



OTTENSITE

a New Mineral from
Qinglong, Guizhou Province, China

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ABSTRACT

Ottensite, $\text{Na}_3(\text{Sb}_2\text{O}_3)_3(\text{SbS}_3)\cdot 3\text{H}_2\text{O}$, is hexagonal, space group $P6_3$, with unit-cell parameters derived from X-ray powder data: $a = 14.1758(2)$, $c = 5.5712(1)$ Å, $V = 969.57(3)$ Å³, $Z = 2$. It is the Na-dominant analog of cetineite. The strongest reflections in the X-ray powder diffraction pattern are $[d(\text{Å})(I)(hkl)]: 12.29(60)(100); 4.64(50)(120); 4.12(50)(201); 2.991(80)(221); 2.906(100)(131); 2.679(50)(410)$. The mineral was found on specimens from the Qinglong antimony deposit (25°30'N; 105°10'E), which is situated in Qinglong County, Guizhou Province, China. Ottensite is a supergene product of stibnite weathering. It forms crusts about 1 mm thick on well-formed, terminated stibnite crystals which are up to 5 cm long and 6 mm wide. The ottensite crusts are composed of spheres with a diameter of up to 0.3 mm. The color is red-brown with an adamantine luster and yellow-brown streak. It is brittle with irregular fracture; cleavage was not observed; it is non-fluorescent. Hardness (Mohs) is about 3½; calculated density is 4.14 g/cm³. Optically, it is uniaxial positive, n (calculated from the Gladstone-Dale relationship) is 1.99; pleochroism is weak: orange-red to red. Average electron microprobe analysis: Na₂O 7.44, K₂O 0.10, Sb₂O₃ 84.64, S 7.43, H₂O (derived from TG analysis) 4.60, $-S=O -3.71$, total 100.50 weight %, corresponding to an empirical formula $(\text{Na}_{2.89}\text{K}_{0.03})_{2.92}(\text{Sb}_2\text{O}_3)_{3.03}(\text{Sb}_{0.93}\text{S}_{2.79})(\text{OH})_{0.13}\cdot 3.01 \text{H}_2\text{O}$, based on 15 anions. The mineral name is for Berthold Ottens (born 1942).

INTRODUCTION

Specimens containing ottensite were first noticed in 2004, and were originally thought to be cetineite. They probably came from a single find, because no other similar specimens have turned up since then. Probably only a few dozen specimens exist.

The mineral name honors Berthold Ottens (born 1942), mineral collector and dealer from Spiegelau, Germany. Mr. Ottens is the author of numerous articles about mineral localities in China and India, published in the *Mineralogical Record*, *Rocks & Minerals*, *Lapis*, *Mineralien-Welt*, etc.; the most important ones are Ottens (2003) and Ottens *et al.* (2004, 2005), as well as several articles in this issue of *Mineralogical Record*. He is widely recognized as one of the few experts in Chinese minerals and localities. The mineral and mineral name *ottensite* (pronounced "ahten-zite") have been approved by the Commission on New Minerals and Mineral Names, I.M.A. (2006-014). The holotype specimen is deposited in the collection of the National Museum, Prague, Czech Republic, under catalog number P1p 1/2006.

OCCURRENCE

Ottensite was found on several specimens from the Qinglong district (25°30'N; 105°10'E), which is situated in Qinglong County, southwestern part of Guizhou Province, China. Qinglong is a large ore district with many mines, the most important one being the Dachang mine. Unfortunately, the exact locality for the ottensite specimens remains unknown.

The Qinglong deposit is of volcano-sedimentary origin and the most important ore mineral is stibnite, which forms crystals to several centimeters long. Associated minerals include quartz, pyrite, fluorite, calcite and clay minerals (Wu and Zhao, 1990). Several supergene minerals are known from Qinglong, including carbonate-cyanotrichite and stibiconite (Ottens, 2005). Ottensite is a supergene product of stibnite weathering in the oxidation zone.

Ottensite forms crusts about 1 mm thick on well-formed termi-



Figure 1. Botryoidal dark red ottensite on stibnite with pale yellow, amorphous oxide, 7.6 cm, from Qinglong. Marcus Origlieri specimen; Wendell Wilson photo.

Figure 2. Botryoidal dark red ottensite, 3 mm, on stibnite with a coating of a pale yellow, amorphous oxide and microcrystalline fluorite, from Qinglong. Marcus Origlieri specimen and photo.



nated stibnite crystals which are up to 5 cm long and 6 mm wide, in some places ottensite is covered by a very thin yellow powdery coating of an amorphous antimony oxide. The ottensite crust has generally grown directly on stibnite, but in some cases there is an empty space between the stibnite and the ottensite crust. The crust

is composed of spheres with a diameter up to 0.3 mm. The spheres typically have a smooth and lustrous surface, but in some cases are composed of crystals with a hexagonal prism {100}, terminated by $c\{001\}$. Radially oriented groups of well-developed columnar crystals were seen only rarely.

Table 1. X-ray powder-diffraction data for ottensite.

<i>I</i>	<i>d</i> _{meas.}	<i>d</i> _{calc.}	<i>h</i>	<i>k</i>	<i>l</i>	<i>I</i>	<i>d</i> _{meas.}	<i>d</i> _{calc.}	<i>h</i>	<i>k</i>	<i>l</i>	<i>I</i>	<i>d</i> _{meas.}	<i>d</i> _{calc.}	<i>h</i>	<i>k</i>	<i>l</i>
60	12.288	12.277	1	0	0	22	1.5609	1.5610	1	7	1	9	1.1651	1.1653	10	1	0
21	7.094	7.088	1	1	0	11	1.5539	1.5538	6	1	2				1	10	0
7	5.075	5.073	1	0	1	7	1.5465	1.5467	3	6	0	12	1.1557	1.1556	6	6	1
51	4.643	4.640	1	2	0	30	1.5127	1.5128	5	4	1	13	1.1505	1.1505	7	5	1
16	4.381	4.380	1	1	1	8	1.4998	1.4998	7	2	0				5	7	1
52	4.125	4.125	2	0	1	11	1.4952	1.4951	4	4	2	9	1.1354	1.1357	8	4	1
41	4.091	4.092	3	0	0	27	1.4902	1.4903	3	6	1	4	1.1221	1.1221	4	6	3
44	3.566	3.565	1	2	1	51	1.4842	1.4842	7	0	2	10	1.1174	1.1175	6	1	4
57	3.406	3.405	3	1	0				5	3	2	11	1.1096	1.1097	1	0	5
			1	3	0	45	1.4792	1.4795	8	0	1				9	2	2
36	3.299	3.298	3	0	1	4	1.4599	1.4600	3	3	3	8	1.1084	1.1083	3	7	3
32	3.070	3.069	4	0	0	26	1.4484	1.4483	7	2	1	3	1.1022	1.1025	10	2	0
77	2.991	2.990	2	2	1				2	7	1				2	10	0
100	2.906	2.905	1	3	1	7	1.4205	1.4204	5	1	3	7	1.0948	1.0950	4	4	4
			3	1	1				1	5	3				11	0	1
27	2.816	2.816	2	3	0	10	1.4175	1.4176	5	5	0	12	1.0906	1.0907	5	3	4
41	2.785	2.786	0	0	2	3	1.4045	1.4043	1	7	2				7	0	4
10	2.716	2.717	1	0	2	9	1.3930	1.3928	0	0	4	6	1.0894	1.0894	7	6	0
32	2.689	2.688	4	0	1	6	1.3915	1.3913	8	1	1	2	1.0873	1.0876	6	6	2
51	2.679	2.679	4	1	0	7	1.3812	1.3812	7	3	0	8	1.0809	1.0809	5	8	0
12	2.593	2.593	1	1	2				3	7	0	5	1.0751	1.0750	1	10	2
6	2.536	2.537	2	0	2	7	1.3692	1.3690	5	4	2	3	1.0710	1.0709	4	8	2
16	2.4552	2.4553	5	0	0	13	1.3666	1.3667	1	1	4	10	1.0690	1.0691	6	7	1
10	2.4149	2.4144	1	4	1	4	1.3521	1.3522	6	3	2	4	1.0645	1.0645	4	9	0
16	2.3880	2.3883	2	1	2	5	1.3498	1.3500	2	5	3				1	11	0
			1	2	2	23	1.3395	1.3395	2	8	0	6	1.0591	1.0590	1	3	5
11	2.3627	2.3626	3	3	0	11	1.3343	1.3340	1	2	4				3	1	5
40	2.3199	2.3201	4	2	0	3	1.3245	1.3249	9	0	1	8	1.0580	1.0578	1	7	4
32	2.2048	2.2050	1	5	0	6	1.3206	1.3206	2	7	2				6	5	3
			5	1	0				7	2	2				9	1	3
23	2.1748	2.1751	3	3	1	10	1.3184	1.3185	1	6	3	4	1.0510	1.0511	9	3	2
28	2.1560	2.1560	1	3	2				6	1	3				3	9	2
20	2.1416	2.1418	2	4	1	3	1.3023	1.3024	8	2	1	9	1.0457	1.0456	4	9	1
			4	2	1	3	1.2964	1.2963	2	2	4				11	1	1
46	2.0496	2.0502	1	5	1	2	1.2893	1.2891	1	3	4	7	1.0352	1.0350	6	3	4
28	2.0181	2.0183	3	4	0	4	1.2869	1.2869	1	9	0				8	3	3
23	1.9805	1.9805	2	3	2				5	6	0	5	1.0252	1.0251	2	10	2
39	1.9656	1.9658	5	2	0	5	1.2819	1.2820	4	4	3				10	2	2
			2	5	0	4	1.2747	1.2751	3	5	3	11	1.0145	1.0146	6	7	2
31	1.9309	1.9309	1	4	2	8	1.2538	1.2539	9	1	1				7	6	2
			4	1	2				6	5	1	8	1.0134	1.0136	9	2	3
14	1.8976	1.8976	4	3	1				5	6	1	3	1.0128	1.0126	2	11	0
			6	1	0	5	1.2486	1.2485	2	3	4	2	0.9991	0.9991	9	5	0
23	1.8538	1.8538	2	5	1	7	1.2410	1.2410	4	7	1	5	0.9969	0.9967	6	6	3
21	1.8418	1.8419	5	0	2	9	1.2375	1.2375	7	3	2	7	0.9944	0.9945	5	1	5
11	1.8362	1.8362	1	0	3				3	7	2				1	5	5
38	1.7828	1.7827	4	2	2	7	1.2358	1.2358	1	4	4				4	9	2
51	1.7743	1.7747	1	6	1	4	1.2251	1.2251	9	0	2	2	0.9800	0.9807	7	3	4
46	1.7536	1.7538	5	3	0	9	1.2234	1.2234	1	7	3			0.9798	1	12	0
22	1.7285	1.7289	1	5	2	11	1.2164	1.2164	8	3	1	4	0.9754	0.9754	10	3	2
			5	1	2	7	1.2116	1.2115	5	0	4			0.9745	9	0	4
7	1.7022	1.7025	2	6	0	13	1.2097	1.2097	2	9	0	7	0.9681	0.9680	4	10	1
			6	2	0				9	2	0	10	0.9651	0.9655	2	8	4
23	1.6886	1.6886	4	4	1	10	1.2073	1.2072	2	8	2			0.9650	12	1	1
11	1.6727	1.6729	5	3	1	8	1.1994	1.1998	5	4	3				1	12	1
			3	5	1	4	1.1942	1.1941	2	4	4	2	0.9576	0.9575	6	1	5
22	1.6454	1.6449	2	2	3				4	2	4				1	6	5
33	1.6302	1.6303	1	3	3	3	1.1885	1.1885	3	6	3	3	0.9517	0.9516	11	2	2
			3	1	3	2	1.1829	1.1830	8	0	3				2	11	2
10	1.6061	1.6062	5	2	2	16	1.1820	1.1821	9	2	1	4	0.9477	0.9476	3	11	1
12	1.5888	1.5889	4	0	3	5	1.1668	1.1668	2	7	3				11	3	1
16	1.5718	1.5719	5	4	0												

Diffractionmeter Philips X'Pert APD, CuK α_1 radiation; all observed reflections were used for unit-cell refinement.

Table 2. Comparison of ottensite and similar phases.

	<i>ottensite</i>	<i>cetineite</i>	<i>synthetic</i>
	this paper	Sabelli and Vezzalini, 1987; Sabelli <i>et al.</i> 1988	Sabelli <i>et al.</i> 1988
formula	Na ₃ (Sb ₂ O ₃) ₃ (SbS ₃)·3H ₂ O	(K,Na) _{3+3x} (Sb ₂ O ₃) ₃ (SbS ₃)(OH) _x ·(2.8-x)H ₂ O	Na _{3.6} (Sb ₂ O ₃) ₃ (SbS ₃)(OH) _{0.6} ·2.4H ₂ O
crystal system	hexagonal	hexagonal	hexagonal
space group	<i>P6</i> ₃	<i>P6</i> ₃	<i>P6</i> ₃
unit a	14.1758(2)	14.2513(3)	14.152(3)
cell c	5.5712(1)	5.5900(1)	5.5758(7)
parameters V	969.57(3)	983.22	967.10
Z	2	2	2
d _{calc.}	4.14	4.22	4.22
strongest lines in the powder pattern	12.288/60	12.41/80	*12.256/100
	4.643/51	4.67/54	*4.633/31
	4.125/52	4.11/55	*4.124/44
	2.991/77	3.000/74	*2.987/76
	2.906/100	2.916/100	*2.902/100
	2.679/51	2.690/61	*2.675/24

* X-ray powder data calculated from crystal structure information

PHYSICAL AND OPTICAL PROPERTIES

The color of ottensite is red-brown, with a vitreous luster. It is brittle with an irregular fracture; the streak is yellow-brown; and cleavage was not observed. The mineral is translucent in thin fragments, showing a dark red color. It is non-fluorescent under both shortwave and longwave ultraviolet light. The hardness (Mohs) is estimated to be about 3½. The density could not be measured because of the small aggregate size, but the calculated density, based on the empirical formula and unit-cell parameters refined from X-ray powder diffraction data, is 4.14 g/cm³. The mineral is uniaxial positive, with an index of refraction much higher than 1.74. N calculated from Gladstone-Dale rule is 1.992. Ottensite is weakly pleochroic: orange-red and red.

X-RAY STUDIES

A hand-picked sample of ottensite was used to produce the X-ray powder diffraction pattern. The observed diffraction lines are similar to the pattern of cetineite and especially synthetic Na_{3.6}(Sb₂O₃)₃(SbS₃)(OH)_{0.6}·2.4H₂O (Sabelli *et al.*, 1988). The unit-cell parameters were obtained from the X-ray powder diffraction pattern (Table 1). Diffraction data were collected using a Philips X'Pert APD diffractometer (40 kV, 40 mA) in the range 5–110° 2θ in the step-scan mode (0.02°/30 s) with CuKα₁ radiation. The positions and intensities of reflections were calculated using the Pearson VII profile shape function in the ZDS program package (Ondruš, 1993). The hexagonal unit-cell (space group *P6*₃) was proposed by analogy to that of cetineite having the formula (K,Na)_{3+3x}(Sb₂O₃)₃(SbS₃)(OH)_x·(2.8-x)H₂O (Sabelli and Vezzalini, 1987; Sabelli *et al.*, 1988), and synthetic material having the formula Na_{3.6}(Sb₂O₃)₃(SbS₃)(OH)_{0.6}·2.4H₂O (Sabelli *et al.*, 1988). The unit-cell parameters of ottensite are *a* = 14.1758(2), *c* = 5.5712(1) Å, *V* = 969.57(3) Å³, refined from X-ray powder diffraction data using the program of Burham (1962). A comparison of the physical properties of ottensite and similar phases is given in the Table 2.

CRYSTAL STRUCTURE

Single-crystal X-ray studies were not possible because of the lack of crystals of sufficient size and quality. The crystal structure of a synthetic analog close to ottensite, as well as that of cetineite, was studied by Sabelli *et al.* (1988). Characteristic for the crystal structures of cetineite-like compounds is the presence of infinite tunnels parallel to the *c* axis, formed by the linkage of SbO₃ pyramids. The first alkali-site (M(H₂O)₆) is statistically located within the tunnel and has a “zeolitic” character, whereas the second site is localized on the interior of the tunnel wall (Sabelli *et al.*, 1988). Synthetically prepared cetineite-like compounds are an attractive subject for research because of their porous crystal structures (containing tunnels with a diameter of about 0.7 nm) and semiconducting properties (e.g. Wang and Liebau, 1999; Starrost *et al.*, 2000; Krasovskii *et al.*, 2001).

Table 3. Chemical composition of ottensite.

Constituent	Wt. %	Range
Na ₂ O	7.44	6.96–7.91
K ₂ O	0.10	0.07–0.11
Sb ₂ O ₃	84.64	83.92–85.22
S	7.43	6.96–7.91
H ₂ O*	4.60	
–S=O	–3.71	
Total	100.50	

* H₂O content derived from TG analysis.

CHEMICAL COMPOSITION

Quantitative chemical analyses (Table 3) were carried out by means of a Cameca SX 100 electron microprobe in wavelength-dispersive mode (Masaryk University, Brno), operated at an acceleration potential 15 kV, a sample current of 20 nA, and an

electron beam size of 5 μm . Albite, sanidine, Sb and ZnS were used as standards. When other standards for S were used, such as chalcopyrite, barite or stibnite, erroneous sulfur levels (about 30% too low) resulted for ottensite as well as for cetineite from the Cetine mine. Raw intensities were converted using the automatic PAP (Pouchou and Pichoir, 1985) matrix correction software package. The average of eight analyses of ottensite is given in Table 3, indicating an empirical formula of:



based on 15 anions. The simplified formula of ottensite is $\text{Na}_3(\text{Sb}_2\text{O}_3)_3(\text{SbS}_3) \cdot 3\text{H}_2\text{O}$.

THERMAL AND INFRARED ANALYSES

Thermo-gravimetric and differential thermal analysis curves with an analysis of escaping gases were obtained on a Setaram Setsys Evolution 1750 under the following conditions: $10^\circ\text{C min}^{-1}$, a dynamic air atmosphere of $20\text{ ml}\cdot\text{min}^{-1}$, a sample mass of 7.5 mg, measured over the range 20° to 1050°C . In the range 20 – 400°C a decrease in mass of 4.60 weight % with no release of SO_2 was observed; in the range 400 – 1050°C the thermal curves have a much more complex character, with several mass decreases and increases, several exotherms and endotherms, and a release of SO_2 in at least three temperature ranges.

The infrared spectrum of ottensite was obtained using an FTIR Nicolet 740 spectrophotometer and the KBr pellet method in the range 4000 to 400 cm^{-1} . The measured absorption bands are: 3444 , 1634 , 1018 , 993 , 762 , 633 and 498 cm^{-1} . This IR spectrum is similar to the spectrum of cetineite from the Cetine mine (Sabelli and Vezzalini, 1987). A very strong band at 3444 cm^{-1} is related to O-H stretching vibration in H_2O molecules and OH groups. A distinct band at 1630 cm^{-1} indicates the presence of structural H_2O molecules. The bands in the region 800 – 450 cm^{-1} (with the strongest band at 633 cm^{-1}) are due to vibrations of the metal-oxygen (Sb-O) bonds.

RELATED MINERALS

The composition of ottensite is very close to the ideal Na end-member composition in the cetineite-ottensite series. The presence of Na in cetineite from the Cetine mine (Sabelli and Vezzalini, 1987, and our results) suggests the possible existence of at least a partial isomorphous series between cetineite and ottensite. For the ideal formulae of cetineite-like minerals of the composition $(\text{K},\text{Na})_{3+x}(\text{Sb}_2\text{O}_3)_3(\text{SbS}_3)(\text{OH})_x(2.8-x)\text{H}_2\text{O}$, as proposed by Sabelli *et al.* (1988), values of $x = 0.5$ (cetineite from the Cetine mine, Sabelli *et al.*, 1988) and $x = 0.6$ (synthetic Na analog of cetineite, Sabelli *et al.*, 1988) have been published. For ottensite from Qinglong, with $\text{K}+\text{Na} = 2.69$ to 3.09 apfu , the x value is close to 0.

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