American Mineralogist, Volume 69, pages 207–209, 1984

Garyansellite, a new mineral from Yukon Territory, Canada

B. Darko Sturman

Department of Mineralogy and Geology
Royal Ontario Museum, Toronto, Ontario M5S 2C6, Canada

and Pete J. Dunn

Department of Mineral Sciences
Smithsonian Institution, Washington, D.C. 20560

Abstract

Garyansellite is the Mg-dominant member of the group that includes phosphoferrite $Fe_3^{2+}(PO_4)_2 \cdot 3H_2O$, reddingite $Mn_3^{2+}(PO_4)_2 \cdot 3H_2O$ and kryzhanovskite $Fe_3^{3+}(PO_4)_2(OH)_3$. Crystals from an iron formation in the northeastern Yukon Territory have Fe^{3+} partially replaced by Mg. The formula for the type material calculated from the microprobe analysis, DTA/TGA, and titration with the potassium dichromate is: $(Mg_{1.45}Fe^{3+}_{1.39}Mn_{0.14}Al_{0.01}Fe^{2+}_{0.01})_{\Sigma=3.00}(PO_4)_{1.99}(OH)_{1.43} \cdot 1.52H_2O$. Garyansellite occurs as plates parallel to {010} or small crystals elongate parallel to [100] and with large faces of {111} and {011}. The hardness is 4 on Mohs' scale, it has good {001} cleavage, and the density is 3.154 g/cm^3 (calc.) and 3.16(4) g/cm^3 (meas.). It is brown in color with brown streak, a vitreous luster, and shows characteristic bronze luster on cleavage surfaces. Garyansellite is biaxial, negative with $2V_x = 55(2)°$(meas.); $\alpha = 1.733(2)$, $\beta = 1.757(2)$, $\gamma = 1.761(2)$; pleochroism: X—reddish brown, Y—yellow, Z—reddish brown; absorption: $Z = X > Y$. Orientation of the indicatrix is $Z \| c$ and $X \| b$. It is orthorhombic, $Pbna$, $a = 9.452(4)$, $b = 9.890(5)$, $c = 8.198(4)$Å. The strongest six lines in the powder pattern are [d in Å (I)(hkl)]: 4.93(50)(020), 4.26(30)(210), 3.156(100)(221), 3.098(40)(202), 2.705(60)(230), 2.535(30)(113).

Introduction

Recent studies of the minerals from a sedimentary iron formation in northeastern Yukon Territory have resulted in the description of several new minerals. Two of those, barićite (Sturman and Mandarino, 1976) and penikisite (Mandarino *et al.*, 1977) are magnesium analogues of previously known species. The partial substitution of iron by magnesium was found in three other minerals from the locality: metavivianite, ludlamite and kryzhanovskite. Study of kryzhanovskite specimens from different outcrops showed that the Fe:Mg ratio varies from specimen to specimen and that crystals are often zoned with approximately ¼ to ½ of total iron replaced by magnesium. A complete study of optical and physical properties, crystallography and chemistry was therefore made using the specimen shown to have the largest amount of Mg.

This new mineral from Canada, a magnesium analogue of kryzhanovskite, is named garyansellite in honor of H. Gary Ansell, Associate Curator of the National Mineral Collection of Canada of the Geological Survey of Canada, for his contributions to the preservation, recovery and curation of Canadian minerals. He has collected and studied specimens from the iron deposit in the northeastern Yukon Territory, and has played an important role in their preservation. The new species and the name were approved by the Commission on New Minerals and Mineral Names, I.M.A., prior to publication. Type material is preserved in the Royal Ontario Museum under catalog number M37306.

Crystallography

The plates and crystals of the kryzhanovskite–garyansellite series show identical habit on all examined specimens from the Yukon. The plates are flattened parallel to {010} and often show {001} cleavage. Crystals are rare and occur on only a few specimens. All crystals have identical habit as shown in Figure 1. They are elongated parallel to [100] with large {111} and {011} faces.

A single-crystal X-ray diffraction study using Weissenberg and precession methods was conducted on a small fragment of garyansellite from the type specimen (ROM #M37306). Optical properties were determined on the same grain and it was later analysed by microprobe. Other grains with similar density were selected from the same specimen for determination of the Fe^{2+}:Fe^{3+} ratio, DTA/TGA data, and powder diffraction data.

The space group of garyansellite, determined by single-

0003–004X/84/0102–0207$02.00

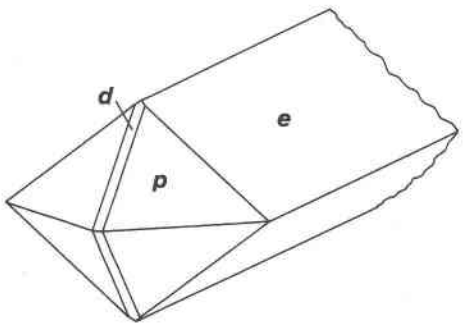

Fig. 1. Crystal drawing of a typical garyansellite crystal with forms e {011}, d {101}, and p {111}.

crystal methods, and the unit cell dimensions, determined by least-squares refinement of powder data, are given in Table 1, and are compared with data for kryzhanovskite from the Yukon (this study) and for co-type kryzhanovskite from Kolbinsk, USSR (Moore *et al.*, 1980). The powder pattern of garyansellite, given in Table 2, was indexed with the aid of the observed intensities on the precession camera films. It is in good agreement with data for kryzhanovskite from Kolbinsk, USSR (Moore *et al.*, 1980).

Table 2. X-ray powder diffraction data for garyansellite

I/I_o	d_{obs}	$d_{calc.}$	hkl	I/I_o	d_{obs}	$d_{calc.}$	hkl
20	5.23	5.249	111	10	2.062	2.066	142
50	4.93	4.945	020			2.064	303
20	4.72	4.726	200	10	1.991	1.991	332
30	4.26	4.264	210	1	1.931	1.932	242
20	3.870	3.864	121	1	1.918	1.922	233
10	3.418	3.417	220			1.921	430
100	3.156	3.154	221	5	1.904	1.905	323
40	3.098	3.096	202	20	1.892	1.893	341
						1.891	422
20	2.994	2.993	122				
10	2.940	2.941	301	5	1.839		
60	2.705	2.704	230	5	1.809		
10	2.627	2.625	103	10	1.725		
		2.624	222	5	1.691		
30	2.535	2.537	113	5	1.608		
1	2.478	2.479	132	10	1.592		
5	2.424	2.422	312	5	1.572		
1	2.395	2.392	023	10	1.553		
10	2.368	2.367	041	5	1.548		
10	2.318	2.319	123	10	1.530		
20	2.298	2.301	213	30	1.492		
		3.296	141				
30	2.213	2.213	411				
30	2.193	2.195	331				
10	2.115	2.117	042				
		2.117	241				

CuKα radiation; Guinier camera; intensities estimated visually. Unit cell parameters used in calculation are given in Table 1.

Table 1. Unit cell parameters and optical and physical data for the kryzhanovskite–garyansellite series

	Kryzhanovskite* Kolbinsk, USSR	Kryzhanovskite** Yukon, M34638	Garyansellite*** Yukon, M37306
Space group	*Pbna*†	*Pbna*	*Pbna*
a	9.450(2)	9.462(3)	9.452(4)
b	10.013(2)	9.874(4)	9.890(5)
c	8.179(2)	8.128(3)	8.198(4)
Z	4	4	4
D calc. (g/cm^3)	3.464	3.35	3.154
D meas. (g/cm^3)	3.31††	3.26(4)	3.16(4)
α	1.79	1.787(3)	1.733(2)
β	-	1.802(3)	1.757(2)
γ	1.82	1.825(5)	1.761(2)
2V meas.	$2V_z$=40-45°	$2V_z$=82(2)°	$2V_x$=55(2)°
2V calc.	-	$2V_z$=79°	$2V_x$=44°
dispersion of optic axes	*r*<*v*	*r*>*v*	*r*<*v*
pleochroism *X*	wine yellow	reddish-brown	reddish-brown
pleochroism *Y*	orange brown	yellow	yellow
pleochroism *Z*	reddish-brown	reddish-brown	reddish-brown
absorption	Z>Y>X	Z=X>Y	Z=X>Y
orientation of the indicatrix		*a*// *Z* *b*// *X* *a*// *Y*	*a*// *Z* *b*// *X* *a*// *Y*
cleavage	{001}	{001}	{001}

*Alekseev analysis in Ginzburg, 1950, gives $(Fe^{3+}_{1.80}Mn_{0.96}Mg_{0.13}Ca_{0.11})_3(PO_4)_2(OH)_{1.80}\cdot 1.20\ H_2O$.

**microprobe analysis gives $(Fe^{3+}_{2.00}Mg_{0.83}Mn_{0.17})_3(PO_4)_2(OH)_{2.00}\cdot 1.00\ H_2O$.

***complete analysis gives $(Mg_{1.45}Fe^{3+}_{1.39}Mn_{0.14}Al_{0.01}Fe^{2+}_{0.01})_3(PO_4)_{1.99}(OH)_{1.43}\cdot 1.52\ H_2O$.

†Moore *et al.* 1980, calculated density and unit cell.

††Ginzburg, 1950, optical data and measured density.

Optical and physical properties

Optical and physical properties of three members of the garyansellite–kryzhanovskite series are given in Table 1. The crystals and plates from many specimens show weak zoning and special care was taken to determine the properties of the zone that was chemically analyzed. All members of the garyansellite–kryzhanovskite series from the Yukon are clove brown in color, have brown streak, vitreous luster, and have characteristic bronze luster on cleavage surfaces. The Mohs' hardness is 4. The {001} cleavage is good.

Densities were determined using the heavy-liquid method. The disparities between calculated and measured values (Table 1) are probably due to air trapped in incipient cleavages. Optical data were determined in sodium light using a Supper spindle-stage on fragments previously oriented by the precession method. The Gladstone-Dale relationship yields $K_P = 0.237$ using the measured density and refractive indices, and $K_C = 0.237$ for the composition given below using the constants of Mandarino (1976). The members of the garyansellite–kryzhanovskite series do not fluoresce in ultraviolet radiation.

Occurrence

Members of the garyansellite–kryzhanovskite series are found in fractures in an iron formation in northeastern

Yukon Territory. Crystals were found in only one outcrop and have the largest dimension of approximately 1–2 mm. On most specimens garyansellite–kryzhanovskite occurs as plates associated with ludlamite, arrojadite, quartz, vivianite, metavivianite and souzalite. The sedimentary strata in which these minerals are found is not metamorphosed, and they apparently were formed at low temperature. The geology of the area is described by Young (1977).

The type specimen of garyansellite was collected on the east side of Rapid Creek, about 1 km north of junction of Lake Creek. The coordinates of the outcrop are 68°34′N and 136°46′W.

Chemical composition

The samples studied herein were chemically analyzed utilizing an ARL-SEMQ electron microprobe with an operating voltage of 15 kV and a beam current of 0.15 μA. The standards used were arrojadite for Fe, Al and Mn, hornblende for Mg, and montgomeryite for P. The data were corrected using Bence–Albee factors. Total iron was determined by microprobe and Fe^{2+} was determined by titration with potassium dichromate; the remaining iron was calculated as Fe^{3+}. Water was determined by DTA/TGA using a Mettler Thermoanalyzer on 11 mg of material with density similar to the grain analyzed by microprobe. The weight loss of 11.0 percent is related to water pressure maxima at 335°, 500° and 612°C. Although the loss of water was observed to occur over the range 80°–785°C, 94% of water loss occurred between 300° and 665°C. The complete analysis is the following: Al_2O_3 0.1, Fe_2O_3 30.5, FeO 0.3, MgO 16.0, MnO 2.7, P_2O_5 38.8, H_2O 11.0, total 99.4%. The empirical formula based on the sum of octahedral cations equal to 3.00 is: $(Mg_{1.45}Fe^{3+}_{1.39}Mn_{0.14}Al_{0.01}Fe^{2+}_{0.01})_{\Sigma=3.00}(PO_4)_{1.99}(OH)_{1.43} \cdot 1.52H_2O$ or ideally: $(Mg,Fe^{3+})_3(PO_4)_2(OH)_{1.5} \cdot 1.5H_2O$.

Moore *et al.* (1980) proposed a general formula for the phosphoferrite group of $M(1)M(2)_2[(OH),H_2O]_3(PO_4)_2$ and reported the occurrence of extensive ordering over the $M(1)$ and $M(2)$ sites with the smallest cations in the $M(1)$ site. We have no structure data permitting us to definitively state such ordering in garyansellite, but we emphasize that garyansellite is a unique species, a Mg-dominant member of the phosphoferrite group, regardless of the presence or absence of such ordering.

Acknowledgments

We thank Ms. Julie Norberg for determination of ferric iron by titration. The authors are grateful to the following staff members of the ROM for their help: Mr. Robert Ramik for the DTA/TGA, Mrs. Cynthia Peat for preparing the X-ray powder diffraction pattern, Miss Helen Driver and Margaret Coutinho for typing the manuscript. We thank Dr. Mandarino and Dr. Gait for helpful discussions during the study, especially concerning the nomenclature of the group. The comments of Drs. D. R. Peacor and A. R. Kampf have greatly improved the manuscript.

References

Ginzburg, A. I. (1950) Kryzhanovskite—a new mineral of the phosphate group. Doklady Akademie Nauk SSSR, 72, 763–766.

Mandarino, J. A. (1976) The Gladstone–Dale relationship. Part I: Derivation of new constants. Canadian Mineralogist, 14, 498–502.

Mandarino, J. A., Sturman, B. D. and Corlett, M. I. (1977) Penikisite, the magnesium analogue of kulanite, from Yukon Territory. Canadian Mineralogist, 15, 393–395.

Moore, P. B., Araki, T., and Kampf, A. R. (1980) Nomenclature of the phosphoferrite structure type: refinements of landesite and kryzhanovskite. Mineralogical Magazine, 43, 789–795.

Sturman, B. D. and Mandarino, J. A. (1976) Baricite, the magnesium analogue of vivianite, from Yukon Territory, Canada. Canadian Mineralogist, 14, 403–406.

Young, F. G. (1977) The mid-Cretaceous flysch and phosphatic ironstone sequence, northern Richardson Mountains, Yukon Territory. Report of Activities, Part C; Geological Survey of Canada, Paper 77–1C, 67–74.

Manuscript received, September 8, 1982;
accepted for publication, May 26, 1983.