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GUSTAVITE: TWO CANADIAN OCCURRENCES

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ABSTRACT

Gustavite was identified from the deposit of Terra Mining and Exploration Co., Camsell River, Northwest Territories, and from the Tanco pegmatite, Bernic Lake, Manitoba. At Camsell River, the mineral occurs as inclusions in the cores of arsenide rosettes associated with bismuthinite and matildite, whereas at Bernic Lake gustavite occurs in grains associated with aikinite-bismuthinite intergrowths, cosalite, chalcopyrite, native bismuth and arsenopyrite. Gustavite has the space group symmetry $P2_1/c$ with $a = 7.077$, $b = 19.566$, $c = 8.272$Å and $\beta = 107.18°$. It has a prominent pseudocell with diffraction aspect Bb^{**} and $a = 13.52$, $b = 19.57$, $c = 4.14$Å. Electron microprobe analyses of gustavite from Camsell River gave the composition $Ag_{1.02}Pb_{1.13}Bi_{3.00}S_{6.38}$, whereas the material from Bernic Lake is $Ag_{0.85}Pb_{1.03}Bi_{2.69}Sb_{0.31}S_{6.04}$.

RÉSUMÉ

Les auteurs ont identifié de la gustavite dans le gisement de Terra Mining and Exploration Company, à la rivière Camsell dans les Territoires du Nord-Ouest ainsi que dans le Tanco pegmatite, du lac Bernic, Manitoba. A la rivière Camsell, le minéral se présente sous forme d'inclusions dans les noyaux de rosettes d'arsénide associées au bismuthinite et au matildite; tandis qu'au lac Bernic la gustavite se présente sous forme de grains associés à la cosalite, chalcopyrite, au bismuth natif, à l'arsénopyrite et à des enchevêtrements d'aikinite-bismuthinite. La gustavite a la symétrie de groupe spatial $P2_1/c$ avec $a = 7.077$, $b = 19.566$, $c = 8.272$Å, et $\beta = 107.18°$. Elle possède une pseudocellule proéminente avec un aspect de diffraction Bb^{**} et $a = 13.52$, $b = 19.57$, $c = 4.14$Å. Des analyses à la micro-sonde électronique de la gustavite de la rivière Camsell ont donné la composition $Ag_{1.02}Pb_{1.13}Bi_{3.00}S_{6.38}$, tandis que le matériel du lac Bernic a la composititon $Ag_{0.85}Pb_{1.03}Bi_{2.69}Sb_{0.31}S_{6.04}$.

INTRODUCTION

Gustavite, a silver-lead-bismuth sulphosalt from the cryolite deposits at Ivigtut in southwestern Greenland was discovered and named by Karup-Møller (1970). Subsequently, Karup-Møller (1972) recorded further occurrences of gustavite in specimens from Alaska mine, Colorado; Old Lout, Ouray County, Colorado; Gladiator mine, Colorado; and Silver Bell mine, Red Mountain, Colorado.

The purpose of this paper is to record the first occurrences of gustavite in Canada and to report additional single-crystal observations which will further characterize the mineral.

GENERAL DESCRIPTION

Gustavite was identified in 1972 during a mineralogical investigation of an ore from the mine of Terra Mining and Exploration Company, Camsell River, Northwest Territories. Later, in 1973, a mineral of similar optical and physical properties, but with a small variation in composition, was encountered in sulphide-rich specimens from the Tanco pegmatite, Bernic Lake, Manitoba.

The Terra property is southeast of Great Bear Lake in the Camsell River silver district between latitudes 65°34′ and 65°38′N and longitudes 117°55′ and 118°10′W. The deposit is a silver-rich ore in which two distinct mineral assemblages, one sulphide and one arsenide, are evident. The sulphide assemblage consists mainly of pyrite, chalcopyrite, sphalerite, galena and tetrahedrite, whereas the arsenide assemblage, which is more complex, consists mainly of nickeline, safflorite, skutterudite, rammelsbergite, arsenopyrite, native silver, native bismuth, bismuthinite, matildite, gustavite, acanthite and a pavonite-type mineral. Gustavite is rare in the ore and occurs as inclusions (up to 200 microns) in the cores of arsenide rosettes associated with bismuthinite, matildite and the pavonite-type mineral. More details of the deposit are reported by Shegelski (1973) and Badham (1975).

The Tanco pegmatite deposit at Bernic Lake in southeastern Manitoba is currently being mined for tantalum oxide minerals, but it also contains refractory-grade spodumene and the world's largest known concentration of pollucite (Crouse & Černý 1972). Rare occurrences of sulphide minerals have been encountered in pegmatite, of which a more detailed study is nearing completion and will be published at a later date. One of the sulphide minerals, gustavite, occurs in grains up to 1×2 mm associated with aikinite-bismuthinite intergrowths, cosalite, native bismuth, chalcopyrite, tetrahedrite, pyrrhotite, stannite and arsenopyrite.

The optical properties of gustavite from both localities are identical and correspond to those reported by Karup-Møller (1970). The mineral is grey to bluish grey and shows moderate to strong anisotropism with colours of light grey to dark steel grey. In contrast to aikinite, the mineral appears bluish, whereas aikinite has a greenish tinge. In the Bernic Lake specimen, gustavite has two distinct cleavages, one parallel and a second oblique to the elongation of the laths. Reflectance and micro-indentation hardness were determined on gustavite from both localities and are given in Table 1.

X-Ray Crystallography

Precession photographs were taken with filtered molybdenum radiation on fragments pre-analyzed by electron microprobe and a Gandolfi camera. The reflection conditions observed were $l = 2n$ for $(h0l)$ and $k = 2n$ for $(0k0)$, corresponding to space group $P2_1/c$. The cell parameters were refined by a least-squares program (PARAM, Stewart *et al.* 1972) using powder diffraction data. The refined values give $a = 7.077(7)$, $b = 19.566(12)$, $c = 8.272(8)$Å, and $\beta = 107.18(9)°$ for the gustavite from Bernic Lake (Table 2).

Karup-Møller (1970) reported that gustavite had an orthorhombic unit cell with diffraction aspect $Bb{*}{*}$ (Table 2) and a superstructure with *a* and *c* double those of the *B*-cell. In the *P*-cell, if the relatively weak $l = 2n+1$ reflections are ignored, the reflection conditions give a pseudo-cell with diffraction aspect $Bb{*}{*}$ corresponding to space groups $Bbmm$, $Bb2_1m$, or $Bbm2$ and with cell dimensions of $a = 13.522$, $b = 19.566$, $c = 4.136$Å (Fig. 1). The *B*-cell is related to the *P*-cell by transformation of 2 0 ½/ 0 1 0/ 0 0 ½ from the *P*-cell. Thus if one assumes the *B*-cell to be a true cell for gustavite, a superlattice with *a* and *c* doubling those of the *B*-cell would be observed. This *B*-cell corresponds well to the *B*-cell reported by Karup-Møller (1970).

TABLE 1. REFLECTANCE AND MICRO-INDENTATION HARDNESS OF GUSTAVITE

	Bernic Lake		Camsell River		Greenland *
Wavelength	Range	Mean	Range	Mean	Range
470 nm	42.7-46.9	44.8	44.0-48.7	46.8	
546	40.0-43.6	42.0	41.5-45.8	44.1	42-46
589	39.4-42.3	40.9	40.8-45.1	43.3	
650	38.9-42.6	40.8	39.5-43.8	42.1	
Micro-indentation hardness (kg/mm^2)	VHN_{50} = 255(188-277)		219(187-235)		VHN_{100} = 175-218

* Gustavite containing Phase X, $Bi_{10}Pb_7Ag_2S_{23}$ (Karup-Møller 1970)

TABLE 2. UNIT CELL OF GUSTAVITE

	Bernic Lake Gustavite	Camsell River Gustavite	Greenland* Gustavite	Greenland* Phase X ($Ag_2Pb_7Bi_{10}S_{23}$)
Space Group	$P2_1/c$	$P2_1/c$	$Bbmm$, $Bb2_1m$, $Bbm2$	
a	7.077(7)Å	7.069(4)Å	13.548(33)Å	13.548Å
b	19.566(12)	19.612(9)	19.449(26)	20.0
c	8.272(8)	8.283(7)	4.105(13)	4.105
β	107.18(9)°	107.23(8)°	90°	90°
Z	4	4	4	1
	Pseudo-cell**		Super-cell	
Space Group	$Bbmm$, $Bb2_1m$, $Bbm2$			
a	13.522Å	13.504Å	13.548 x 2Å	
b	19.566	19.612	19.449	
c	4.136	4.142	4.105 x 2	

* Karup-Møller (1970). ** *P*-cell → *B*-cell by 2 0 ½ / 0 1 0 / 0 0 ½

Doubling of each reflection on the precession photographs of some of the fragments was observed. The doubling is interpreted as arising from two gustavite crystals in an approximately parallel intergrowth. Karup-Møller's exsolved phase X, $Bi_{10}Pb_7Ag_2S_{23}$, with the same space group, *a* and *c* values identical to those of gustavite, and a relatively large *b* dimension (20.0Å), was not found.

X-ray powder diffraction data for gustavite were obtained using a Gandolfi camera. The pattern was indexed by comparison of the observed *d*-values with the calculated values obtained from single-crystal data, and the in-

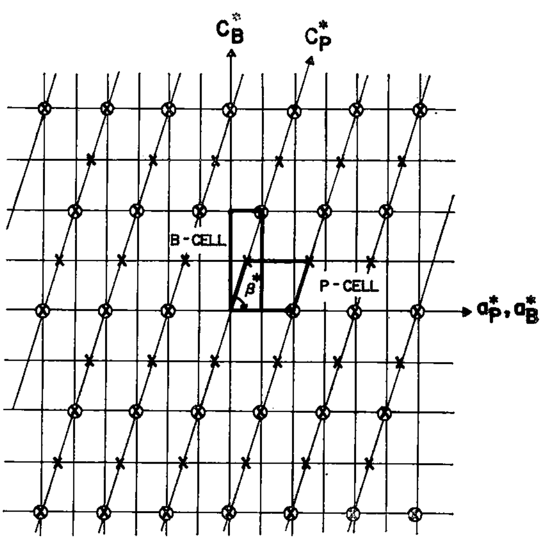

FIG. 1. Reciprocal points of the *b*-axis precession photographs of gustavite. ○ zero-level; × 1st, 2nd, or 3rd level.

TABLE 3. X-RAY POWDER DIFFRACTION DATA OF GUSTAVITE

		Bernic Lake[1]		Camsell River[1]		Greenland[2]	
hkl	d_{calc}	d_{obs}	I_{est}	d_{obs}	I_{est}	d_{obs}	I_{est}
						9.846	1
						6.381	2
						5.565	1
						4.705	1
140	3.967	3.960	3	3.973	4	3.977	5
						3.844	2
022	3.669	3.660	4	3.667	4	3.640	8
150	3.392					3.401	8
032	3.384	3.381	10	3.379	10	3.376	8
200	3.376					3.363	10
210	3.327	3.319	1	3.321	2	3.326	5
						3.237	1
220	3.192	3.195	1	3.195	2	3.190	3
102	3.043	3.051	1	3.044	1	3.068	3
						3.033	2
112	3.007	3.007	5	3.007	6	2.996	10
160	2.942	2.943	1	2.938	2	2.911	5
122	2.906	2.905	7	2.900	8	2.895	10
132	2.759	2.756	4	2.759	4	2.751	8
170	2.588	2.589	1	2.590	2		
072	2.286	2.285	3	2.287	3		
202	2.259	2.265	3	2.260	3		
232	2.135	2.132	3	2.131	4		
330	2.128						
$\bar{1}04$	2.071	2.069	2	2.070	4		
242	2.051	2.050	5	2.048	8		
340	2.045						
0.10.0	1.961	1.954	3	1.959	5		
252	1.957						
182	1.909	1.906	2	1.907	4		
262	1.858	1.856	1	1.858	2		
044	1.834	1.830	2	1.833	2		
290	1.831						
370	1.755	1.756	7	1.755	5		
302	1.746	1.748	1	1.747	2		
2.10.0	1.696	1.694	3	1.697	2		
410	1.682			1.680	1		
420	1.664	1.663	2	1.662	2		

1. Cu$K\alpha_1$ radiation (λ = 1.5405 Å); corrected by back reflections; 114.6 mm Gandolfi camera; *d* calculated from *a*= 7.069 *b*=19.612 *c*= 8.283 Å and β=107.23°

2. Karup-Møller (1970). Guinier camera. Cu$K\alpha$ radiation. The original data included several unindexable lines: 6.130(2), 5.806(1), 3.721(3), 3.590(2), 3.516(3), 3.304(4), 3.282(2), 2.953(4), and 2.804(2).

tensities were checked using single-crystal photographs as a guide. Film shrinkage was corrected using back reflections. The data are listed in Table 3 in comparison with those of the type specimen from Greenland (Karup-Møller 1970).

The powder diffraction data of gustavite from Bernic Lake and Camsell River are nearly identical. The discrepancy in Karup-Møller's data from the present data is apparently due to the presence of impurity in his sample, indicated by the presence of several unindexable lines in his data. The powder diffraction data of gustavite from Bernic Lake and Camsell River are similar to those of the unknown (Pb,Bi,Cu,Ag?)-sulphosalt from Castlegar, British Columbia, reported by Drummond *et al.* (1969), and it is very likely that this unknown sulphosalt is gustavite.

Electron Microprobe Analysis

Microprobe analyses were carried out on several grains of gustavite from both localities. The grains were of sufficient size that inclusions or interferences from adjacent phases were avoided. The instrument used for the analyses was a Materials Analysis Company (MAC) electron microprobe with the data processed by the computer program (EMPADR VII) of Rucklidge & Gasparrini (1969). The following synthetic standards and *x*-ray lines were used: $AgBiS_2$ for Ag$L\alpha$, Bi$L\alpha$, S$K\alpha$, PbS for Pb$L\alpha$ and Sb_2S_3 for Sb$L\alpha$. Results of the analyses are listed in Table 4.

TABLE 4. ELECTRON MICROPROBE ANALYSES OF GUSTAVITE

	Weight per cent				Atomic ratio			
	Bernic Lake Manitoba		Camsell River N.W.T.	Red Mountain Colorado*	Bernic Lake Manitoba		Camsell River N.W.T.	Red Mountain Colorado
Ag	8.9	7.8	9.4	9.2	0.89	0.80	1.02	0.92
Cu	-	-	-	0.4	-	-	-	0.06
Pb	18.9	20.2	19.9	18.3	0.99	1.07	1.13	0.95
Bi	52.0	50.3	53.2	53.1	2.71	2.67	3.00	2.73
Sb	3.3	3.6	-	3.1	0.29	0.33	-	0.27
S	17.7	17.6	17.4	17.5	6.00	6.08	6.38	5.87
Total	100.8	99.5	99.9	101.6				

* Karup-Møller (1972).

Karup-Møller (1970) suggested, from the chemical data for gustavite from Ivigtut, Greenland and the Silver Bell mine, Colorado, that the name gustavite should be restricted to the end-member of a solid-solution series, of which the composition would be $AgPbBi_3S_6$. Analysis of gustavite (Karup-Møller 1972) from Old Lout, Ouray County, Colorado yields a composition very close, if not identical, to $AgPbBi_3S_6$, with minor substitutions of copper and antimony for silver and bismuth, respectively. The analyses of gustavite from the Camsell River, and Bernic Lake localities support the $AgPbBi_3S_6$ formula. The present observations do not support Karup-Møller's proposal that a solid-solution series exists between lillianite ($Pb_3Bi_2S_6$) and gustavite ($AgPbBi_3S_6$) because the two minerals possess different crystal symmetry. It is possible that variations in compositions reported by Karup-Møller can be attributed to interferences from adjacent phases or unrecognized inclusions as shown in his *x*-ray powder data. The analyses of gustavite from Greenland for which Karup-Møller derived a composition of $Bi_{11}Pb_5Ag_3S_{23}$ may be questioned, as the analyses were carried out on four grains containing unusually thick lamellae of phase X ($Bi_{10}Pb_7Ag_2S_{23}$).

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References

BADHAM, J. P. N. (1975): Mineralogy, paragenesis and origin of the Ag-Ni,Co arsenide mineralization, Camsell River, N.W.T. Canada. *Mineralium Deposita* **10**, 153-175.

CROUSE, R. A. & ČERNY, P. (1972): The Tanco pegmatite at Bernic Lake, Manitoba: I. Geology and paragenesis. *Can. Mineral.* **11**, 591-608.

DRUMMOND, A. D., TROTTER, J., THOMPSON, R. M. & GOWER, J. A. (1969): Neyite, a new sulphosalt from Alice Arm, British Columbia. *Can. Mineral.* **10**, 90-96.

KARUP-MØLLER, S. (1970): Gustavite, a new sulphosalt from Greenland. *Can. Mineral.* **10**, 173-190.

——— (1972): New data on pavonite, gustavite and some related sulphosalt minerals. *N. Jb. Miner. Abh.* **117**, 19-38.

RUCKLIDGE, J. & GASPARRINI, E. L. (1969): Electron micro-probe analytical data reduction (EMPADR VII). *Dept. Geol. Univ. Toronto.*

SHEGELSKI, R. J. (1973): *Geology and Mineralogy of the Terra Silver Mine, Camsell River, Northwest Territories.* M.Sc. thesis, Dept. Geol., Univ. Toronto.

STEWART, J. M., KRUGER, G. J., AMMON, H. L., DICKINSON, C. & HALL, S. R. (1972): The *x*-ray system of crystallographic programs for any computer. *Univ. Maryland, Computer Sci. Center, Tech. Rept.* TR-192.

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