

Mantle xenoliths and xenocrysts from the Cross kimberlite, British Columbia, Canada: implications for upper mantle evolution beneath western Canada

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The Cross kimberlite is located in the Front Ranges of the Rocky Mountain Fold and Thrust Belt of southeastern British Columbia, Canada. This Early Triassic intrusion postdates Proterozoic to Early Paleozoic extensional magmatism, and predates the Mesozoic-Cenozoic thrusting of the Columbian Orogeny. It has therefore been transported >100 km northeastward relative to the mantle and crystalline basement through which it penetrated. The kimberlite intruded Pennsylvanian sedimentary rocks of the Bourgeau thrust sheet, which contains a facies change that marks the western edge of deposition on thick continental crust (Price 1981). The highly altered suite of xenoliths and xenocrysts is derived from the mantle beneath the extensional western margin of Paleozoic North America.

Mantle xenoliths are extensively serpentized. Garnet, spinel, and amphibole are the only primary phases commonly preserved. Spinel peridotite predominates over garnet peridotite. Eclogites and megacrysts are absent. The xenoliths are friable, and few were recovered, but xenocrysts are common in the kimberlite. Spinel and garnet predominate, although amphibole and clinopyroxene xenocrysts have been recovered. Unaltered olivine and orthopyroxene xenocrysts have not been found.

Olivine is Fo₉₂ in garnet peridotite and Fo₉₀ in spinel peridotite. Orthopyroxene and clinopyroxene exhibit a bimodal distribution of Al₂O₃ contents reflecting derivation from garnet (Al₂O₃<2 wt%) or spinel (Al₂O₃>3 wt%) peridotite. Clinopyroxene xenocrysts (this study and Fipke et al 1989) exhibit a similar distribution of Al₂O₃ contents.

Garnet in xenoliths is Mg-rich (Mg/(Mg+Fe)>0.82) and Cr-rich (Cr₂O₃=5-10.5 wt%). The compositional range of xenocrysts is more extensive and defines four groups (Fig. 1). One group consists of red to purple

Mg-rich Iherzolite garnet (Mg/(Mg+Fe)>0.82) with an extensive range of Cr₂O₃ contents (1.5-10.0 wt.%). All xenolith garnet compositions fall within this group. Another group of xenocrysts consists of orange Mg-poor Iherzolitic garnet (Mg/(Mg+Fe)<0.82) that is relatively Ti- and Cr-poor (Cr₂O₃ <4.5 wt%), and has no equivalents among the xenoliths. This group is relatively Ca-rich at a given Cr₂O₃ content compared to the Mg-rich group, and defines a steeper array on the CaO-Cr₂O₃ plot. A third group of xenocrysts is Fe- and Ti-rich, and has compositions similar to Cr-poor megacrysts. The fourth group consists of uncommon Ca-poor G10 garnet (CaO< 3 wt%), consistent with a harzburgite source.

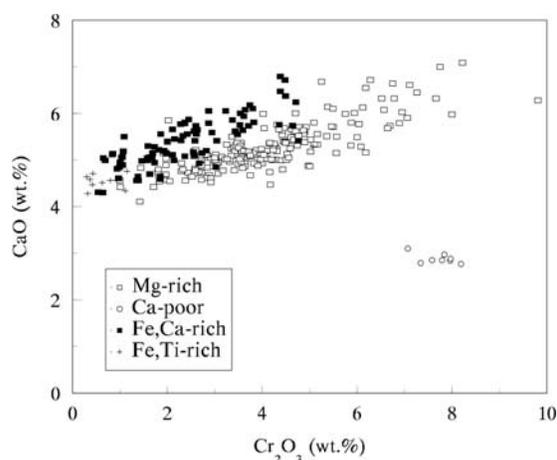


Figure 1: CaO versus Cr₂O₃ plot of Cross garnet xenocrysts.

Spinel compositions in garnet xenoliths have a restricted range (Cr/(Cr+Al)=0.7-0.8) relative to those in garnet-free xenoliths (Cr/(Cr+Al)=0.1-0.9). Xenocrysts encompass the entire range. There are no criteria to unambiguously distinguish between

xenocrysts derived from garnet-bearing versus garnet-free peridotite, particularly in the absence of an abundant suite of xenoliths, but many of the relatively Cr-poor xenocrysts may be derived from spinel peridotite. The Al-poor xenocrysts ($Cr/(Cr+Al) > 0.8$) are relatively Ti- and Fe^{3+} -rich, and may be related to metasomatism. The Al-poor spinel in one garnet-free xenolith ($Cr/(Cr+Al) = 0.91$) is texturally associated with phlogopite. Amphibole compositions range from edenitic hornblende to pargasite, typical of hornblende peridotite. The restricted mineral assemblages limit application of thermobarometric techniques. Two garnet peridotites yield $\sim 1100^\circ\text{C}$ at 43 kb. Single pyroxene thermobarometry (Nimis and Taylor 2000), as applied to Al-poor clinopyroxene xenocrysts yields $\sim 870^\circ\text{C}$ at 46 kb, and those reported by Fipke et al. (1989) give $\sim 1030^\circ\text{C}$ at 44 kb and 830°C at 36 kb. Nickel thermometry applied to a subset of the garnet xenocrysts gives a range of $890\text{--}1350^\circ\text{C}$ (Canil et al. 2003). Zn contents in spinel in xenoliths (Ryan et al. 1996) give $900\text{--}1150^\circ\text{C}$ for garnet-bearing xenoliths and $575\text{--}750^\circ\text{C}$ for garnet-free xenoliths. Spinel xenocrysts yield $580\text{--}1170^\circ\text{C}$, with most between $600\text{--}820^\circ\text{C}$. Many of the latter are likely derived from garnet-free xenoliths.

The kimberlite sampled a significant depth range, including both depleted and relatively fertile mantle. Highly depleted harzburgitic mantle, as evidenced by the low-Ca garnet xenocrysts, was not sampled in abundance, and may be a very minor component of the underlying mantle. Among the lherzolite-trend garnets xenocrysts, trace element concentrations reported by Canil et al. (2003) indicate a general lack of the highly depleted compositions that are typical of Archean mantle. The substantial population of Fe-rich garnet xenocrysts, however, implies the presence of a significant relatively fertile mantle reservoir. The Fe- and Ca-rich compositions plot along the CCGE trend of Kopylova et al. (2000), and may be derived from spinel-bearing peridotite. These Fe- and Ca-rich garnet xenocrysts from Cross have elevated Sc/V ratios relative to Mg-rich xenocrysts (Fig. 2), a feature that may result from preferential partitioning of V into co-existing spinel.

The Rocky Mountains in southeastern British Columbia overlie the Archean Hearne Province (Ross et al. 1991), yet the Cross kimberlite apparently sampled little Archean mantle. Canil et al. (2003) attributed this to Proterozoic replacement or modification of the mantle root, possibly during the accretion of the Wyoming Province to Laurentia. The Triassic mantle sampled by the Cross kimberlite, located beneath the western edge of thick continental crust on the margin of North America, evidently still

possessed a root that survived Late Proterozoic to Early Phanerozoic extension and magmatism.

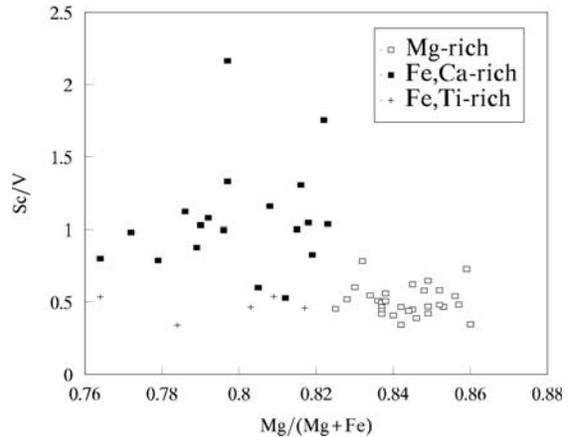


Figure 2: Sc/V versus Mg/(Mg+Fe) plot for Cross garnet xenocrysts. Sc and V values from Canil et al. (2003).

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