COEXISTING Cr-RICH AND Cr-POOR GARNET FROM A CALC-SILICATE GNEISS, LABRADOR

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ABSTRACT

A Cr-rich granoblastic xenolith of calc-silicate gneiss in a small granodiorite body near the Kiglapait layered intrusion, Labrador, contains coexisting Cr-rich and Cr-poor garnet. The gneiss, which crystallized near 2 kbar and 500°C, consists of diopside, garnet, calcite, quartz, plagioclase, chromite and titanite, with retrograde prehnite, epidote, and chlorite. Commonly, a bright green garnet is in very sharp contact with colorless garnet. Microprobe analyses of garnet pairs indicate a compositional gap located approximately between Uv_{10} and Uv_{30}. The ugrandite ranges in composition from $Uv_{72}Gr_{13}An_{15}$ to $Uv_{22}Gr_{36}An_{42}$, and the grandite ranges in composition from $Uv_{10}Gr_{31}An_{59}$ to $Uv_1Gr_{91}An_8$. Ganguly (1976) has calculated a miscibility gap in the ugrandite system based on the approximate mixing properties of grossular, andradite and uvarovite. The garnet in this gneiss seems to have formed under equilibrium conditions, and thus confirms the existence of immiscibility in ugrandite garnet, albeit with a significantly different compositional configuration.

Keywords: garnet, ugrandite, uvarovite, grossular, andradite, miscibility gap, chromian, calc-silicate, xenolith, Labrador.

SOMMAIRE

Une enclave de gneiss à calc-silicates granoblastiques et enrichie en chrome, située dans un petit massif de granodiorite près du complexe stratiforme du Kiglapait, au Labrador, contient deux grenats coexistants qui diffèrent dans leur teneur en Cr. Le gneiss, qui a recristallisé à environ 2 kbar et 500°C, est formé de diopside, grenats, calcite, quartz, plagioclase, chromite et titanite, avec prehnite, épidote et chlorite rétrogrades. Un grenat vert brillant a généralement un contact très franc avec un grenat incolore. Les analyses des deux grenats à la microsonde révèlent une lacune de miscibilité entre Uv_{10} et Uv_{30}. La composition de l'ugrandite varie entre $Uv_{72}Gr_{13}An_{15}$ et $Uv_{22}Gr_{36}An_{42}$, et celle de la grandite, entre $Uv_{10}Gr_{31}An_{59}$ et $Uv_1Gr_{91}An_8$. Ganguly (1976) avait calculé la lacune de miscibilité dans le système de l'ugrandite en utilisant les propriétés de mélanges approximatifs des termes grossulaire, andradite et uvarovite. La formation des grenats dans ce gneiss semble indiquer des conditions d'équilibre, et confirme donc l'existence d'une lacune de miscibilité dans les grenats ugranditiques, quoique les aspects géométriques de cette lacune diffèrent sensiblement de celle calculée précédemment.

(Traduit par la Rédaction)

Mots-clés: grenat, ugrandite, uvarovite, grossulaire, andradite, lacune de miscibilité, chromifère, calc-silicates, enclave, Labrador.

INTRODUCTION

It is generally assumed that multicomponent solid-solution exists within the two distinct types of garnet, ugrandite and pyralspite. The general formula of a garnet can be represented by $X_3^{2+}Y_2^{3+}Si_3O_{12}$, in which X represents an eight-coordinated divalent cation (Fe^{2+}, Mg, Ca, Mn) in a distorted square antiprism and Y represents a six-coordinated cation (Al, Fe^{3+}, and Cr^{3+}) present in a distorted octahedron. In the ugrandite group, X is Ca. Where Y is completely filled with Cr^{3+}, the end-member uvarovite is formed; where it is filled with Fe^{3+}, the end-member andradite is formed; and where filled with Al, grossular is formed.

Uvarovite is one of the rarer forms of garnet. Its wide stability is exemplified by the range of environments in which uvarovite as a phase and component may be found. Uvarovite-rich garnet occurs in mafic and ultramafic rocks that have undergone metamorphism or serpentinization at low temperature and pressure (*e.g.*, in the Bushveld Complex: Willemse & Bensch 1964, Frankel 1959). It is also found in calc-silicate rocks and skarn ore deposits (*e.g.*, in the Karelia deposit: von Knorring 1957). The uvarovite component in garnet solid-solutions is also stable in the high-pressure and high-temperature environment associated with kimberlites (*e.g.*, as inclusions in diamonds: Meyer & Boyd 1972).

The wide range of stability of the garnet group of minerals makes this phase important in calculations to determine the $P-T$ history of natural systems. In view of the wide range in compositions of natural garnet, it is important to accurately define activity–composition relations in the garnet system so that the application of garnet chemistry to $P-T$ calculations can be improved. A number of investigators have thus attempted to refine the data on binary mixing properties in the garnet systems through thermodynamic and crystal-chemical analyses. In this paper, we do not intend to evaluate theoretically the binary mixing properties among garnet end-members, but to present data from a natural system that imply a miscibility gap in the ugrandite system, as suggested by one of the theoretical studies (Ganguly 1976).

GEOLOGICAL SETTING

The granoblastic calc-silicate gneiss occurs as a xenolith in a granodiorite dyke or small intrusive

Table 1. REPRESENTATIVE CHEMICAL COMPOSITIONS OF GARNETS

	1	2	3	4	5	6	7	8	9	10
SiO_2	34.33	36.16	37.34	37.14	36.64	38.43	34.77	37.17	35.08	35.68
Al_2O_3	5.30	9.19	5.67	13.80	5.76	11.74	2.68	9.98	3.93	7.47
TiO_2	0.50	0.29	0.55	0.00	0.55	0.04	0.29	0.00	0.59	0.58
Cr_2O_3	15.51	1.57	15.13	0.07	15.24	0.07	22.71	0.05	19.64	6.83
Fe_2O_3*	9.47	18.34	6.80	13.20	7.24	15.51	4.96	17.76	6.27	14.06
FeO	0.00	0.00	1.51	0.00	0.91	0.16	0.00	0.00	0.00	0.00
MnO	0.50	0.32	0.28	0.23	0.34	0.28	0.31	0.25	0.27	0.23
MgO	0.23	0.08	0.22	0.03	0.17	0.02	0.16	0.02	0.24	0.15
CaO	33.88	34.71	33.53	35.89	33.37	35.52	35.34	35.43	33.98	35.50
Total	99.72	100.61	101.03	100.36	100.22	101.77	101.22	100.66	100.00	100.50
Si	2.820	2.898	3.009	2.910	2.979	3.000	2.833	2.958	2.882	2.873
Al	0.513	0.868	0.539	1.275	0.552	1.089	0.257	0.936	0.380	0.709
Ti	0.031	0.017	0.033	0.000	0.034	0.002	0.018	0.000	0.036	0.035
Cr	1.007	0.099	0.964	0.004	0.980	0.004	1.463	0.003	1.275	0.435
Fe^{3+}*	0.585	1.106	0.412	0.779	0.443	0.911	0.304	1.063	0.387	0.852
Fe^{2+}	0.000	0.000	0.102	0.000	0.062	0.011	0.000	0.000	0.000	0.000
Mn	0.035	0.022	0.019	0.015	0.023	0.019	0.021	0.017	0.019	0.016
Mg	0.028	0.010	0.026	0.004	0.021	0.002	0.019	0.002	0.029	0.018
Ca	2.981	2.980	2.895	3.013	2.907	2.971	3.085	3.021	2.991	3.063
Total	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000	8.000
Gr	24.37	41.87	28.15	61.95	27.95	54.34	12.58	46.75	18.61	36.10
And	27.79	53.35	21.51	37.85	22.43	45.46	14.88	53.10	18.95	41.75
Uv	47.84	4.78	50.34	0.19	49.62	0.20	72.54	0.15	62.44	22.15

*Calculated, based on idealized stoichiometry of 12 oxygen atoms and 8 cations.
Compositions 1 & 2, 3 & 4, and 5 & 6 represent pairs of coexisting garnets.

body located on the west shore of Wendy Bay, Labrador, Canada, near the contact of the Kiglapait layered intrusion with the Aphebian supracrustal Snyder and Falls Brook groups (Morse 1969, Berg 1976). The granodiorite was intruded either contemporaneously with or after the emplacement of the Kiglapait intrusion (Morse 1969). In his field notes, S.A. Morse (pers. comm.) described the outcrop as one that strongly resembles an igneous breccia, or agmatite. Most of the xenoliths in the agmatite are amphibolitic in nature. Some of the angular fragments in the breccia are relatively large, 1–1.5 m long and approximately 1 m wide, and are locally veined and dyked by the granodiorite.
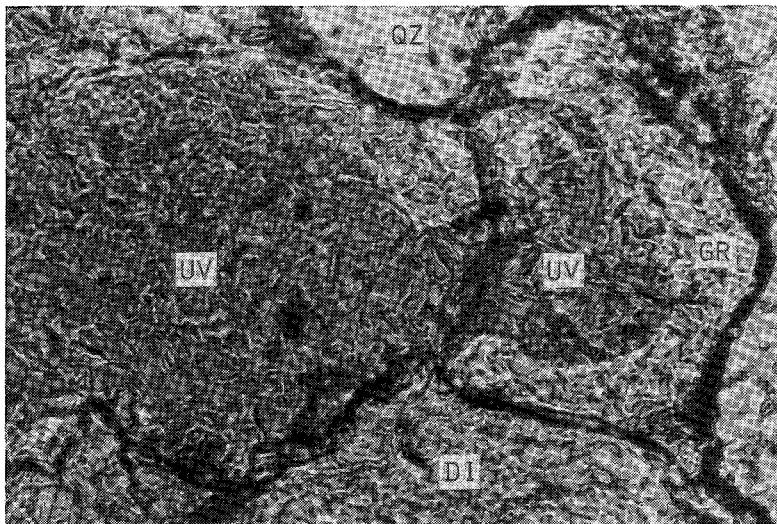

FIG. 1. The sharp contact between Cr-rich (dark) and Cr-poor (light) garnets is shown in this plane-light photomicrograph. The Cr-rich garnet ranges in composition from $Uv_{50}Gr_{23}An_{27}$ to $Uv_{37}Gr_{30}An_{33}$, whereas the Cr-poor garnet in contact with it ranges from $Uv_0Gr_{48}An_{52}$ to $Uv_{11}Gr_{36}An_{53}$. Abbreviations: Uv uvarovite; Gr grossular; Di diopside; Qz quartz. Width of field 0.38 mm.

PETROGRAPHIC DESCRIPTION

The gneissic calc-silicate xenolith consists of Cr-rich diopside (73%), quartz (16%), calcite (3%), garnet (3%), plagioclase (2%, An_{83}–An_{91}), titanite (1%), and minor amounts of prehnite, epidote, chlorite and chromite. Most of the minerals form a granoblastic texture, but the prehnite, epidote and chlorite appear as felty masses in restricted layers. The subhedral to anhedral pyroxene crystals are pale green diopside. Commonly, these crystals possess lamellar or lens-like areas of colorless diopside. These lamellar features are not as regular as normal pyroxene exsolution lamellae, but are more similar in appearance to coarse perthite. The orientation of the lamellar features is normal to the optic plane (010) of the diopside host, and does not appear to be related to parting or fracture in the crystal. Chromite is rare and is armored by a corona of green garnet. Green garnet is zoned from bright emerald green to pale green and coexists with a colorless garnet. There are numerous instances where a green garnet is in very sharp contact with colorless garnet (Fig. 1). Garnet grains range from subhedral to anhedral, and there is no correlation between grain shape or habit and color (Fig. 2). Both garnets may occur isolated in clusters or juxtaposed. Green garnet may be rimmed by colorless garnet (Fig. 1); it may show nearly euhedral boundaries in contact with colorless garnet (Fig. 2B), or it may occur as elongate patches
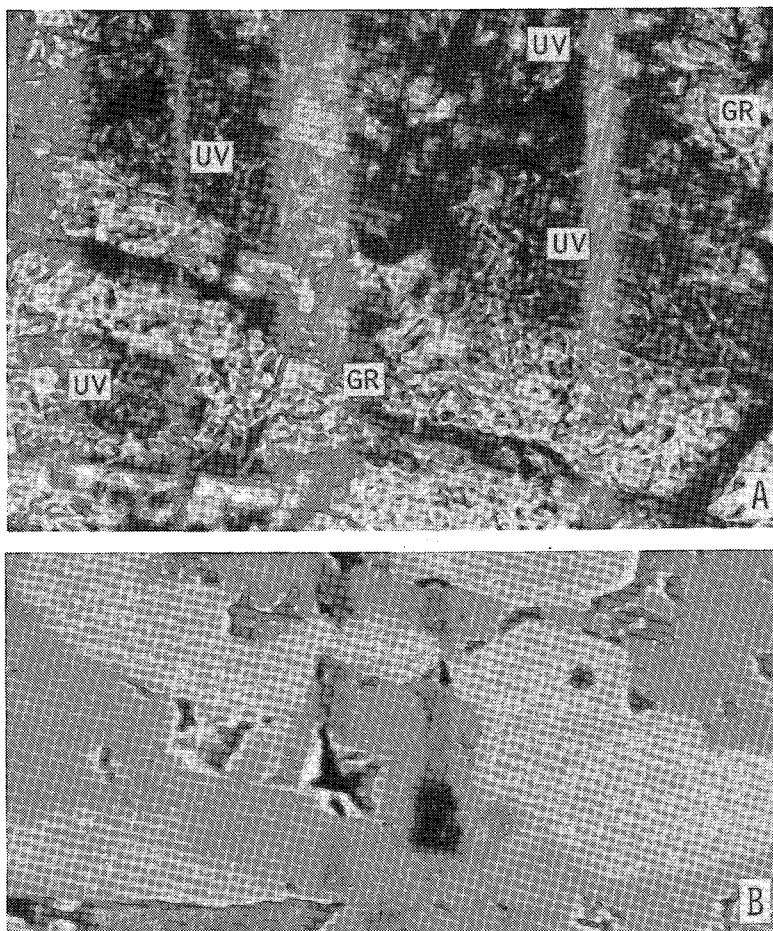

FIG. 2. Cr-rich garnet intimately associated with Cr-poor garnet. (A) In plane-light photomicrograph, green Cr-rich garnet is dark, and colorless Cr-poor garnet is light. Width of field is 0.38 mm. Abbreviations are the same as in Figure 1. (B) Composite CrKα X-ray map and BEI of the same area show abrupt contacts between Cr-rich and Cr-poor garnets. The CrKα X-ray map also indicates that in some cases the Cr-rich regions (light) extend slightly beyond the boundaries observed optically in transmitted light. Note that some of the boundaries of the Cr-rich regions exhibit apparent dodecahedral forms.

in colorless garnet, with a sharp Becke line present between the two.

MINERAL CHEMISTRY

Mineral analyses were obtained using the JEOL JXA-50A automated electron microprobe at Northern Illinois University. Operating conditions were 15 kV accelerating potential, 0.03 μA beam current, 20-second counting time, and a focused beam having a diameter of 2–3 μm. Synthetic and natural silicates and oxides were used as standards, and corrections were made using the method of Bence & Albee (1968) and the correction factors of Albee & Ray (1970). Ferric iron was calculated for garnet,

diopside and chromite assuming standard stoichiometries. More than 275 microprobe analyses of minerals in this specimen were obtained, of which at least 230 were of garnet. Representative compositions and structural formulae of ten grains of Cr-rich and Cr-poor garnet are listed in Table 1, and compositions and structural formulae of the coexisting minerals are given in Table 2. The pale green diopside found in this assemblage contains up to 1.61 wt.% Cr_2O_3, whereas the colorless diopside contains no detectable chromium (Table 2, compositions 3 & 4). The rare chromite crystals contain 60–62 wt.% Cr_2O_3.

The garnet in this rock ranges from Cr-rich ugrandite to Cr-poor grandite (Fig. 3). The uvarovite in
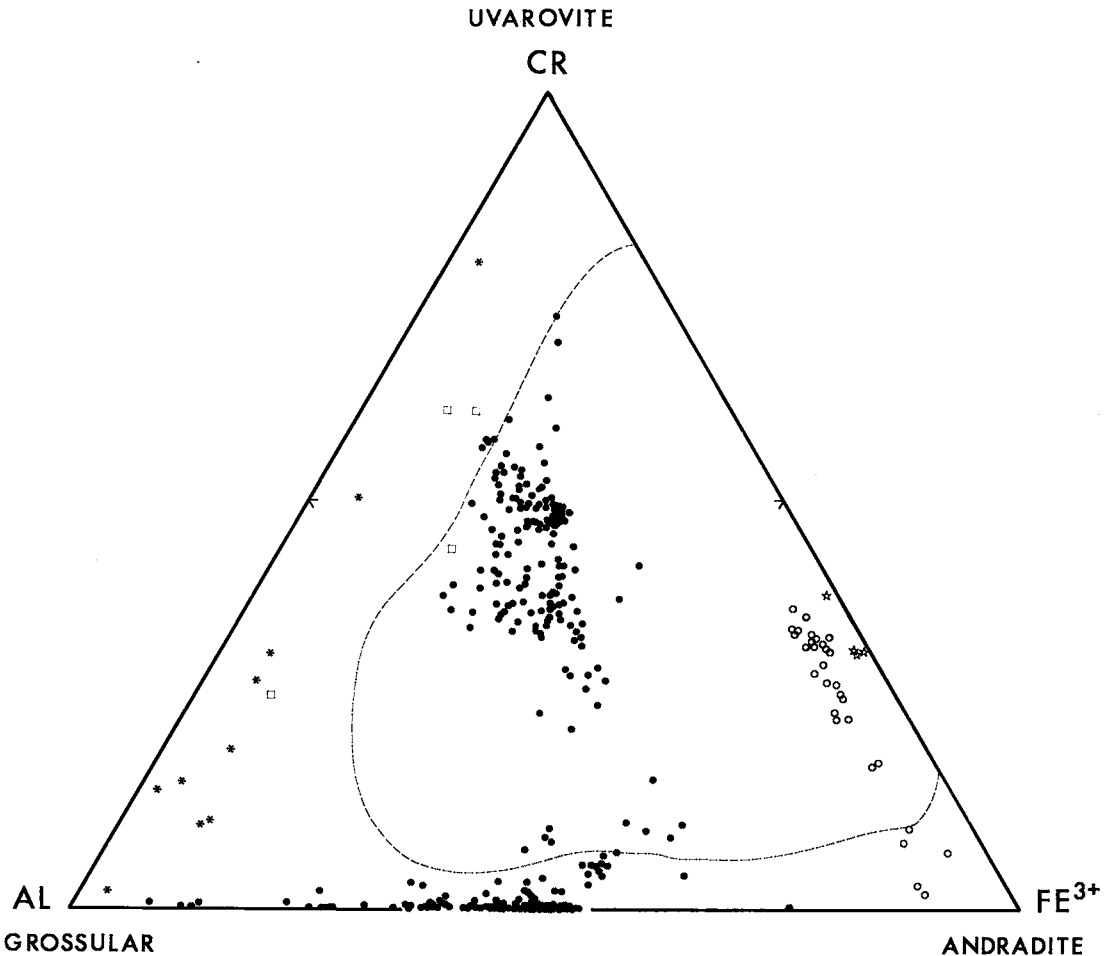

FIG. 3. Chemical compositions of Cr-rich and Cr-poor garnet from the Labrador calc-silicate gneiss (solid circles), derived from microprobe data, plotted in the system andradite–grossular–uvarovite. Also presented for comparison are the microprobe data for ugrandite reported by Jan *et al.* (1984; open stars), Duke & Bonardi (1982; open circles), Dunn (1978; asterisks), and Prestvik (1974; open squares). The 400°C spinodal postulated by Ganguly (1976) for the ugrandite system is also shown.

contact with the chromite possesses up to 23 wt.% Cr_2O_3 ($Uv_{72.5}Gr_{12.5}An_{15}$, Table 1, composition 7). Although we find a wide range in garnet compositions, there is a definite paucity of compositions between Uv_{10} and Uv_{30} (Fig. 3). This corroborates the petrographic information, as shown in Figures 1 and 2A, which shows sharp contacts between green garnet and colorless garnet. Of the few compositions between Uv_{10} and Uv_{30}, most are from near such a contact and may represent composites of Cr-rich and Cr-poor garnet, thus artificially blurring the gap in compositions. This is substantiated by the $CrK\alpha$ X-ray map (Fig. 2B), which indicates that in some cases Cr-rich areas extend slightly beyond the boundaries observed optically in transmitted light. By plotting only garnet compositions that are demonstrably coexisting, i.e., directly adjacent (Fig. 4), the gap in compositions becomes even more obvious than in Figure 3.

PRESSURE–TEMPERATURE–X(CO₂) CONSTRAINTS

Assuming that the metamorphism of the xenolith was approximately contemporaneous with the emplacement of the Kiglapait intrusion, the gneissic calc-silicate xenolith crystallized at 2 kbars (Berg 1979, unpubl. data). This estimate is based on several independent barometers applied to nearby rocks in the Kiglapait contact aureole, especially the Fe-rich orthopyroxene–olivine–quartz barometer (Bohlen & Boettcher 1981) and the Fe-rich pigeonite–ferroaugite–olivine–quartz barometer (Lindsley 1980).

Based on textures and modal abundances, we interpret the prehnite, zoisite and, possibly, chlorite as retrograde minerals. If this interpretation is correct, the crystallization temperature of the xenolith is largely constrained by the association of garnet–plagioclase–calcite–quartz, which is controlled by the
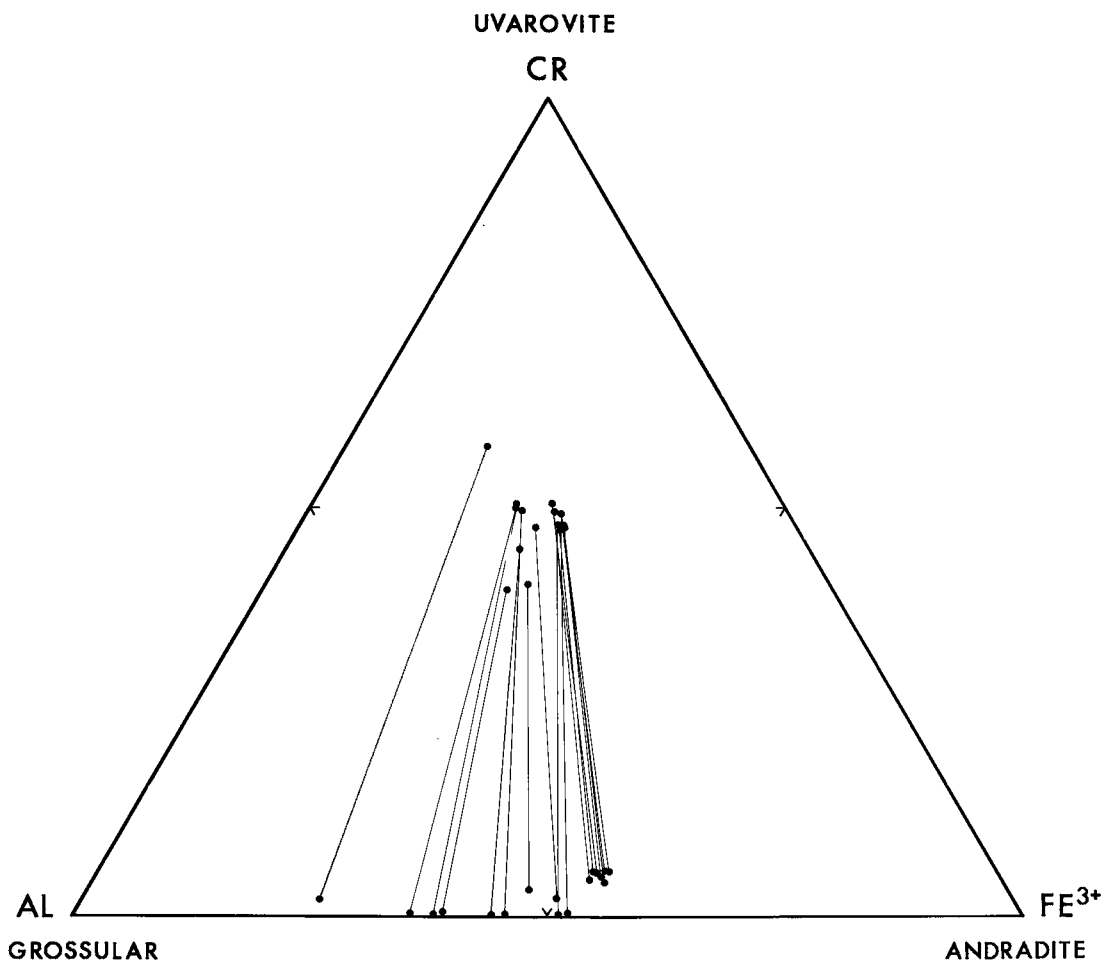

FIG. 4. Compositions of coexisting garnet pairs in direct contact in the specimen of calc-silicate gneiss from Labrador.

Table 2. REPRESENTATIVE CHEMICAL COMPOSITIONS OF
SELECTED MINERALS FROM THE CR-RICH GNEISS

	1	2	3	4	5
SiO$_2$	44.49	46.14	50.34	51.90	0.00
Al$_2$O$_3$	24.82	35.57	1.34	0.10	2.11
TiO$_2$	0.00	0.00	0.05	0.00	0.02
Cr$_2$O$_3$	0.00	0.03	1.61	0.00	63.12
Fe$_2$O$_3$*	n.d.	n.d.	1.72	2.83	3.41
FeO	0.63	0.13	10.34	8.15	29.22
MnO	0.01	0.00	1.33	0.35	1.73
MgO	0.00	0.00	9.63	12.19	0.74
CaO	26.35	18.35	24.43	24.66	0.47
Na$_2$O	0.01	0.99	n.d.	0.05	n.d.
Total	96.31	101.21	100.88	100.23	100.82
Si	6.055	2.097	1.919	1.959	0.000
Al	3.982	1.906	0.060	0.004	0.090
Ti	0.000	0.000	0.001	0.000	0.001
Cr	0.000	0.000	0.049	0.000	1.815
Fe^{3+}*	n.d.	n.d.	0.049	0.080	0.093
Fe^{2+}	0.072	0.005	0.333	0.257	0.889
Mn	0.001	0.000	0.043	0.011	0.053
Mg	0.000	0.000	0.547	0.686	0.040
Ca	3.843	0.894	0.998	0.997	0.018
Na	0.000	0.087	0.000	0.004	n.d.
Total	13.995	4.992	4.000	4.000	3.000

*Calculated, based on idealized stoichiometry of 12 oxyten atoms
and 8 cations.
1. prehnite - based on 22 atoms of oxygen
2. anorthite - based on 8 atoms of oxygen
3. Cr-rich diopside - based on 6 atoms of oxygen
4. Cr-poor diopside - based on 6 atoms of oxygen
5. chromite - based on 4 atoms of oxygen

reaction: anorthite + 2 calcite + quartz = grossular + 2 CO$_2$. For P_{fluid} = 2 kbars, this reaction is restricted to a temperature range from about 490 to 575°C, and to fluid compositions in the $X(CO_2)$ range 0.06–0.14 (Rice 1983). Dilution of the grossular by a considerable amount of the andradite component and minor uvarovite component would shift the reaction to lower temperatures and higher $X(CO_2)$, although the dilution of the anorthite by a modest amount of albite component would have a slight opposite effect. The presence of diopside and the absence of tremolite for these fluid compositions, in conjunction with the association of anorthite and calcite, suggest that the minimum temperature of crystallization was unlikely to have been lower than 450°C (Rice 1983).

The low metamorphic temperature (500 ± 50°C) and H$_2$O-rich fluids suggest that the metamorphic recrystallization probably was caused by the granodiorite, or hydrothermal fluids associated with it, because the Kiglapait-aureole isotherm for this location can be inferred to have been about 700°C (Berg & Docka 1983); furthermore, the Kiglapait intrusion was extremely dry and apparently did not develop a convective hydrothermal system (Kalamarides 1984, unpubl. data).

DISCUSSION

The coexistence of the Cr-rich and Cr-poor garnets in the Cr-rich calc-silicate gneiss may provide evidence of a miscibility gap in the ugrandite gar-

net. On the other hand, it may represent a case of disequilibrium, resulting perhaps from metasomatism. The low metamorphic temperatures and Ca-rich nature of the assemblage certainly allow metasomatism to be a viable hypothesis. The lack of a tight clustering of compositional fields and the presence of a few compositions within the compositional gap argue against the miscibility-gap hypothesis and thus suggest disequilibrium. Even if the miscibility hypothesis is correct, one would have to suggest that different pairs formed at different temperatures. The fact that some Cr-rich garnet compositions appear to be rimmed by Cr-poor garnet might also suggest disequilibrium. Other features that might support metasomatic disequilibrium include evidence for possible metasomatic effects in other minerals, such as the two slightly different compositions of diopside, although the orientation of the Cr-poor lamellae parallel to (010) suggest an internal mechanism for their origin rather than a metasomatic one.

Nevertheless, a number of strong arguments support the existence of a miscibility gap. Firstly, the compositional gap is real and is difficult to explain by any means other than a discontinuity in the solid-solution series. As discussed above, some of the compositional blurring could be artificial due to composite probe analyses. Secondly, the most Cr-rich garnet does not coexist with Cr-poor garnet. Only the green garnet with lowest chromium content coexists with grandite (Fig. 4). If the grandite had formed by secondary metasomatic processes, it seems unlikely that these would have selectively avoided the most Cr-rich garnet compositions for replacement or adjacent growth. Thirdly, the directly coexisting pairs have compositions that are more clustered than those of grains not in direct contact, and the tie lines are relatively systematic (Fig. 4). If disequilibrium were involved, one might expect little regularity in tie lines between adjacent grains. Furthermore, the tie lines appear to shorten, on average, as the andradite content increases, suggestive of a closure on a solvus. Finally, although in some instances the Cr-rich garnet is partly rimmed by Cr-poor garnet, in others the Cr-rich garnet has formed euhedral faces adjacent to the Cr-poor garnet. This argues for contemporaneity in growth of the two garnets. On balance, the evidence supports the existence of a miscibility gap.

Unfortunately, previous analytical, experimental, and theoretical studies of ugrandite do not shed much light on solid-solution relationships among garnet end-members. The literature possesses a dearth of microprobe investigations on Cr-rich grandite, and only a handful of investigators have sought to determine the stability of uvarovite and uvarovite-rich ugrandite. The microprobe results of Jan et al. (1984), Duke & Bonardi (1982), Dunn (1978), and

Prestvik (1974) are shown in Figure 3. These authors report total iron as ferric iron, and thus they probably overestimate the andradite component. The samples reported by Duke & Bonardi (1982) are from a serpentinized wehrlite, in which the chromian andradite is presumed to have formed at low temperatures during serpentinization. Jan *et al.* (1984) reported a chromian andradite + chrysotile assemblage from a chromitite seam in dunite, which developed under greenschist-facies conditions at <380 to 525°C, depending upon the pressure. All these compositions fall in the general pattern outlined by the garnet compositions found in the Labrador xenolith, as do three of the four compositions presented by Prestvik (1974). Two of the garnet compositions ($Uv_{61}Gr_{27}An_{12}$, $Uv_{61}Gr_{30}An_9$) reported by Prestvik occur with Cr-rich chlorite and traces of pyrite. The garnet appears to be secondary in origin and was formed at low temperatures. A third example of ugrandite ($Uv_{44}Gr_{38}An_{18}$) falls in an area that we consider to be the uvarovite-rich edge of the compositional gap. Although Prestvik indicates that the formation of the uvarovite was not related to postmetamorphic events, and thus that the uvarovite presumably formed at high temperature, it bears many similarities to the Labrador occurrence. Prestvik's specimen, found in the contact zone around nordmarkite, possesses the assemblage quartz + albite + prehnite ± uvarovite ± pyrrhotite. Unlike his other samples, the uvarovite in this rock is very inhomogeneous and zoning is not regular; the composition that he presented had the highest chrome content in the sample. The fourth example of ugrandite ($Uv_{26}Gr_{66}An_8$) of Prestvik (1974) plots within our gap in terms of uvarovite component, but at a much lower andradite component than our examples. However, this garnet apparently formed at high temperature and does not represent a postmetamorphic product. This garnet, from the Velfjorden area, Norway, has a similar mode of occurrence to the Labrador specimen in that it was found in calc-silicate inclusions in monzodioritic rocks. The assemblage reported for it is diopside + chromian grossular + pyrrhotite ± pyrite; in other places in the rock, quartz is a dominant mineral. The ten garnet compositions presented by Dunn (1978) are of museum specimens from isolated localities, and assemblages and *P–T* information were not published. If these Cr-rich garnets formed at high temperatures, they offer no constraints to our possible low-temperature miscibility gap. If, however, they formed at low temperatures, one would conclude that the possible miscibility gap achieves closure on approaching the grossular–uvarovite join.

In their study of the solid solution between uvarovite and grossular at 1 bar, Huckenholz & Knittel (1975) investigated the join $CaSiO_3$–Cr_2O_3–Al_2O_3 in the system $CaSiO_3$–Cr_2O_3–Al_2O_3–SiO_2 at temperatures between 800 and 1550°C. Their study showed that grossular forms a complete solid solution with uvarovite. This work was followed by a study on the stability of uvarovite on the $CaSiO_3$–Cr_2O_3 join up to 10 kbars (Huckenholz 1975), which confirmed the earlier work. Unfortunately, these investigations do not address the stability of uvarovite at lower temperatures.

In contrast to the experimental work mentioned above, the study of Ganguly (1976) approached solid solution in ugrandite by the use of calculated and inferred thermodynamic mixing properties. Ganguly (1976) cautioned that "tenuous approximations" were involved in deriving the interaction parameters relating to the binary solid-solutions of uvarovite, and thus certain aspects of the model may be artifacts of the approximations. Nonetheless, he indicated that the binary solid-solutions of grossular are intrinsically stable for all compositions. Based on his calculations, however, the uvarovite–andradite join is unstable with respect to phase separation below the critical temperature 890 ± 140°C. A phase diagram presented by Ganguly, indicating the intrinsic stability of solid solution in the ternary system grossular–uvarovite–andradite, shows the calculated spinodals from 900–400°C and the position of the solvus at 800°C. Ganguly's 400°C ternary spinodal is shown in Figure 3. The spinodals extend out from the uvarovite–andradite join toward the grossular end-member, with the spinodal intersecting the uvarovite–andradite join at temperatures below 900°C.

Although Ganguly's (1976) calculations do indicate a solvus in the ugrandite system, the shape of the solvus (and spinodal) is different from the compositional gap shown by our data. As stated above, the tie lines presented in Figure 4 seem to suggest that our compositional gap would not likely extend to the uvarovite–andradite join. Supporting our conclusion are the garnet compositions reported by Duke & Bonardi (1982) and Jan *et al.* (1984), which imply that there is solid solution along that join even at low temperatures. Our data suggest, instead, that the compositional gap would intersect the grossular–uvarovite join at low temperatures, with very little solid solution of uvarovite in grossular, but extensive solid solution of grossular in uvarovite. As indicated above, the data of Dunn (1978) may or may not contradict this conclusion.

CONCLUSIONS

Although disequilibrium brought on by metasomatic replacement perhaps cannot be ruled out entirely as an explanation for the coexisting garnets, the weight of evidence supports the existence of a miscibility gap in the ugrandite system. An obvious compositional gap, rather systematic tie lines between

coexisting garnets, the absence of tie lines between extremely Cr-rich and extremely Cr-poor garnets, and textural evidence for contemporaneous growth of the two garnets are some of the stronger supporting facts. The postulated solvus of Ganguly (1976), despite its poor correlation with the compositions of natural ugrandite, can be taken as support in general for a miscibility gap in the ugrandite system. Evaluation of the miscibility gap and its compositional location inferred from our data will require more compositional data on natural specimens, new experimental data in the ugrandite system, or better thermodynamic data on solution properties for uvarovite.

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