GREEN GARNETS AND WEHRLITES FROM KIMBERLEY, SOUTH AFRICA

Daniel J. Schulze

Department of Geological Sciences, Queen's University
Kingston, Ontario, Canada K7L 3N6

Xenocrysts of green garnet form a very minor fraction of the concentrate of the Kampfersdam kimberlite, Kimberley, R.S.A. Some are intergrown with clinopyroxene and/or spinel, thus providing an opportunity to better characterize the paragenesis of green garnets. With the exception of two green garnet-bearing wehrlite xenoliths from kimberlites in Yakutia, U.S.S.R. (Sobolev et al., 1973), such garnets are only known as xenocrysts in kimberlite (e.g. Hornung and Nixon, 1973; Clarke and Carswell, 1977; Scott and Skinner, 1979).

The Kampfersdam green garnets range from very deep blue-green to dark-purple with green tinges. They are rich in CaO (11.2-18.8 wt %) and Cr_2O_3 (9.5-13.3 wt %), and thus plot well above the trend of garnets from lherzolites (Fig. 1) noted by Sobolev et al. (1973). The lherzolite trend in Fig. 1 is approximated by garnets from Kimberley wehrlites, dark purple Kampfersdam xenocrysts, and Kao green garnets (Hornung and Nixon, 1973). The Kampfersdam green garnets overlap those from the Newlands kimberlites in South Africa (Clarke and Carswell, 1977) in their CaO and Cr_2O_3 values, but are generally lower in CaO than the Newlands examples. Green garnets from the Premier Mine in South Africa (Scott and Skinner, 1979) also overlap the Kampfersdam samples on Fig. 1., but extend to more Cr-rich values. One purple garnet from Kampfersdam plots in the green garnet field, but most of the dark purple garnets (without a green tinge) from this pipe plot on the lherzolite trend. The Mg/(Mg + Fe) values of the green garnets range from 0.763-0.860, somewhat higher than the Newlands examples (Fig. 2). Clinopyroxenes intergrown with the Kampfersdam green garnets are also magnesian, with Mg/(Mg + Fe) values of 0.914-0.969. They are quite calcic (Fig. 2), with values of Ca/(Ca + Mg) of 0.474-0.494, with one exception at 0.432, and their Cr_2O_3 range from 1.3-3.4 wt %. The intergrown spinels are similar to those from the green garnet wehrlites from Yakutia (Sobolev et al., 1973) and most coarse-textured garnet lherzolites, in terms of Mg/(Mg + Fe) (0.50-0.60) and Cr/(Cr + Al) (0.74-0.80).

Because the green garnets plot on the CaO-rich side of the lherzolite trend (Fig. 1), they could not have equilibrated with orthopyroxene, and are probably xenocrysts from disaggregated wehrlites. Two such green garnet-bearing wehrlites have been described by Sobolev et al. (1973) from the Dalnaya and Sytikanskaya pipes in Yakutia, U.S.S.R. Similar rocks have been inferred as the source of the very calcium-rich green garnets from the Newlands pipe by Clarke and Carswell (1977).

Four garnet-bearing, orthopyroxene-free wehrlites from Kampfersdam and the Kimberley dumps were also investigated (Figs. 1, 2). The garnets in these nodules, however, plot on the lherzolite trend, and the compositions of all phases are typical of the garnet peridotites from Kampfersdam and the Kimberley dumps (Boyd and Nixon, 1978).

In the absence of orthopyroxene, estimation of the pressure and temperature conditions of equilibration is restricted to calculation of temperature at an assumed pressure, using the garnet-clinopyroxene Fe-Mg exchange thermometer of Ellis and Green (1979). Even this estimation may be in error, in view of the very high calcium and chromium contents. Nevertheless, at an assumed pressure of 50 kb, eight composite xenocrysts yield a temperature range of 1040-1380°C, although only two of these are above 1200°C. Sodium content of the clinopyroxenes correlates positively with equilibration temperature. The four wehrlites yield a temperature range of 1125-1235°C, using the same method. As the compositions of the garnets in the latter indicate equilibration with both pyroxenes, however, it is valid to use pyroxene thermometry to calculate their equilibration temperatures. Using the 20 kb solvus of Lindsley and Dixon (1976), they yield a temperature range of 980-1080°C. This corresponds to the high-temperature end of the range for garnet peridotites from the Kimberley pipes (Boyd and Nixon, 1978), using the same thermometer. Considering the above assumptions and estimates, all that can be realistically stated is that most of these composite xenocrysts probably equilibrated at temperatures comparable to the lower P-T nodules of the Kimberley suite, with the exception of the highest temperature xenocryst assemblage, which has a strikingly different garnet-clinopyroxene tie line orientation (Fig. 2).

Although Clarke and Carswell (1977) proposed that the green garnets from Newlands formed in very high temperature and pressure wehrlite cumulates (1600-2200°C, 200-250 km), there is no evidence in these nodules for such extreme conditions. It is suggested here that green Ca- and Cr-rich garnets may have originated in subducted serpentinites. Most occurrences, world-wide, of uvarovitic garnets are restricted to serpentinites (Deer et al., 1982), where they form by Ca- and Si-metasomatism (Ca released from pyroxenes during serpentinization) of chromite. Serpentinites are anomalously Ca-poor relative to most anhydrous peridotites, and the Ca enrichment associated with uvarovite formation must be very localized. During subduction and emplacement of a "cool" slab, temperatures would never rise above those of a steady-state geothermal gradient. The persistence of such low temperatures is essential for long term (billions of years for mantle rocks with Archean ages) preservation of both small scale inhomogeneities, such as the millimeter scale chemical variation described by Clarke and Carswell (1977), and large scale inhomogeneities. The latter are exemplified by the presence of both anomalously Ca-rich (green garnet wehrlite) and Ca-poor (low-Ca garnet harzburgite and dunite) peridotite bodies within an upper mantle that is virtually saturated in both pyroxenes. It should be noted that most single-pyroxene garnet peridotites, both wehrlites and harzburgites, are actually "closet lherzolites", in that their garnets plot on the lherzolite trend. This indicates that the rock equilibrated with both pyroxenes, although one may not be present in the sample. Real single-pyroxene garnet peridotites, such as green garnet wehrlites and low-Ca garnet harzburgites, are very rare.

Boyd, F.R., and Nixon, P.H. 1978. Ultramafic nodules from the Kimberley pipes, South Africa. Geochimica et Cosmochimica Acta 42, 1367-1382.

Clarke, D.B., and Carswell, D.A. 1977. Green garnets from the Newlands kimberlite, Cape Province, South Africa. Earth and Planetary Science Letters 34, 30-38.

Deer, W.A., Howie, R.A., and Zussman, J. 1982. Rock-forming Minerals, Vol. 1A, Orthosilicates, Longman, London.

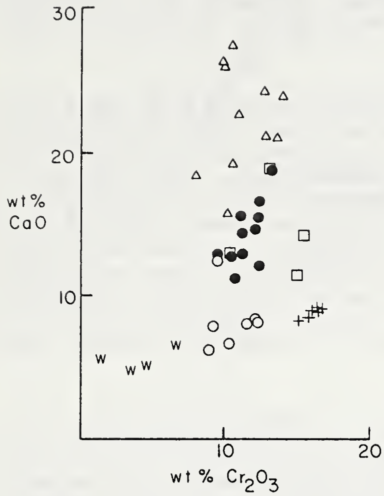
Ellis, D.J., and Green, D.H. 1979. An experimental study of the effect of Ca upon garnet-clinopyroxene Fe-Mg exchange equilibria. Contributions to Mineralogy and Petrology 71, 13-22.

Hornung, G., and Nixon, P.H. 1973. Chemical variations in the knorringite-rich garnets. In Nixon, P.H. ed., Lesotho Kimberlites, pp. 122-127, Cape and Transvaal, Cape Town.

Lindsley, D.H., and Dixon, S.A. 1976. Diopside-enstatite equilibria at 850°C to 1400°C, 5 to 35 kb. The American Journal of Science 276, 1285-1301.

Scott, B.H., and Skinner, E.M.W. 1979. The Premier kimberlite, Transvaal, South Africa, Kimberlite Symposium II, pp. 95-101, Cambridge.

Sobolev, N.V., Lavrent'ev, Yu. G., Pokhilenko, N.P., and Usova, L.V. 1973. Chrome-rich garnets from the kimberlites of Yakutia and their parageneses. Contributions to Mineralogy and Petrology 40, 39-52.



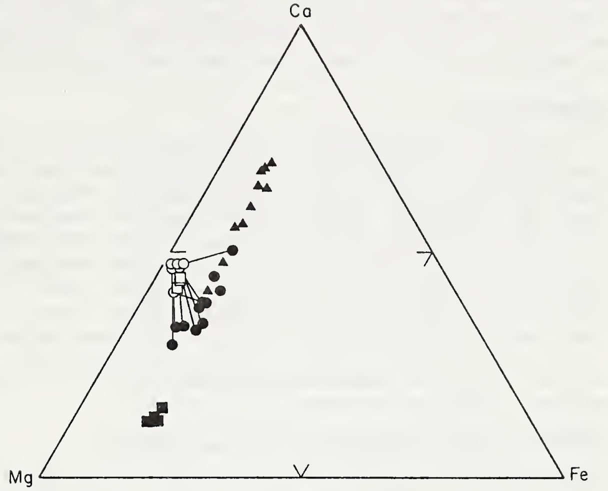


Fig. 1 (left). Plot of CaO vs. Cr_2O_3 for selected garnets. Filled circles = Kampfersdam green garnets, open circles = Kampfersdam dark purple garnets, open triangles = Newlands green garnets (Clarke and Carswell, 1977; Schulze, unpublished data), open squares = Premier green garnets (Scott and Skinner, 1979; Boyd, unpublished data), crosses = Kao green garnets (Hornung and Nixon, 1973), W = Kimberley wehrlite garnets.

Fig. 2 (right). Ca-Mg-Fe values (mole %) of selected garnets (filled symbols) and clinopyroxenes (open symbols). Circles = Kampfersdam green garnets and coexisting clinopyroxenes, squares = Kimberley garnet wehrlites (tie lines not shown), triangles = Newlands green garnets (Clarke and Carswell, 1977; Schulze, unpublished data).