

Garyansellite, a new mineral from Yukon Territory, Canada

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Abstract

Garyansellite is the Mg-dominant member of the group that includes phosphoferrite $\text{Fe}_3^{2+}(\text{PO}_4)_2 \cdot 3\text{H}_2\text{O}$, reddingite $\text{Mn}_3^{2+}(\text{PO}_4)_2 \cdot 3\text{H}_2\text{O}$ and kryzhanovskite $\text{Fe}_3^{3+}(\text{PO}_4)_2(\text{OH})_3$. 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: $(\text{Mg}_{1.45}\text{Fe}_{1.39}^{3+}\text{Mn}_{0.14}\text{Al}_{0.01}\text{Fe}_{0.01}^{2+})_{\Sigma=3.00}(\text{PO}_4)_{1.99}(\text{OH})_{1.43} \cdot 1.52\text{H}_2\text{O}$. 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 $3.16(4) \text{ g/cm}^3$ (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 $2V_x = 55(2)^\circ$ (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 $Z \parallel c$ and $X \parallel b$. It is orthorhombic, *Pbna*, $a = 9.452(4)$, $b = 9.890(5)$, $c = 8.198(4) \text{ \AA}$. The strongest six lines in the powder pattern are [d in \AA (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, baričite (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 $\frac{1}{4}$ to $\frac{1}{2}$ 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 northeast-

ern 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 $\text{Fe}^{2+}:\text{Fe}^{3+}$ ratio, DTA/TGA data, and powder diffraction data.

The space group of garyansellite, determined by single-

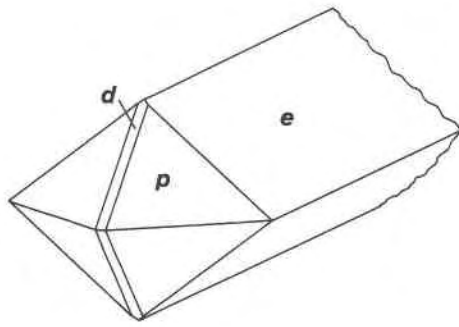


Fig. 1. Crystal drawing of a typical garyansellite crystal with forms e {011}, d {101}, and p {111}.

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

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

| | Kryzhanovskite* | Kryzhanovskite** | Garyansellite*** |
|-------------------------------|--|---|---|
| | Kolbinsk, USSR | Yukon, M34638 | Yukon, M37306 |
| Space group | $Pbma$ [†] | $Pbma$ | $Pbna$ |
| 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 _z = 55(2)° |
| 2V calc. | - | 2V _z = 79° | 2V _z = 44° |
| dispersion of optic axes | $n < v$ | $n > v$ | $n < v$ |
| pleochroism | X wine yellow Y orange brown Z reddish-brown | reddish-brown yellow reddish-brown | reddish-brown yellow reddish-brown |
| absorption | Z > Y > X | Z = X > Y | Z = X > Y |
| orientation of the indicatrix | \parallel | $a \parallel Z$ $b \parallel X$ $a \parallel Y$ | $a \parallel Z$ $b \parallel X$ $a \parallel Y$ |
| cleavage | {001} | {001} | {001} |

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

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

***complete analysis gives $(Mg_{1.45}Fe_{1.39}Mn_{0.14}Al_{0.01}Fe_{0.01}^{2+})_3(PO_4)_2(OH)_{1.43} \cdot 1.52 H_2O$.

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

^{††}Ginzburg, 1950, optical data and measured density.

Table 2. X-ray powder diffraction data for garyansellite

| I/I_0 | d_{obs} | $d_{calc.}$ | hkl | I/I_0 | 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 | | | | |

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

for kryzhanovskite from Kolbinsk, USSR (Moore *et al.*, 1980).

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 μ A. 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 Fe²⁺ was determined by titration with potassium dichromate; the remaining iron was calculated as Fe³⁺. 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: Al₂O₃ 0.1, Fe₂O₃ 30.5, FeO 0.3, MgO 16.0, MnO 2.7, P₂O₅ 38.8, H₂O 11.0, total 99.4%. The empirical formula based on the sum of octahedral cations equal to 3.00 is: (Mg_{1.45}Fe_{1.39}³⁺Mn_{0.14}Al_{0.01}Fe_{0.01}²⁺)_{Σ=3.00}(PO₄)_{1.99}(OH)_{1.43} · 1.52H₂O or ideally: (Mg,Fe³⁺)₃(PO₄)₂(OH)_{1.5} · 1.5H₂O.

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.

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