A single-pyroxene thermobarometer for lherzolitic Cr-diopside and its application in diamond exploration

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Chrome diopside has long been known as a diamond indicator mineral, however, its usefulness has previously been limited because no clear method has been devised to distinguish Cr-diopside of diamond-facies and non-diamond-facies origins. In this contribution we outline a thermobarometer formulation that allows an accurate P and T to calculated for Cr-diopside of garnet lherzolite derivation. The thermobarometer does not require knowledge of the compositions of coexisting phases and so can be used for isolated single grains. The thermobarometer has been calibrated on the basis of literature and in-house experimental data. The experiments cover a wide compositional range in both simple-system and complex-system peridotites.

The pyroxene thermometer is based on exchange of enstatite component between orthopyroxene and clinopyroxene with explicit corrections for the effect of minor components including Fe, Ti and tschermak endmembers. The thermometer reproduces experimental temperatures with a accuracy of 30°C or better at the 1σ level.

The new single pyroxene barometer formulation is based on Cr exchange (via the $CaCrAlSiO_6$ or Cr-tschermak molecule) between Cr-diopside and garnet in which correction terms have been introduced to account for non-ideal interaction between Cr and Na. Garnet compositional factors have been empirically expressed in terms of clinopyroxene Cr/(Cr+Al) ratio so that the composition of the coexisting garnet is not required. The new barometer reproduces experimental pressures to within 2.2 kbar at the 1σ level with no systematic deviations among the different experimental datasets.

Combination of the single pyroxene thermometer and barometer enables the pressure and temperature of equilibration of individual Cr-diopside grains to be determined using ordinary WDS, or carefully calibrated EDS, electron microprobe analyses. No special analytical methods are required. Where the paragenesis of Cr-diopside is uncertain, the discriminant diagrams of Ramsay (1992) can be used to select grains that are most likely to be of garnet lherzolite origin. A further classification procedure is often necessary to exclude Cr-diopside grains of wehrlitic origin. The accuracy of the method appears to be as good as or better than existing mineral pair thermometers. There are obvious applications in diamond exploration, e.g. palaeogeotherm determinations, based on heavy mineral concentrates containing xenocrystic Cr-diopside or on altered xenolithic materials from kimberlites and related rocks.

Application to Cr-diopside of xenolithic and xenocrystic origin from the classic Lesotho kimberlite localities (Fig. 1) shows that granular lherzolites fall on a ~42 mW/m^2 conductive geotherm which lies at the high end of the range of typical cratonic geotherms. The sheared lherzolites and discrete nodules yield P-T conditions near 50-60 kbar and 1380-1480°C showing that there has been significant thermal perturbation of the deeper lithosphere in this region consistent with the marginal diamond grades of most Lesotho kimberlites. Application of the thermobarometer to xenocrystic Cr-diopside from the highly diamoniferous Argyle olivine lamproite pipe (Fig. 2), which intrudes an early Proterozoic cratonized mobile belt, reveals extensive deep mantle sampling (55-60 kbar) within the diamond stability field. Thermal conditions were equivalent to a conductive geotherm near 42 mW/m^2 consistent with some earlier P-T estimates from diamondiferous xenoliths (Jaques et al., 1990). These results confirm the existence of a relatively cool, deep mantle root in this Proterozoic terrane. Further examples of geotherm determinations from the Kaapvaal, Siberian and Northern Australian cratons and some off-craton regions will be discussed.

Fig.1 Cr-Diopside from Lesotho Xenoliths

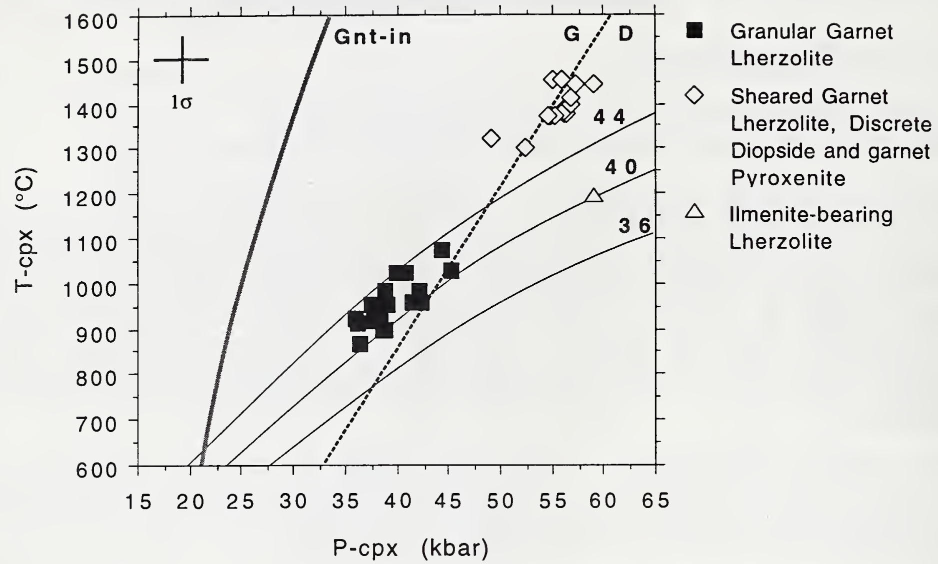

Figure 1: Pressure-temperature plot showing equilibration conditions of garnet lherzolite xenoliths and discrete diopside nodules using the new Cr-diopside thermobarometer of Taylor and Nimis. Conductive geotherms are labelled in units of mW/m2 The garnet-in curve is estimated for depleted peridotite compositions.

Fig.2 Cr-Diopside from the Argyle lamproite

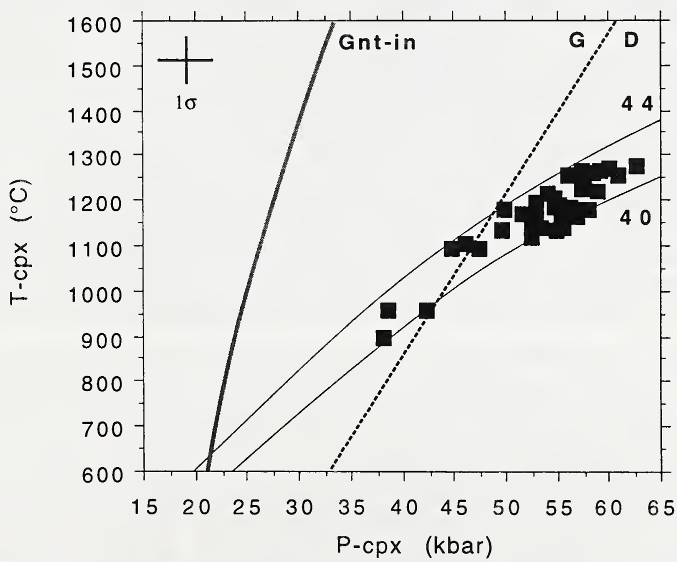

Figure 2: Pressure-temperature plot for xenocrystic Cr-diopside from the Argyle olivine lamproite pipe showing deep mantle sampling in the diamond stability field and a geotherm of ~42 mW/m2.

References

Jaques, A.L., O'Neill, H.St.C., Smith, C.B., Moon, J., and Chappell, B.W., 1990, Diamondiferous peridotite from the Argyle (AK1) lamproite pipe, Western Australia, Contrib. Mineral. Petrol., 104, p.255-276.

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