Xenoliths from kimberlite pipes of the Lac de Gras area, Slave Craton, Canada

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The composition, structure and thermal state of the lithosphere beneath the Lac de Gras area in the Slave Craton have been determined from a suite of mantle-derived xenoliths. The xenoliths in this study come from kimberlite pipes DO-18, DO-27 and A154 and have been recovered after the crushing stage during the processing of the kimberlite. They are generally small fragments 1-2 cm^3 in volume that have survived the jaw crusher, whereas the larger xenoliths (up to 20 cm in diameter) seen in drill core are extremely friable and have disaggregated. This sampling bias limits the the conclusions that can be made on the proportions of rock types, while the small size makes it difficult to obtain robust modal or bulk chemical information.

Several lithological groups have been recognised in the xenolith sample population.

Lherzolites (ol+opx+cpx+grt±crt): Grt lherzolites show a broad spectrum of microstructures (granoblastic, porphyroclastic, mylonitic) and range in grain size (<1mm up to >1cm). Fo contents in olivine range from an average of 91.5 in sheared lherzolites to 92.8 in fine-grained, cpx-poor samples. The overall range in garnet composition is XMg 80.1 to 85.1; CaO wt % 4.5-7.9; Cr_2O_3 wt % 2.4-12.2 (Fig. 1). Zoning in a number of samples is characterised by increasing CaO, Cr_2O_3 and decreasing XMg from core to rim. Other samples show the reverse of this trend, although in both cases, the zoning is parallel to lherzolite trend in a plot of CaO vs Cr_2O_3. Cpx (Cr-diopside) modal abundance is low <5% and in several samples with extremely low abundances, cpx occurs only in intimate association with Cr-spinel.

Harzburgites (ol+opx+grt±crt): A number of cpx-free samples with harzburgitic mineralogy occur in the suite but the garnet compositions indicate coexistence with cpx in all but one xenolith. The lack of cpx in the sample might reflect local modal variation or be a consequence of the small sample size. The garnets are lherzolitic (G9) and with Cr_2O_3 > 6 wt%. No xenoliths from DO-18, DO-27 or A154 with subcalcic garnets have yet been analysed, although such garnets are abundant in concentrate (Griffin et al., 1998). However, Boyd and Canil (1997) have analysed subcalcic garnets in harzburgite xenoliths from the Grizzly Pipe.

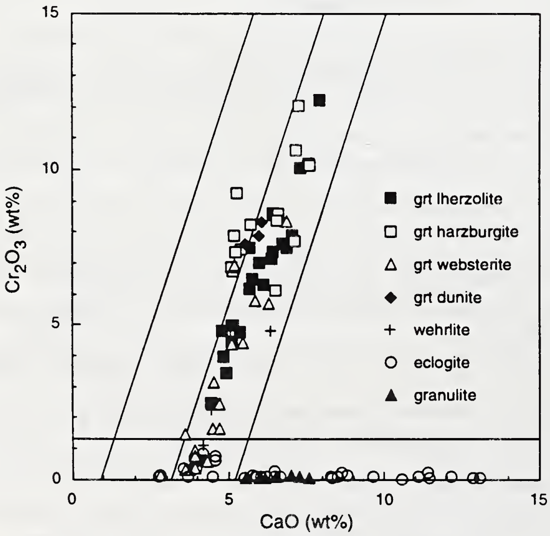

Fig.1 CaO vs Cr_2O_3 wt% in garnet

Dunites (ol±grt±crt): Fine-grained granoblastic olivine-rich xenoliths may represent modal variants of the lherzolite suite. In contrast, some samples are large (up to 2 cm), single olivine grains, commonly strained and with inclusions of other minerals. These are similar to megacrystalline dunites of the Siberian kimberlites (Boyd et al., 1997).

Wehrlites (ol+cpx+grt±crt): Wehrlite xenoliths are not abundant and probably represent a modal variant of the lherzolite suite. The garnet is Cr-pyrope (up to 5 wt% Cr_2O_3) and the olivine is more Fe-rich than in the lherzolites (Fo 90.5-91.2).

Websterites (opx+grt±cpx±ol±crt): Two types of websterites are distinguished on the basis of mineral compositions. Websterites with Cr-pyrope garnet and chrome diopside (low Xjd) are considered to be modal variants of the lherzolite suite. Garnet plots along the lherzolite trend with Cr_2O_3 up to 7%. Mineral compositions in the other type indicate more Fe-rich bulk compositions and lower Cr contents. Higher Xjd (up to 20 mol%) in some of the clinopyroxenes suggests affinities of these websterites with the eclogite compositional spectrum.

Garnet Clinopyroxenites (grt+cpx): Bimineralic grt-cpx assemblages with Cr-pyrope and chrome diopside represent a compositional variant in the lherzolite suite and are not eclogite s.s., but are similar to the griquaites of Nixon (1987).

Eclogites (cpx+grt±rut±ky): Two main types have been recognised: one is characterised by CaO <7wt% in garnet and Xjd 15-35 in cpx and the other by garnet with CaO 9-13 wt % and Na_2O >0.1 wt %, and cpx with Xjd ≥ 50. Some samples of the second type contain kyanite and the garnet and omphacite compositions are similar to other kyanite eclogites from southern Africa (Pearson et al., 1995) and eastern Australia (Pearson et al., 1991). Both types show varying degrees of the breakdown of omphacite to diopside+plag along grain boundaries and compositionally distinct overgrowths on garnet. These features are common in crustal and mantle-derived eclogites and are interpreted as the result of decompression and/or heating in the presence of fluids.

Granulites (plag+cpx+grt±opx): These mafic granulites are fine- to medium-grained with well-equilibrated granoblastic microstructures. The ratio of modal opx:cpx:grt most likely reflects bulk compositional variation within the group, rather than breakdown of opx+plag to grt+cpx. The garnets have similar Xgr to low-Ca eclogites but are distinguished by lower XMg. Cpx has low Jd/Ts, in contrast to the omphacite granulites present in other lower crustal xenolith suites. Despite this feature, there are no exposed granulites in the Lac de Gras area similar to the mafic granulite xenoliths and the granulite xenoliths are interpreted as being derived from the lower crust.

Geothermobarometry on the peridotite and websterite xenoliths has involved the evaluation and comparison of those methods most commonly accepted in this type of study. Although discrepancies occur between the P-T estimates for individual xenoliths using different combinations of thermometers and barometers, the overall features of the distribution of points in P-T space remain independent of P-T methods (Fig. 2). P-T estimates for low temperature xenoliths (<900°C) fall near a $35mWm^{-2}$ conductive model geotherm, whereas xenoliths with higher equilibrium temperatures lie between this geotherm and a $40mWm^{-2}$ geotherm. The change in gradient is a step, rather than the 'kink' that is characteristic of P-T arrays from other xenolith suites (e.g., Lesotho). The occurrence of sheared grt lherzolite xenoliths with equilibration temperatures >1150°C indicates obvious similarities with high-T sheared lherzolite xenoliths from the Kaapvaal and Siberian cratons. The high-T xenolith population is not uniformly composed of sheared lherzolites, but also includes undeformed peridotites and websterites. This is also borne out by the garnet concentrate data (Griffin et al., 1998): one group of high-T garnets have trace element signatures indicative of melt-related metasomatism, whereas many garnets from the same T range are unmetasomatised.

A minimum lithosphere thickness of ≥200 km is estimated using the occurrence of the high-T unmetasomatised xenoliths and the extension of the conductive geotherm to ~1200-1250°C. The eclogites can be incorporated into the rock-type stratigraphy by projecting grt-cpx temperatures to the model geotherms. Temperature estimates range from ~890 to 1250°C, thus placing the eclogites into the deeper layer. A stratification of the 2 types of eclogite is also apparent with a bimodal temperature distribution: the eclogites with low CaO garnet give a T range of 890-1050 °C; the high CaO garnet eclogites yield T ≥ 1100°C. The garnet websterites are also concentrated in the lower layer, but a few produce P-T estimates that plot on the 35 mWm^{-2} geotherm of the shallow layer. The high-Cr variants of this group tend toward the high end of the T range (> 1100°C) and come from the deeper part of the lower layer.

The step in the xenolith geotherm is also seen in the Garnet Geotherm (Griffin et al., 1998), although a mechanism for this effect is problematic. One explanation is that the step is a transient feature, produced by heating at the time of kimberlite volcanism. Alternatively, the offset of the steady-state conductive geotherms reflects a conductivity difference between compositionally distinct layers, with a boundary at ~900°C. This corresponds to a marked change in mean compositions of the garnet concentrates (Griffin et al., 1998) and in the mean Fo contents of olivine. However, the difference in the estimated bulk compositions of the 2 layers only produces 20% of the conductivity contrast required to produce the step in the geotherm. All of the peridotite xenoliths are characterised by high olivine/opx ratios, in contrast to most other Archean xenoliths (Boyd 1987, Griffin et al., 1998). The results obtained in this study are comparable to those obtained by Boyd and Canil (1997), and the mantle beneath the Lac de Gras area is significantly different from the lithosphere of the Kaapvaal and Siberian cratons.

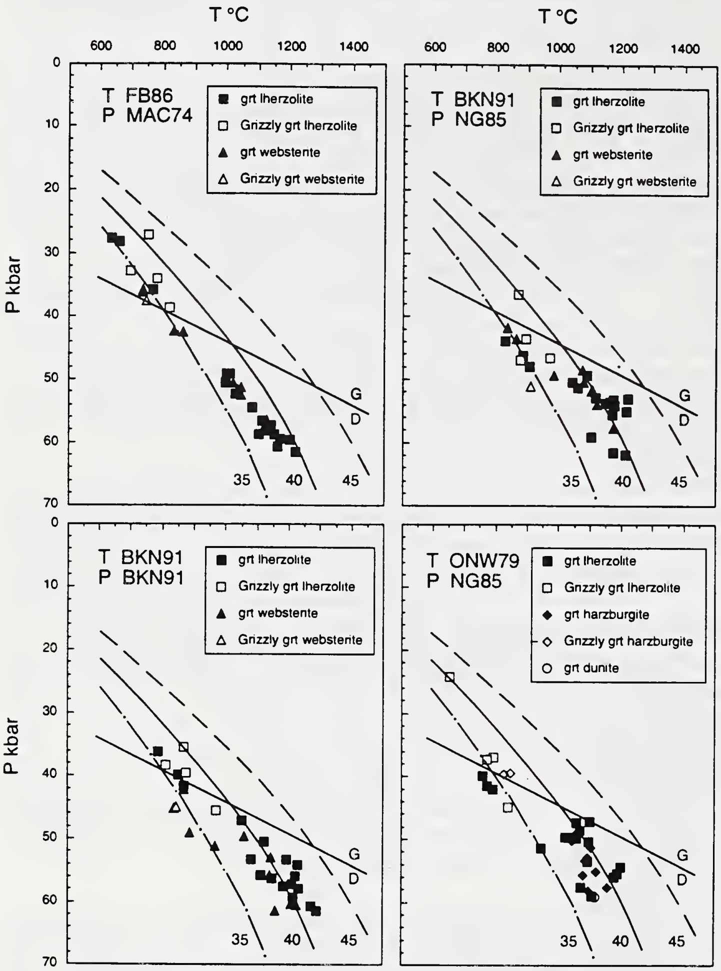

Fig.2 P-T plots for Lac de Gras xenoliths for selected geothermometer and geobarometer combinations.

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