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CHROMIAN ANDRADITE FROM REAUME TOWNSHIP, ONTARIO

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ABSTRACT

Chromian andradite occurs as minute (10^{-2} mm) green crystals filling hairline fractures in a serpentinized, chromite-rich poikilitic wehrlite in Réaume township, northeastern Ontario. The garnet contains as much as 10.5% Cr_2O_3; the grains are zoned, with the rims being more chrome-rich than the cores. Their compositions may be described almost entirely in terms of the end members andradite (57 to 89 mole %), uvarovite (1.7 to 37 mole %), and grossularite (3.6 to 9.1 mole %). The formula calculated from the average composition is $(Ca_{3.01} Mg_{0.05}) (Fe^{3+}_{1.30} Cr_{0.50} Al_{0.14} Ti_{0.03}) (Si_{2.94} Al_{0.06}) O_{12}$, and the cell edge calculated from the X-ray-diffraction powder pattern is 12.061(3) Å. The garnet is a product of the breakdown of magmatic chromite and calcic clinopyroxene, possibly during prograde regional metamorphism.

Keywords: chromian andradite, demantoid, serpentinite, Ontario.

SOMMAIRE

On trouve une andradite chromifère en très petits cristaux (10^{-2} mm) verts le long de microfissures dans une wehrlite poecilitique serpentinisée et riche en chromite du canton de Réaume, situé dans le secteur nord-est de l'Ontario. Le grenat contient jusqu'à 10.5% de Cr_2O_3; la bordure en contient plus que le centre. Sa composition s'exprime presque entièrement par les pôles andradite (de 57 à 89%, base molaire), uvarovite (de 1.7 à 37%) et grossulaire (de 3.6 à 9.1%). Sa composition globale moyenne est $(Ca_{3.01} Mg_{0.05} (Fe^{3+}_{1.30} Cr_{0.50} Al_{0.14} Ti_{0.03}) (Si_{2.94} Al_{0.06}) O_{12}$ et l'arête de la maille, calculée à partir du cliché de diffraction X sur poudre, est égale à 12.061(3) Å. Le grenat est un produit de décomposition de chromite et de clinopyroxène magmatiques; la décomposition se serait déroulée au cours d'une épisode de métamorphisme régional prograde.

(Traduit par la Rédaction)

Mots-clés: andradite chromifère, démantoïde, serpentinite, Ontario.

INTRODUCTION

An unusual, emerald green garnet of the ugrandite series occurs in lot 11, concession V of Réaume township, about 10 kilometres southwest of Cochrane in northeastern Ontario. The garnet may be classified as chromian andradite and occurs as minute crystals filling hairline fractures in serpentinized peridotite. The sample material was collected from the westernmost of two small pits on a chromite occurrence discovered in the early years of this century (Gibson 1914, Hopkins 1918). A specimen has been deposited in the Systematic Reference Series of the National Mineral Collection, Geological Survey of Canada, under catalogue number 61528.

This locality is of some historical interest inasmuch as it was originally reported as a site at which diamonds occurred in association with chromite (Gibson 1914), and has remained an unconfirmed occurrence of diamond (*e.g.*, Traill 1970, p. 185). The presence of diamonds in this geological setting would be most extraordinary; it is likely that this was a case of misidentification of the garnet that we describe in this paper. In this regard it is interesting to note that the varietal name applied to green andradite is demantoid, from the German root *demant* meaning diamond.

PETROGRAPHY

The host rock is a serpentinite containing antigorite, chrysotile, magnetite, diopside, chlorite, calcite and chromite, in addition to garnet. The primary texture of the igneous protolith is pseudomorphously preserved; it is evident that the rock was a fine grained poikilitic wehrlite comprising about 85 modal % olivine, 10% calcic clinopyroxene, and 5% chromite. Oikocrysts of clinopyroxene on the order of 10 mm in size poikilitically enclose euhedra of olivine 1 to 3 mm in size and of chromite about 0.05 to 0.15 mm in size. The olivine has been entirely altered to bladed antigorite and very fine grained, "dusty" magnetite. Some magmatic clinopyroxene is preserved but the remainder has been replaced by an intergrowth of diopside, serpentine and chlorite. The chromite is rimmed by secondary magnetite. The garnet occurs as minute subhedra that average 0.01 to 0.02

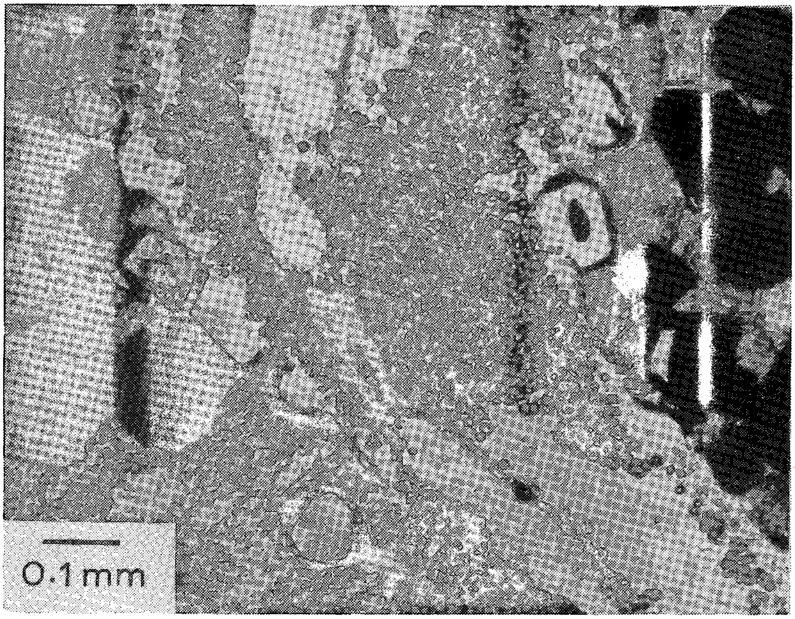

FIG. 1. Chromian andradite crystals (dark grey) filling fracture in serpentinized peridotite. Opaque grains are chromite rimmed by magnetite. The light grey and white areas are mainly serpentine. Note the magnetite "atolls" from which the chromite has been removed (plane, transmitted light).

mm in size. The garnet grains are localized along fractures about 0.1 to 1 mm in width, associated in places with calcite and serpentine (Fig. 1). The whole-rock composition, as determined by X-ray-fluorescence analysis, is 37.3% SiO_2, 0.18% TiO_2, 3.2% Al_2O_3, 1.5% Cr_2O_3, 7.3% Fe_2O_3, 4.9% FeO, 0.18% MnO, 33.6% MgO, 1.25% CaO, and 10.9% H_2O.

Garnet Composition and Diffraction Data

The chemical compositions of 30 garnet grains were determined using an electron microprobe operated in the energy-dispersion mode. Analytical standards used were kaersutite for Na, Mg and Ti, gehlenite for Si, Ca and Al, biotite for Fe and Mn, and chromite for Cr. Representative results of analyses are given in Table 1. Despite the small size of the garnet grains, we are confident that our analyses have not been affected by excitation of adjacent grains. The garnet compositions may be described almost entirely in terms of the andradite, uvarovite and grossularite end members. The MgO and TiO_2 contents are each generally much less than 1%, and MnO, Na_2O and K_2O concentrations are below the analytical detection limits. Charge-balance considerations suggest that the iron is entirely trivalent. The compositions are plotted in the ugrandite triangular diagram in Figure 2. A range of compositions is evident involving mainly a substitution of Cr^{3+} for Fe^{3+}. The proportion of grossularite does not vary greatly, ranging from about 3.6 to 9.1 mole %, but there is a trend toward higher grossularite content with increasing andradite content (Fig. 2). There is also a tendency for the more chromium-rich garnets to have slightly higher titanium contents. Qualitative energy-dispersion analysis using a scanning electron microscope showed that the garnets are consistently zoned, with the crystal rims being much more chromium-rich than the cores. However, the variation in microprobe results may reflect grain-to-grain heterogeneity as well as zoning of individual grains. The electron microscope also revealed tiny inclusions (0.001 mm) of calcium–magnesium silicate, presumably calcic pyroxene or amphibole in the garnets.

The X-ray powder-diffraction data are included in Table 2. The cell edge was refined on the basis of six lines between 3.014 and 1.610 Å for which unambiguous indexing was possible. A value of 12.061(3) Å was determined and is very close to, but slightly greater than the cell edge of pure synthetic andradite (*a* 12.059 Å) determined by Huckenholz & Knittel (1976). A somewhat lower value might have been expected owing to the solid solution of uvarovite (*a* 11.999 Å) and grossularite (*a* 11.848 Å). One might speculate that the substitution of Al^{3+} for Si^{4+} in tetrahedral co-ordination evident from our chemical analyses would have the effect of increasing the cell size.

Discussion

Chrome garnets are most typically solid solutions of uvarovite and grossularite; chromian andradite is not common. For example, Dunn (1978) presented results of analyses of green garnets from a number of Canadian localities and noted that most are chromian grossularite; only two are uvarovite. These are plotted in Figure 2 for purposes of comparison with our data. We believe that this is the first documented occurrence of chromian andradite in Canada and one of only a very few worldwide. Other localities include Val Malenco, Italy (Amthauer *et al.* 1974) and Nizhny Tagilsk in the Urals (Rost *et al.* 1979).

The chromian andradite in Réaume township was presumably formed at a relatively low temperature during either serpentinization or later regional metamorphism of the host peridotite. In our experience, postmagmatic serpentinization of similar bodies in the Abitibi greenstone belt is dominated by the development of lizardite

TABLE 1. CHROMIAN ANDRADITE, REAUME TOWNSHIP, ONTARIO

	1	2	3	4	5	Average
Weight Percent						
SiO_2	34.29	35.37	34.88	35.51	35.19	35.23 (0.40)
TiO_2	0.19	0.32	0.33	0.45	0.55	0.47 (0.16)
Al_2O_3	3.26	1.83	2.06	1.89	1.76	2.05 (0.40)
Cr_2O_3	0.53	2.93	5.34	8.47	10.54	7.57 (2.94)
Fe_2O_3	27.56	26.34	23.95	19.66	17.41	20.79 (3.14)
MgO	0.18	0.23	0.11	0.47	0.47	0.42 (0.26)
CaO	34.05	33.18	33.34	33.46	33.78	33.67 (0.34)
Total	100.06	100.20	100.01	99.91	99.70	100.20
Formula: cations/12 oxygen						
Si	2.875	2.956	2.924	2.957	2.933	2.937
Ti	0.012	0.020	0.021	0.028	0.034	0.030
Al	0.322	0.181	0.204	0.185	0.173	0.201
Cr	0.035	0.194	0.354	0.558	0.695	0.499
Fe	1.739	1.656	1.511	1.230	1.091	1.305
Mg	0.023	0.029	0.014	0.058	0.058	0.052
Ca	3.059	2.972	2.994	2.983	3.015	3.007

Analyses 1 to 5 selected to show range of composition. Average is mean of 31 analyses, standard deviations of means given in parentheses.

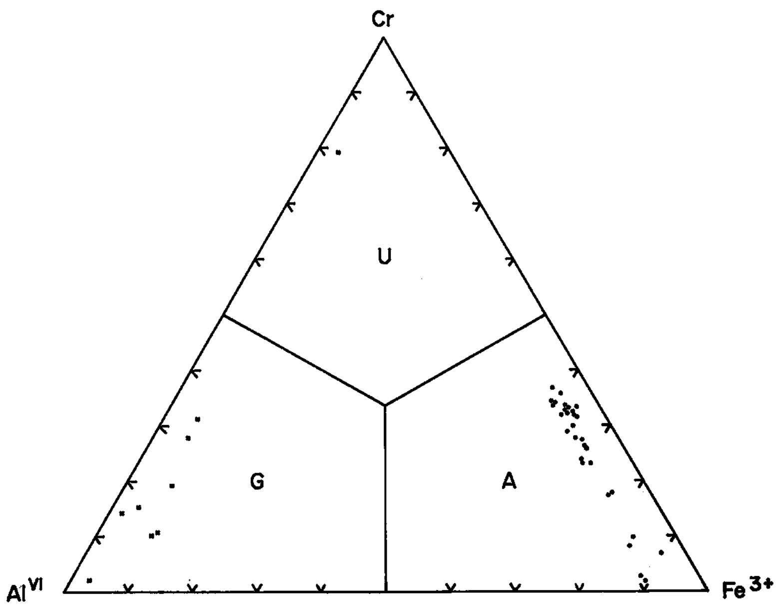

FIG. 2. Al^{VI} – Cr – Fe^{3+} triangular diagram showing fields of grossularite (G), uvarovite (U) and andradite (A). Filled circles are garnets from Réaume township; squares are other green garnets reported from Canadian localities (Dunn 1978).

TABLE 2. X-RAY POWDER-DIFFRACTION DATA

I/I_o	d_{meas}(Å)	d_{calc}(Å)	hkl
80	3.014	3.015	400
100	2.697	2.697	420
10	2.569	2.571	332
90	2.462	2.462	422
30	2.367	2.365	431
30	2.202	2.202	521
40	1.956	1.957	611
20	1.905	1.907	620
10	1.741	1.741	444
60	1.672	1.673	640
90	1.610	1.612	642
20	1.506	1.508	800
5	1.485	1.485	741
40	1.349	1.349	840
40	1.316	1.316	842
30	1.286	1.286	664
5	1.218	1.218	941
30	1.119	1.120	10.4.0

cell edge = 12.061(3)Å

Data obtained with a Debye-Scherrer 114.6 mm camera, using Ni-filtered CuKα radiation (λ = 1.54178Å), film corrected for shrinkage. Intensities were estimated visually. Pattern indexed with a = 12.061Å.

and chrysotile in pseudomorphic texture (*i.e.*, type-3 serpentinization, Wicks & Whittaker 1977). The development of antigorite and relatively coarse grained secondary diopside is characteristic of prograde regional metamorphism. The regional metamorphism in this part of the Abitibi belt is typically of greenschist facies (Jolly 1978), and this would be consistent with the observed serpentinite assemblage (Evans 1977). The fractures in which the garnet occurs appear to cut across the serpentine; formation of the garnet may thus have occurred late in the sequence of events.

Huckenholz & Knittel (1976) found complete solid solution between andradite and uvarovite at low pressure but their experiments were run at rather higher temperatures than we envisage for the crystallization of the Réaume township garnet. However, our data suggest rather extensive solid solution at low temperature (up to at least 40% uvarovite) and contradict the solvus between the two end-members predicted by Ganguly (1976) on the basis of thermodynamic calculations. Huckenholz & Knittel (1976) noted that chrome-rich garnets are not common despite their apparent stability over a wide range of geologic conditions, and suggested that garnet crystallizes in only a restricted range of whole-rock compositions. In any event, the inhomogeneous nature of the garnet in our samples is indicative of disequilibrium.

The garnet in our samples probably formed from constituents released by the breakdown of primary chromite and clinopyroxene. Evans & Frost (1975) have studied the progressive metamorphism of chrome spinel in ultramafic rocks, and reported that "the stable spinel in antigorite-serpentinites is Al-poor magnetite, Cr-magnetite, or ferrit-chromite, depending on the local Cr/Fe^{3+} ratio in the rock" (p. 959). Thus igneous chromite, such as that in the Réaume peridotite, would tend to react to give more iron-rich compositions. The relict chromite is rimmed by magnetite that probably formed during the early stages of serpentinization and served to armor the chromite against reaction. However, it is significant that the rock contains numerous magnetite "atolls" (Fig. 1) from which the relict chromite presumed to have been present has disappeared and has been replaced by serpentine. The solution of this chromite would release Cr, Al and Fe, whereas the replacement of clinopyroxene by an intergrowth of diopside, serpentine and chlorite would generate an excess of Ca and Si.

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