			
2	1	2		2.143				
3	4	1	2.127	2.126	6	2.153	21.0	
4	3	1				2.147	13.7	
5	0	1				2.141	32.2	m
4	4	0	2.104	2.104	7	2.141		m
1	5	1				2.128	4.6	
5	1	1	2.078	2.079	3	2.106	4.0	
2	2	2	2.046	2.048	21	2.049	21.9	
5	3	0				2.070	0.3	
3	0	2	2.013	2.014	1	2.018		m
2	5	1				2.033	1.4	m
0	6	0				2.033		m
1	3	2				1.996	1.2	
5	2	1	1.990	1.991	10	2.018	21.8	m
3	1	2				1.989	1.3	
1	6	0				2.004	3.6	m
6	0	0				2.004		m
6	1	0				1.978	0.4	
4	4	1	1.920	1.920	4	1.946	3.5	
3	2	2	1.908	1.909	2	1.914	1.7	
2	6	0				1.926	3.3	
3	5	1	1.878	1.877	15	1.903		m
6	2	0				1.903	20.1	m
5	3	1	1.866	1.866	11	1.892		m
4	5	0				1.892	11.9	m
5	4	0				1.889	8.0	
0	6	1	1.836	1.839	19	1.864	9.9	
4	0	2		1.836		1.843	29.1	m
1	4	2				1.831	2.2	
1	6	1	1.816	1.817	5	1.843		m
6	0	1		1.816				
4	1	2				1.822		m
3	3	2				1.806	0.8	
6	1	1				1.822	0.5	m
3	6	0				1.813	1.4	
6	3	0				1.798	0.7	
2	4	2	1.762	1.762	6	1.771	12.6	
4	2	2				1.764	9.0	m
2	6	1				1.780	5.0	
6	2	1	1.738	1.738	1	1.764		m
4	5	1				1.755	1.4	
5	4	1				1.751	4.9	
1	7	0				1.725	0.3	
5	5	0				1.713	0.1	
3	4	2				1.684		m
7	1	0				1.701	0.4	
4	3	2				1.679	3.7	
3	6	1				1.690	7.2	
5	0	2				1.675		m
1	5	2	1.660	1.660	9	1.670	9.4	
4	6	0				1.684	6.8	m
5	1	2	1.648	1.648	9	1.659	5.9	
6	4	0				1.675	7.0	m
7	2	0				1.654	3.2	
2	5	2				1.624	0.1	
0	7	1				1.633	0.1	
1	7	1				1.618	0.5	
7	0	1				1.612	3.9	
5	5	1				1.608	2.1	

be required for formation of abuite and gatumbaite. Also the amount and activity of Ca and F contents within the alteration fluid, and the balance with coexisting minerals such as apatite, crandallite and topaz, could be the key to their formation and distinction.

Table 2. (Continued)

			Abuite			$SrAl_2(PO_4)_2F_2$		
h	*k*	*l*	d_{obs}	d_{cal}	I/I_0	d_{cal}^*	I/I_0^*	
7	1	1				1.598	1.0	m
3	7	0				1.598		m
4	4	2	1.566	1.566	1	1.577	6.0	m
4	6	1				1.584	2.4	m
7	3	0				1.584		m
6	4	1				1.577		m
0	1	3				1.542	3.6	m
1	0	3				1.542		m
3	5	2	1.543	1.542	10	1.554	9.5	m
5	3	2	1.536	1.536	9	1.548	7.2	m
1	1	3		1.536		1.530	5.6	
7	2	1		1.535		1.559	7.0	
5	6	0				1.554		m
6	5	0				1.548		m
0	6	2	1.521	1.521	7	1.533	10.1	
0	2	3				1.509		m
1	6	2				1.520	3.7	m
6	0	2	1.506	1.508	1	1.520		m
1	2	3				1.495	4.7	m
0	8	0				1.525	4.6	
2	1	3				1.495		m
6	1	2				1.509	2.6	m
3	7	1				1.512		m
1	8	0				1.512	4.0	m
8	0	0	1.476	1.477	1	1.503	4.3	
7	3	1		1.476		1.499	5.6	
2	6	2				1.485	2.7	
8	1	0				1.492	1.7	
2	2	3	1.464	1.465	9	1.462	4.3	
6	2	2		1.462		1.475	6.5	
4	5	2				1.471	4.0	m
5	4	2	1.453	1.455	1	1.468	2.0	
2	8	0		1.453		1.478	1.8	
3	0	3		1.452		1.450	3.2	m
5	6	1		1.451		1.473	4.9	
6	5	1				1.471		m
1	3	3	1.442	1.444	4	1.442	1.9	
3	1	3		1.442		1.439	4.5	m
8	2	0				1.460	2.7	
0	8	1				1.450		m
3	6	2				1.431	2.4	m
1	8	1				1.439		m
4	7	1				1.435	2.3	
2	3	3	1.412	1.413	2			
3	2	3		1.412		1.411	8.1	m
6	3	2				1.425		m
8	0	1				1.431		m
7	4	1				1.425	5.4	m
8	1	1				1.421	3.1	
2	8	1	1.387	1.388	2	1.409	8.4	
5	7	0		1.387		1.411		m
0	4	3				1.387		m
4	0	3				1.381	8.9	m
7	5	0	1.380	1.381	1	1.405	6.3	
1	4	3				1.376	6.6	
1	7	2				1.387	2.3	m
4	1	3				1.373	2.4	
8	2	1				1.393	1.9	
7	0	2				1.383	2.0	
5	5	2	1.365	1.367	14	1.381		m
3	3	3		1.365				
7	1	2				1.375	2.7	
4	6	2	1.353	1.352	2	1.366	11.1	m
2	4	3	1.349	1.349	2	1.350	2.3	m
2	7	2				1.360	2.9	m
4	2	3	1.346	1.346	3	1.347	2.9	m
6	6	1				1.366		m
3	8	1				1.363	7.1	
4	8	0				1.360		m
7	2	2				1.350		m
7	5	1				1.345	2.1	
1	9	0				1.347		m
3	4	3	1.308	1.307	2	1.310		m
9	1	0	1.305	1.305	1	1.328	0.4	
3	7	2		1.305		1.319	0.5	
5	0	3				1.306	2.9	m
7	3	2				1.310	4.1	m
6	7	0				1.315	0.4	
4	8	1				1.306		m
0	9	1				1.302	0.7	
5	6	2				1.293	1.8	
2	5	3				1.281	0.6	
8	4	1				1.295	2.4	m
1	9	1				1.295		m
5	2	3				1.277	1.1	m
5	8	0				1.288	1.5	
9	0	1				1.285	1.0	m
0	8	2				1.277		m
3	9	0				1.285		m
1	8	2				1.269		m
4	7	2				1.266	1.0	m
8	0	2	1.250	1.250	2	1.264	5.6	m
9	3	0				1.269	1.1	m
6	7	1	1.247	1.246	1	1.266		m
7	4	2		1.246		1.260	3.3	
7	6	1				1.264		m
8	1	2				1.257		m
3	5	3	1.243	1.242	3	1.246	2.4	
5	3	3	1.240	1.239	3			
9	2	1				1.257	2.7	m
2	8	2				1.249	0.5	

* Calculated X-ray diffraction data for synthesized $SrAl_2(PO_4)_2F_2$ (PDF #04-011-4811). Overlapped reflections are given an 'm' qualifier. This is because the instrumental resolution is assumed to be insufficient to resolve the overlapped reflections.

Table 3. Chemical compositions of gatumbaite

wt%	1	2	3	4	5	6
P_2O_5	41.35	41.95	43.61	43.64	42.24	44.08
SiO_2			0.03	0.05		
TiO_2		0.13				
Al_2O_3	28.09	30.16	30.82	31.33	30.34	31.67
Fe_2O_3	2.20	0.04				
MgO			0.03	0.00		
CaO	17.35	16.22	16.69	16.28	16.69	17.42
MnO	0.30		0.05	0.00		
FeO			0.00	0.11		
ZnO			0.03	0.00		
SrO			0.67	1.08		
PbO			0.11	0.00		
Na_2O	0.30		0.67	0.89		
K_2O			0.02	0.00		
F			10.04	10.09		11.80
F = O	0.00	0.00	4.23	4.22		4.97
H_2O*	11.05	11.05	6.29	6.30	10.72	5.60
Total	100.64	99.55	104.84	105.54	100.00	105.60
	10 anions pfu, O = 8, F + OH = 2, H_2O = 1					
P	1.98	2.00	2.00	1.99	2	2
Si	0.00	0.00	0.00	0.00		
Ti	0.00	0.01	0.00	0.00		
Al	1.88	2.00	1.97	1.99	2	2
Fe^{3+}	0.09	0.00	0.00	0.00		
Mg	0.00	0.00	0.00	0.00		
Ca	1.05	0.98	0.97	0.94	1	1
Mn	0.01	0.00	0.00	0.00		
Fe^{2+}	0.00	0.00	0.00	0.00		
Zn	0.00	0.00	0.00	0.00		
Sr	0.00	0.00	0.02	0.03		
Pb	0.00	0.00	0.00	0.00		
Na	0.03	0.00	0.07	0.09		
K	0.00	0.00	0.00	0.00		
F	0.00	0.00	1.72	1.72		2
OH	2.00	2.00	0.28	0.28	2	

1, Buranga pegmatite, Rwanda (Von Knorring and Fransolet, 1977). 2, Mount Perry, Queensland, Australia (Duggan et al., 1990). 3, 4, Verneřov, Bohemia, Czech Republic (Breiter et al., 2009). 5, Ideal chemical composition for gatumbaite; $CaAl_2(PO_4)_2(OH)_2 \cdot H_2O$. 6, Abuite with ideal chemical composition calculated as gatumbaite. [*] H_2O was calculated by stoichiometry.

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REFERENCES

Breiter, K., Škoda, R. and Veselovský, F. (2009) Neobvyklý P-, Li- a Sn-bohatý pegmatit z Verneřova u Aše, Česká republika. Bulletin Mineralogicko-petrografického oddělení Národního muzea v Praze, 17, 41-59 (written in Czech with English abstract).

Duggan, M.B., Jones, M.T., Richards, D.N.G. and Kamprad, J.L. (1990) Phosphate minerals in altered andesite from Mount Perry, Queensland, Australia. Canadian Mineralogist, 28, 125-131.

Ek, R. and Nysten, P. (1990) Phosphates mineralogy of the Hålsjöberg and Hökensås, kyanite deposits. Geologiska Föreningens i Stockholm Förhandlingar, 112, Pt. 1, 9-18.

Kamitani, M. (1977) Genesis of the Andalusite-bearing Roseki Ore Deposits in the Abu District, Yamaguchi Prefecture, Japan. Monthly Reports of the Geological Survey of Japan, 28, 201-264.

von Knorring, O. and Fransolet, A.-M. (1977) Gatumbaite, $CaAl_2(PO_4)_2(OH)_2 \cdot H_2O$: a new species from the Buranga pegmatite, Rwanda. Neues Jahrbuch für Mineralogie, Monatshefte, 561-568.

Le Meins, J.-M. and Courbion, G. (1998) Hydrothermal synthesis and crystal structure of $SrAl_2(PO_4)_2F_2$: a new three-dimensional framework with channels delimited by a helical anionic border. European Journal of Solid State Inorganic Chemistry, 35, 639-653.

Matsubara, S. and Kato, A. (1998) Phosphates from the Hinomaru-Nako mine, Abu-cho, Yamaguchi Prefecture, Western Japan. Memoirs of the National Science Museum, Tokyo, 30, 167-183.

Wise, W.S. (1975) The origin of the assemblage: Quartz + Al-silicate + rutile + Al-phosphate. Fortschritte Mineral, 52, 151-159.

Wise, W.S. and Loh, S.E. (1976) Equilibria and origin of minerals in the system Al_2O_3-$AlPO_4$-H_2O. American Mineralogist, 61, 409-413.

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