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WAGNERITE, AN ACCESSORY PHASE IN CORDIERITE–ANTHOPHYLLITE GNEISS FROM STAR LAKE, MANITOBA

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ABSTRACT

Wagnerite from the Star Lake area, near Sherridon, Manitoba, occurs in a garnet – cordierite – anthophyllite gneiss of Precambrian age. Optically, the wagnerite is colorless, translucent, has a vitreous luster, and is biaxial positive. The mineral is generally prismatic and vertically striated along the {100} and {120} imperfect cleavages. Refinement of X-ray powder-diffraction data gives *a* 11.985(2), *b* 12.738(2), *c* 9.663(1) Å, β 108.36(1)°, V 1400.0(2) $Å^3$ (powder diffractometer, Cu*K*α radiation). Electron-microprobe data lead to the average formula $(Mg_{1.77}Fe_{0.17}Ti_{0.03})_{\Sigma 1.97}P_{1.00}O_4(F_{0.70}OH_{0.30})_{\Sigma 1}$. The Manitoba occurrence differs from other examples of wagnerite on the basis of its minor Ti content and relatively low F content.

Keywords: wagnerite, garnet – cordierite – anthophyllite gneiss, magnesium fluorophosphate, Star Lake, Manitoba.

SOMMAIRE

Nous avons découvert un exemple de wagnérite dans la région du lac Star, près de Sherridon (Manitoba), dans un gneiss à grenat – cordiérite – anthophyllite. Au microscope, la wagnérite est incolore et translucide, et son éclat est vitreux; elle est biaxe positive. Les cristaux sont prismatiques, et striés verticalement sur les clivages imparfaits suivant {100} et {120}. Un affinement des données obtenues par diffraction X (méthode des poudres) mène aux paramètres réticulaires *a* 11.985(2), *b* 12.738(2), *c* 9.663(1) Å, β 108.36(1)°, *V* 1400,0(2) $Å^3$. Les analyses à la microsonde électronique donnent la composition moyenne $(Mg_{1.77}Fe_{0.17}Ti_{0.03})_{\Sigma 1.97}P_{1.00}O_4(F_{0.70}OH_{0.30})_{\Sigma 1}$; la wagnérite manitobaine est donc appauvrie en Ti et relativement éloignée du pôle fluoré.

Mots-clés: wagnérite, gneiss à grenat – cordiérite – anthophyllite, fluorphosphate de magnésium, lac Star, Manitoba.

INTRODUCTION

Wagnerite, $(Mg,Fe)_2PO_4F$, a member of the triploidite group, is a rare mineral recently discovered within Ca-depleted, Al-rich rocks of the Star Lake area, near Sherridon, northern Manitoba. It was first reported in 1821, from hydrothermal quartz–carbonate veins that penetrate Werfenian sediments at Höllgraben and Radelgraben in Salzburg, Austria (Hegemann & Steinmetz 1927). It was found among residual minerals in the Zechstein salt deposits in the south Hannover area, Germany (Braitsch 1960), and from Bamle, Norway (Henriques 1957). Wagnerite also occurs in pegmatite and aplite veins of the Kyakhta sillimanite deposit, Buryatia (former USSR) (Fin'ko 1962), as a fine-grained aggregate in a pegmatite near Dolni Bory, Czechoslovakia (Stanek 1965), in a layer of sillimanite–plagioclase gneiss of Precambrian age at Santa Fe Mountain near Idaho Springs, in the Colorado Front Range (Sheridan *et al.* 1976), as a trace constituent of rutile-bearing biotite – quartz – plagioclase gneiss, about 3.5 km southeast of Santa Fe Mountain in the Colorado Front Range (Sheridan *et al.* 1976), as an accessory phase in a rutile-bearing kyanite quartzite from the Dome Rock Mountains, Yuma County, Arizona (Marsh & Sheridan 1976), within a piece of magnetite-rich ore from Silverberg, near Bodenmais, Bavarian Forest, Germany (Propach 1976), in a single block of pyrope-rich rock in a field near Velká Bíteš Skřinářov, Moravia, Czechoslovakia (Novák & Povondra 1984), in a phlogopite schist in the Lepontine area of the Central Alps in Switzerland (Irouschek-Zumthor & Armbruster 1985), and in sillimanite – garnet – pyroxene-rich paragneisses and migmatites from the Benson mines, in the west-central Adirondack Highlands of New York (Jaffe *et al.* 1992). Our study documents the first reported occurrence of wagnerite in Canada.

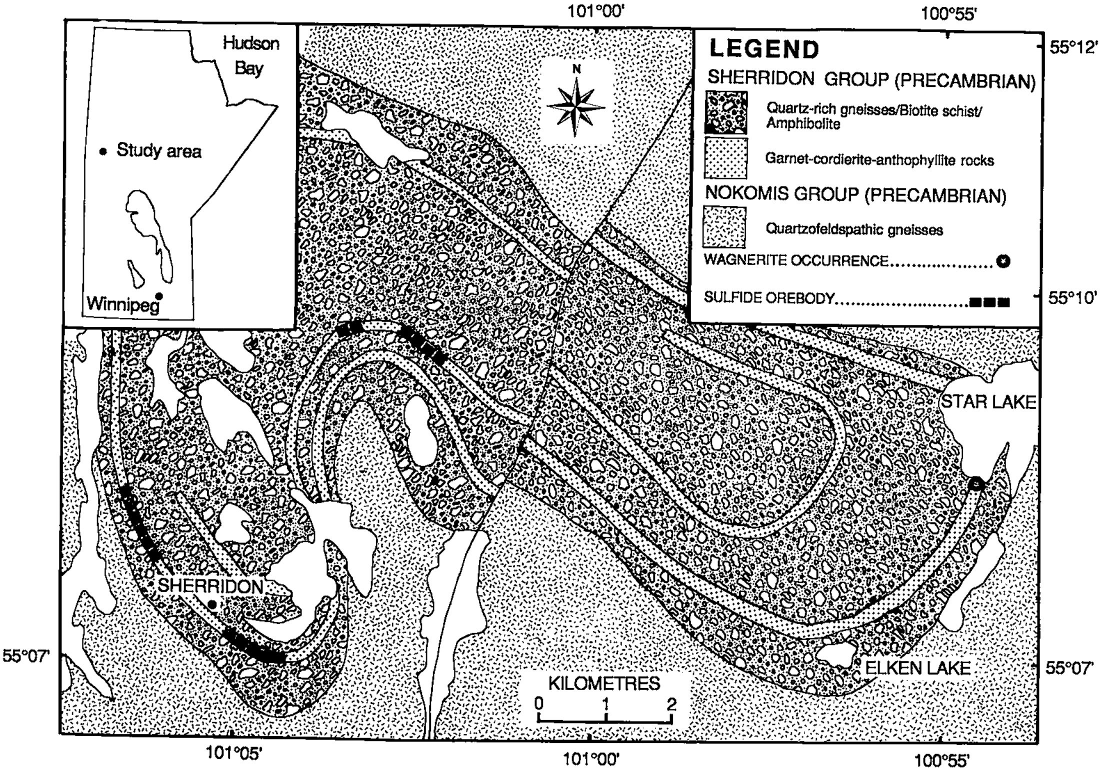

FIG. 1. Geological sketch map of the Sherridon area. Modified after Froese & Goetz (1981).

GEOLOGICAL SETTING

The Sherridon Group, of Precambrian age, is a stratigraphic unit of the Kisseynew gneiss belt, near Sherridon, Manitoba, and is dominated by quartz–biotite gneisses. Discontinuous lenses of extremely coarse (crystals up to 10 cm in size) garnet – cordierite – anthophyllite gneiss occur within the quartz–biotite gneiss units (Fig. 1). The garnet – cordierite – anthophyllite rocks are underlain by a sillimanite-bearing unit at Star Lake. Within the garnet – cordierite – anthophyllite rocks, three mappable units are present. From the structural base upward, these are: Unit 1, characterized by quartz, garnet, anthophyllite and biotite, Unit 2, characterized by garnet, anthophyllite and minor cordierite, and Unit 3, characterized by anthophyllite and cordierite (Gunter & Yamada 1986). In general, these units are composed of coarse-grained, poikiloblastic anthophyllite, cordierite and garnet (80–90% by volume), with biotite–sillimanite and quartz making up much of the remainder of the rock. Dispersed throughout the gneisses are magnetite, hercynite, staurolite and chlorite. The wagnerite (<1% by volume) is found exclusively within Unit 2, closely associated with garnet, cordierite and anthophyllite.

WAGNERITE

Optical properties

In hand specimen, the wagnerite from Star Lake is anhedral, bright orange and mostly fine-grained (1.0–1.5 cm in size). It occurs as small, irregularly shaped grains in close association with coarse-grained garnet, cordierite and anthophyllite; inclusions of anthophyllite in the wagnerite are rimmed with apatite, which also surrounds quartz grains and occupies microfractures in the wagnerite (Fig. 2). The wagnerite has poor {100} and {120} cleavages. It is colorless in plane-polarized light and is biaxial positive; its luster is vitreous to slightly resinous.

X-ray diffraction

X-ray-diffraction data were obtained from one of the wagnerite grains analyzed by electron microprobe (see below). The sample was characterized by powder-diffraction methods using Ni-filtered Cu$K\alpha$ radiation and a Philips PW1050/70 diffractometer; annealed CaF_2 was added as an internal standard. The unit-cell parame-

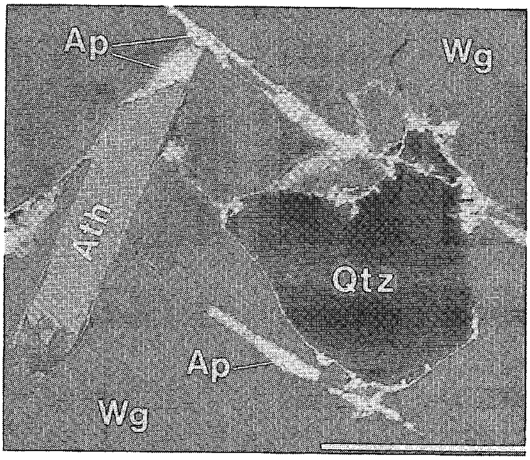

FIG. 2. Wagnerite (Wg), a Mg-rich phosphate $(Mg,Fe^{2+})_2PO_4F$, is generally fine grained, with inclusions of quartz (Qtz) and anthophyllite (Ath). These inclusions are rimmed with apatite (Ap), separating them from the enveloping wagnerite (Wg). Scale bar: 100 μm. Back-scattered electron image.

TABLE 1. POWDER-DIFFRACTION DATA FOR WAGNERITE, STAR LAKE, MANITOBA

h	*k*	*l*	*d* (calc)	*d* (obs)	*I*
2	0	0	5.69	5.69	4
1	2	0	5.56	5.55	2
0	2	1	5.23	5.23	6
$\bar{2}$	2	1	4.25	4.25	9
$\bar{1}$	2	2	3.838	3.840	5
2	2	1	3.546	3.545	6
1	2	2	3.297	3.297	65
3	2	0	3.258	3.256	9
2	0	2	3.122	3.123	63
$\bar{1}$	4	1	2.986	2.985	100
$\bar{4}$	0	2	2.852	2.854	59
$\bar{2}$	2	3	2.813	2.813	15
2	4	0	2.779	2.779	15
0	2	3	2.756	2.758	25
$\bar{4}$	2	1	2.711	2.710	22
$\bar{2}$	4	2	2.557	2.558	6
$\bar{3}$	4	1	2.485	2.484	13
$\bar{2}$	0	4	2.405	2.405	7
0	0	4	2.293	2.293	6
$\bar{1}$	2	4	2.245	2.244	10
2	2	3	2.243		
2	4	2	2.229	2.229	9
$\bar{5}$	2	2	2.208	2.206	12
$\bar{4}$	4	2	2.125	2.126	8
1	4	3	2.079	2.080	12
0	6	1	2.068	2.069	13
$\bar{2}$	6	1	1.990	1.988	11
$\bar{6}$	0	2	1.987		
2	0	4	1.926	1.926	11
$\bar{2}$	4	4	1.919	1.919	10
2	6	1	1.901	1.900	13
6	0	0	1.896	1.894	15
$\bar{6}$	2	1	1.895		
0	4	4	1.861	1.861	6
1	6	2	1.860		
$\bar{6}$	2	3	1.822	1.822	4
$\bar{5}$	4	3	1.801	1.801	8
$\bar{4}$	4	4	1.779	1.779	5
$\bar{2}$	6	3	1.759	1.754	8 *
$\bar{4}$	2	5	1.755		
5	2	2	1.752		
0	6	3	1.744	1.744	8
5	4	1	1.731	1.731	12
3	2	4	1.674	1.673	10
$\bar{3}$	4	5	1.633	1.633	5
2	6	3	1.589	1.588	13
6	0	2	1.585	1.584	16
$\bar{3}$	6	4	1.563	1.563	8
2	2	5	1.556	1.555	10
$\bar{6}$	2	5	1.545	1.545	8
2	8	0	1.533	1.533	9

a 11.985(2), *b* 12.738(2), *c* 9.663(1) Å, *β* 108.36(1) °, *V* 1400.0(2) Å^3

Ni-filtered Cu$K\alpha$ radiation, Philips PW 1050/70 diffractometer.
*: broad. All intensities are peak heights.

ters were refined by least-squares methods (Table 1), with the CELREF program (Appleman & Evans 1973). Indexing of the powder pattern (39 lines) and refinement of the cell dimensions gave *a* 11.985(2), *b* 12.738(2), *c* 9.663(1) Å, β 108.36(1)° and *V* 1400.0(2) Å^3.

Chemistry

The composition of three specimens of wagnerite was determined with a JEOL 733 electron microprobe using Tracor-Northern TN5500 and TN5600 automation. The operating conditions were: 15 kV, 25 mA, beam diameter 10 μm. The following standards were used: diopside (Mg, Ca, Si), almandine (Fe), titanite (Ti), synthetic tephroite (Mn), albite (Na), apatite (P) and topaz (F). Analyses for F used integrated intensities, not peak heights, because of differences in the shape of the F peak for topaz and wagnerite. A conventional ZAF routine in the Tracor Northern TASK series of programs was used for data reduction. Data for F were reduced using both the ZAF routine and a more rigorous $\phi(\rho z)$ treatment (Packwood *et al.* 1983). The results of each approach were statistically identical; the ZAF result is given in Table 2. The average composition derived from results of seven electron-microprobe analyses is $(Mg_{1.77}Fe_{0.17}Ti_{0.03})_{\Sigma 1.97}P_{1.00}O_4(F_{0.70}OH_{0.30})_{\Sigma 1}$. Table 2 also shows compositions of wagnerite from other localities. The Star Lake wagnerite shows significant Fe replacing Mg compared to other localities; however, the ratio Fe:Mg varies only slightly from 0.089 to 0.105. The significantly low concentration of F (8.02 wt.%) compared to the theoretical value for end-member wagnerite (11.68 wt.%) indicates substantial substitution of F by

TABLE 2. CHEMICAL COMPOSITION OF WAGNERITE

		1	2	3	4	5
Na_2O	*wt.%*	0.03	—	—	—	0.00
MgO		43.21	48.31	48.35	42.84	49.59
CaO		0.10	—	—	—	0.00
MnO		0.04	0.49	0.70	0.45	0.00
FeO		7.21	1.72	0.95	8.67	0.00
TiO_2		1.28	—	—	—	0.00
SiO_2		0.01	—	—	—	0.00
P_2O_5		43.11	42.89	43.45	41.56	43.65
F		8.02	10.72	11.49	10.05	11.68
Cl		0.00	0.48	—	—	0.00
H_2O *		1.65	—	—	0.65	0.00
O=F,Cl		-3.38	-4.61	-4.84	-4.22	-4.92
		101.28	100.00	100.10	100.00	100.00
		Atoms per 5 (O,F,OH,Cl)				
Na		0.002	—	—	—	0.000
Mg		1.770	1.978	1.963	1.799	2.000
Ca		0.003	—	—	—	0.000
Mn		0.001	0.011	0.016	0.011	0.000
Fe		0.166	0.040	0.022	0.204	0.000
Ti		0.026	—	—	—	0.000
Si		0.000	—	—	—	0.000
P		1.003	0.998	1.002	0.991	1.000
		2.971	3.027	3.003	3.005	3.000
O		4.000	4.046	4.010	3.983	4.000
F		0.697	0.931	0.990	0.895	1.000
Cl		0.000	0.022	—	—	0.000
OH		0.303	—	—	0.122	0.000
		5.000	5.000	5.000	5.000	5.000

* Determined by stoichiometry

1. Star Lake, Manitoba (average of 7 analyses)
2. Santa Fe Mountain, Colorado, USA (Sheridan *et al.* 1976)
3. Werfen, Austria (Hegemann & Steinmetz 1927) recalc. by Sheridan *et al.* (1976)
4. Kyakhta, USSR (Fin'ko 1962) recalc.by Sheridan *et al.* (1976)
5. Ideal composition of wagnerite

"—": not sought

OH; the ratio OH:F varies from 0.202 to 0.399. Significant replacement of Mg by Ti has occurred in the Star Lake wagnerite compared to other localities (Table 2); the TiO_2 content increases slightly toward the grain boundaries, perhaps as a result of reaction with biotite or anthophyllite, both of which are Ti-bearing.

CONCLUSIONS

This study reports on the first known Canadian occurrence of wagnerite, a member of the triploidite group. This occurrence closely parallels the first known occurrence in the United States, on Santa Fe Mountain near Idaho Springs, in the Colorado Front Range. In both cases, the wagnerite occurs as a minor constituent in thin layers and lenses of Precambrian gneiss which, though differing in major mineralogy, are both relatively rich in alumina and poor in calcium compared to the bulk of the Precambrian gneisses that comprise the bedrock in these areas.

In the vicinity of Sherridon, Manitoba, the Sherridon Group of the Kisseynew gneiss belt (Aphebian in age) occupies a structural basin surrounded by older rocks of the Nokomis Group. The garnet – cordierite – anthophyllite rocks occur as discontinuous lenses along stratigraphic horizons within the quartz-rich gneisses of the Sherridon Group (Fig. 1); some occurrences are associated with sulfide mineralization (Sherritt Gordon deposit at Sherridon, Manitoba). The chemical composition of the Star Lake gneisses seems to indicate intense hydrothermal alteration (1800–1700 Ma: Goetz 1980) of a basaltic precursor, to produce chlorite-rich alteration pipes (Goetz & Froese 1982, Leroux 1989). In the case of the Sherritt Gordon deposit, the large lateral extent of the orebodies and the absence of underlying zones of alteration indicate that the ore was deposited away from the hydrothermal vent (Goetz & Froese 1982). This alteration involved a depletion in alkalis and alkaline earths, and an apparent enrichment in Al and Mg. These chemical modifications are interpreted to have resulted from reactions between heated seawater and basaltic rocks of the oceanic crust. Fluorine, of probable volcanic derivation, was adsorbed by the altered products in varying amounts in different localities. Somewhat later (1750–1650 Ma: Goetz 1980), regional metamorphism redistributed the fluorine and other volatiles, therefore promoting the growth of coarse crystals in the garnet – cordierite – anthophyllite gneiss belt.

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