

GAITITE, $H_2Ca_2Zn(AsO_4)_2(OH)_2$, A NEW MINERAL FROM TSUMEB, NAMIBIA (SOUTH WEST AFRICA)

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ABSTRACT

Gaitite occurs as coatings and as small crystals on prosperite, adamite and austinite on specimens from Tsumeb, Namibia (South West Africa). Gaitite is white to colorless with vitreous lustre; white streak; hardness (Mohs) 5. Cleavage is good on {010}, {001} and {011}. Gaitite $H_2Ca_2Zn(AsO_4)_2(OH)_2$ and talmessite $H_2Ca_2Mg(AsO_4)_2(OH)_2$ are isostructural and form a solid-solution series. The indices of refraction of the zone with the composition $H_{2.00}Ca_{1.98}(Zn_{0.88}Mg_{0.14}Fe_{0.01}Mn_{0.01})(AsO_4)_{2.00}(OH)_{2.00}$ are α 1.713(2), β 1.730(2), γ 1.748(2); $2V\gamma$ 88°; the orientation of the indicatrix is X ($\phi = 28^\circ$, $\rho = 32^\circ$), Y ($\phi = 185^\circ$, $\rho = 60^\circ$) and Z ($\phi = -79^\circ$, $\rho = 80^\circ$). Gaitite is triclinic, space group $P1$ or $P\bar{1}$. Cell dimensions, similar to those of β -roselite and talmessite, are a 5.90(1), b 7.61(1), c 5.57(1) Å; α 111°40', $\beta = 70^\circ50'$, γ 119°25', all $\pm 5'$; D_{calc} is 3.80 g/cm³ for $Z = 1$, D_{meas} is 3.81(5) g/cm³. The strongest nine lines in the X-ray powder-diffraction pattern are: 5.05(40)(100), 3.581(40)($\bar{1}\bar{2}1$), 3.350(50)(110), 3.208(50)(020), 3.080(80)($\bar{1}\bar{1}1$), 2.781(100)($2\bar{2}1, 111$), 2.750(70)($\bar{1}\bar{1}2$), 2.165(40)($\bar{1}\bar{3}2$) and 1.721(60) Å.

Keywords: Gaitite, Tsumeb, Namibia, arsenate, new mineral description.

SOMMAIRE

On trouve la gaitite en enduits et en petits cristaux sur prosperite, adamite et austinite sur des spécimens de Tsumeb, Namibie (Afrique du Sud-Ouest). C'est un minéral blanc à incolore, à l'éclat vitreux, rayure blanche, dureté Mohs de 5 et bons clivages {010}, {001} et {011}. La gaitite $H_2Ca_2Zn(AsO_4)_2(OH)_2$ et le talmessite $H_2Ca_2Mg(AsO_4)_2(OH)_2$ forment une solution solide complète et sont donc isostructurelles. Les indices de réfraction de la zone de composition $H_{2.00}Ca_{1.98}(Zn_{0.88}Mg_{0.14}Fe_{0.01}Mn_{0.01})(AsO_4)_{2.00}(OH)_{2.00}$ sont: α 1.713(2), β 1.730(2), γ 1.748(2), $2V\gamma$ 88°; l'indicatrice a l'orientation X (ϕ 28°, ρ 32°), Y (ϕ 185°, ρ 60°), Z (ϕ -79°, ρ 80°). Triclinic; le groupe spatial reste indéterminé. Les dimensions de la maille ressemblent à celles de la β -rosélite et de la talmessite: a 5.90(1),

b 7.61(1), c 5.57(1) Å, α 111°40(5)', β 70°50(5)', γ 119°25(5)'; $D_{calc} = 3.80$ pour $Z = 1$, $D_{meas} = 3.81(5)$. Les neuf raies les plus intenses du cliché de poudre sont (d, l, hkl): 5.05(40)(100), 3.581(40)($\bar{1}\bar{2}1$), 3.350(50)(110), 3.208(50)(020), 3.080(80)($\bar{1}\bar{1}1$), 2.781(100)($2\bar{2}1, 111$), 2.750(70)($\bar{1}\bar{1}2$), 2.165(40)($\bar{1}\bar{3}2$) et 1.721(60) Å.

(Traduit par la Rédaction)

Mots-clés: gaitite, Tsumeb, Namibie, arséniate, nouvelle espèce minérale.

INTRODUCTION

During the study of prosperite (Gait *et al.* 1979), another phase found on the type specimen from Tsumeb, Namibia (South West Africa) was tentatively identified as talmessite, $H_2Ca_2Mg(AsO_4)_2(OH)_2$. However, an examination of the optical properties indicated that a large proportion of Mg must be replaced by another element, later identified by X-ray fluorescence as Zn. Subsequent microprobe analysis confirmed this observation and also showed that the grains are strongly zoned with large variations in the Mg:Zn ratios.

We take pleasure in naming this new mineral species in honor of Dr. Robert I. Gait, Curator of Mineralogy at the Royal Ontario Museum. We do so in recognition of his contributions to mineralogy (in particular his curatorial excellence) and his many exhibits explaining the concepts of mineralogy.

The name and the mineral have been approved by the Commission on New Minerals and Mineral Names, I.M.A. The name is pronounced GĒT•AIT. A type specimen, containing about 50 mg of gaitite, is preserved in the Royal Ontario Museum, Toronto (M35388). A polished thin section of the grain analyzed by microprobe has been registered at the United States National Museum of Natural History,

CRYSTALLOGRAPHY

Smithsonian Institution, Washington, D.C. (NMNH 144 799).

The strong Mg–Zn zoning indicates complete solid-solution between gaitite $H_2Ca_2Zn(AsO_4)_2(OH)_2$ and talmessite $H_2Ca_2Mg(AsO_4)_2(OH)_2$. The name *gaitite* is to be used for members in which Zn predominates.

There is some confusion about the name for the Mg end-member. Two names, talmessite and arsenate–belovite, have been used. The first, and unfortunately incomplete, description of the phase $H_2Ca_2Mg(AsO_4)_2(OH)_2$ was given by Nefedov (1954), who proposed the name belovite. However, the name belovite was also given to the Sr analogue of hydroxyl-apatite, described by Borodin & Kazakova (1954).

Yakhontova & Sidorenko (1956) proposed that the name arsenate–belovite be used for the mineral with the composition $H_2Ca_2Mg(AsO_4)_2(OH)_2$, and the name phosphate–belovite for $Sr_5(PO_4)_3(OH)$. The data were still incomplete, and it had not been determined whether arsenate–belovite belonged to the monoclinic roselite group or to the triclinic β -roselite group.

Bariand & Herpin (1960) described a triclinic modification of $H_2Ca_2Mg(AsO_4)_2(OH)_2$, from Talmessi in Iran, that is isostructural with β -roselite, $H_2Ca_2Co(AsO_4)_2(OH)_2$, and they used the name talmessite for it. Later, Pierrot (1964), after studying the type material of both talmessite and arsenate–belovite, showed that they are the same species. The name talmessite is now used by most mineralogists; in 1976 the Commission on New Minerals and Mineral Names, I.M.A., officially approved its use.

TABLE 1. CRYSTALLOGRAPHIC AND OPTICAL DATA FOR GAITITE

UNIT CELL:			
$H_2Ca_2(Zn_{0.84}Mg_{0.14}Fe_{0.01}Mn_{0.01})(AsO_4)_2(OH)_2$			
Space group $P\bar{1}$ or $P\bar{1}$; $Z = 1$			
$a = 5.90(1)\text{\AA}$		$d_{100} 5.05(1)\text{\AA}$	
$b = 7.61(1)\text{\AA}$		$d_{010} 6.41(1)\text{\AA}$	
$c = 5.57(1)\text{\AA}$		$d_{001} 5.09(1)\text{\AA}$	
$\alpha = 111^\circ 40(5)'$		$\alpha^* = 75^\circ 20(5)'$	
$\beta = 70^\circ 50(5)'$		$\beta^* = 100^\circ 30(5)'$	
$\gamma = 119^\circ 25(5)'$		$\gamma^* = 65^\circ 05(5)'$	
COORDINATES:			
	ϕ	ρ	
Forms	{100}	$65^\circ 05'$	$90^\circ 00'$
	{010}	$0^\circ 00'$	$90^\circ 00'$
	{001}	$-51^\circ 29'$	$23^\circ 57'$
	{011}	$211^\circ 01'$	$33^\circ 59'$
Principal Vibration Directions	X	28°	32°
	Y	185°	60°
	Z	-79°	80°
OPTICAL DATA:			
α	1.713(2)	$2V_\alpha = 88(2)^\circ$ (meas.)	
β	1.730(2)		
γ	1.748(2)	$2V_\gamma = 89^\circ$ (calc.)	

Gaitite is developed mostly as a polycrystalline coating; only a few small crystals were found, with the largest dimension of about 1 mm. The faces of only four forms were observed. The edges between the well-developed faces {010}, {001} and {011} enable one to find the a axis on the crystals or fragments; the face of {100} is usually very small.

The crystals were first examined with the two-circle optical goniometer. Then, the unit cell, similar to that given for talmessite, was found on the projections of the 0 and 1 levels of the reciprocal lattice, prepared from Weissenberg

TABLE 2. X-RAY POWDER-DIFFRACTION DATA FOR GAITITE AND TALMESSITE

TALMESSITE, JCPDS card #17-164		GAITITE			
I	d_{meas}	I	d_{meas}	d_{calc}	hkl
5	6.43	20	6.40	6.414	010
60	5.09	10	5.08	5.167	110
40	4.62	40	5.05	5.054	100
10	3.95	20	4.64	4.640	111
60	3.56	5	3.958	3.964	101
		40	3.581	3.583	121
		30	3.570	3.572	011
5	3.44	50	3.350	3.343	110
40	3.34	5	3.306	3.300	101
80	3.21	50	3.208	3.207	020
100	3.07	30	3.098	3.088	021
		80	3.080	3.077	111
		5	2.838	2.842	211
		30	2.815	2.810	111
		100	2.781	2.782	221
100	2.77	70	2.750	2.746	111
5	2.67	30	2.607	2.602	012
20	2.58	10	2.582	2.583	220
5	2.51	d10	2.520	2.527	200
20	2.44	10	2.445	2.447	131
		5	2.356	2.357	201
5	2.32	20	2.335	2.336	231
		5	2.303	2.320	222
40	2.16	40	2.165	2.304	120
		5	2.135	2.166	132
5	2.12	5	2.118		
10	2.07	30	2.071		
5	2.04	10	2.039		
		10	2.022		
20	2.01	20	2.010		
20	1.89	30	1.892		
20	1.86	10	1.870		
20	1.829	10	1.829		
20	1.782	10	1.801		
60	1.717	15	1.782		
		60	1.721		
		20	1.712		
40	1.697	30	1.700		
		5	1.688		
		5	1.601		
		10	1.584		
		20	1.581		
		10	1.555		
		5	1.545		
		20	1.538		
		10	1.538		
		5	1.521		
		5	1.492		
		10	1.461		
		5	1.432		
		10	1.407		
		5	1.390		
		5	1.373		
		5	1.339		
		5	1.242		

Guinier-de Wolff camera, $CuK\alpha$ radiation; intensities estimated visually; d = double.

photographs. The rotation- and precession-camera methods were used to complete the single-crystal study reported in Table 1.

The X-ray powder-diffraction pattern was indexed using the unit-cell dimensions determined by the single-crystal methods, and the intensities observed on films prepared by the single-crystal methods. In Table 2 the indexed pattern for gaitite is compared to the pattern of talmessite. The indexing for gaitite does not agree entirely with that of talmessite (*cf.*, PDF 17-164).

PHYSICAL AND OPTICAL PROPERTIES

The small grain size and zoning made an accurate determination of density nearly impossible. Density was determined by heavy-liquid methods on a small crystal fragment that was later analyzed with the microprobe (Table 3). Examination of the indices of refraction showed that the major part of the fragment is homogeneous. The measured density, 3.81(5) g/cm³, compares well with the calculated density of 3.80 g/cm³ for gaitite with the composition given in Table 3. The Mohs hardness is approximately 5.

Cleavage is not easily observed, but there are probably three equally good cleavages, {010}, {001} and {011}. Most gaitite fragments have an irregular outline with only one or two cleavages visible.

Gaitite is white to colorless; the lustre is vitreous and the streak is white. The optical properties were determined on the fragments that were analyzed with the microprobe. Optical data for the zone with the composition of H₂Ca₂(Zn_{0.84}Mg_{0.14}Fe_{0.01}Mn_{0.01})(AsO₄)₂(OH)₂ are shown in Table 1 and Figure 1.

Indices of refraction and indicatrix orientation were determined with the spindle stage in Na light on an analyzed grain that was oriented by X-ray single-crystal methods. The optic axial angle was determined on the universal stage.

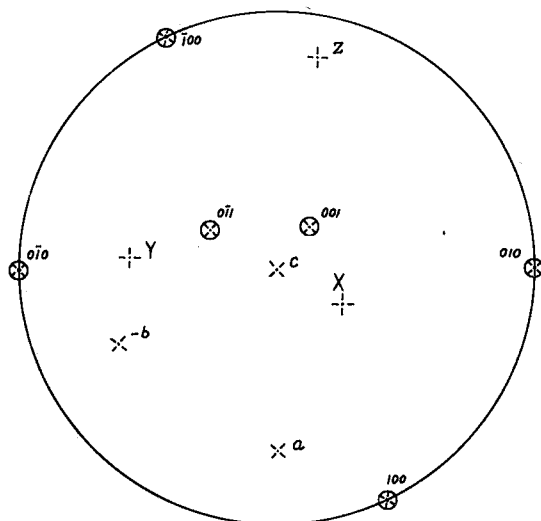


FIG. 1. Stereographic projection of optical and crystallographic elements of gaitite.

It was impossible to determine accurately the relationship between the Zn:Mg ratio and optical properties because of the strong zoning and small grain size. A zone with Zn:Mg = 1:1 is optically negative, $2V_{\alpha} = 85(5)^{\circ}$, and α 1.689(4), β 1.707(4) and γ 1.727(4). Replacement of Zn with Mg seems to lower the density, decrease the indices of refraction and change the optic axial angle to a negative value. The orientation of the indicatrix in the zones with different Zn:Mg ratios is nearly identical, as is indicated by nearly identical extinction for all zones.

Gaitite does not fluoresce in either long- or short-wave ultraviolet radiation. The Gladstone-Dale constant K_c (Mandarino 1976), calculated from the chemical composition given in Table 3, is 0.188, which compares well with the value $K_F = 0.192$, calculated from the measured density and indices of refraction.

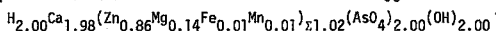
TABLE 3. MICROPROBE ANALYSIS OF GAITITE

	Analysis	Theory
MgO	1.2	0.0
CaO	24.2	24.42
ZnO	15.3	17.71
FeO	0.2	0.0
MnO	0.2	0.0
As ₂ O ₅	50.2	50.04
H ₂ O	7.8*	7.83
Total	99.1	100.00

Accuracy of data: $\pm 3\%$ of the amount present.

*H₂O determined by DTA/TGA

Empirical formula calculated on the basis of 10 oxygen atoms:



CHEMISTRY

Crystals of gaitite were analyzed using an ARL-SEMQ electron microprobe utilizing an operating voltage of 15 kV and a sample current of 0.15 μA . The data were corrected using Bence-Albee factors. The standards used for analysis were fluor-apatite for Ca, synthetic ZnO for Zn, synthetic olivenite for As, manganite for Mn and hornblende for Mg and Fe. A wavelength-dispersive scan indicated the absence of any elements with an atomic number above 9, except those reported here. The analysis (Table

3) is in good agreement with the theoretical composition.

DTA/TGA were performed with a Mettler Thermoanalyzer on 16 mg of material. The accurate Mg:Zn ratio of the grains used for analyses is not known, but it is probably similar to that of the grain analyzed with the microprobe (Table 3). The grains used for DTA/TGA were separated with heavy liquids and later examined on the microscope in the immersion liquids to ensure that major parts of the grains have density and indices of refraction similar to those of the grain analyzed with the microprobe. A total weight loss of 7.8% is related to two endothermic peaks, at 470 and 513°C, indicating that the water content can be expressed as hydroxyl in the formula. We do not have any additional evidence that hydroxyl and hydrogen are present, but propose to write the formula in this way until the structure is solved or IR analysis is made. At the moment, however, it is impossible to select enough material for IR analysis without destroying the type specimen.

The empirical formula calculated on the basis of O = 10 from the composition given in Table 3 is $H_{2.00}Ca_{2.198}(Zn_{0.86}Mg_{0.14}Fe_{0.01}Mn_{0.01})_{2=1.02}(AsO_4)_{2.00}(OH)_{2.00}$ or, ideally, $H_2Ca_2(Zn_{0.84}Mg_{0.14}Fe_{0.01}Mn_{0.01})(AsO_4)_2(OH)_2$.

The gaitite crystals examined in the present study are strongly zoned. The solid-solution series between gaitite and talmessite extends at least from Zn:Mg 86:14 to 36:64. In general, the Zn-rich zones occur in the centre of the crystals.

ASSOCIATED MINERALS

Gaitite was found on the specimen from Tsumeb, Namibia (South West Africa) on which prosperite was first identified. The associated minerals on this specimen are described in detail by Gait *et al.* (1979). Gaitite is one of the last minerals formed and is developed as a very thin, polycrystalline coating on prosperite, adamite and conichalcite. The matrix of the type specimen of gaitite is strongly altered chalcocite.

Subsequent to its characterization as a species, gaitite was found independently by Dr. Paul Keller of the University of Stuttgart, Federal Republic of Germany. Through the courtesy of Dr. Keller, we describe here the paragenesis on his specimen, which is different than that on the type specimen: the matrix is a severely altered chalcocite, coated liberally with the alteration product, conichalcite. The conichalcite is covered by massive, polycrystalline gaitite with a maximum grain size of 0.5 mm. No euhedral crystals were obser-

ved. Gaitite is followed in the sequence of formation by euhedral crystals of light green austinite, yellow barite and colorless to light pink quartz, in that order.

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