CONTINUED STUDY OF THE ORIGIN OF CRATONIC UPPER MANTLE

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ABSTRACT

Mantle peridotite xenoliths from Archean cratons generally have high molar Mg/(Mg+Fe), or Mg#. The best known suites, from the Kapvaal and Siberian cratons, have high modal orthopyroxene (Opx). These high Opx compositions are probably not residues of partial melting (Kelemen et al., 1998). Less well known cratonic xenolith suites from Greenland and North America include high Mg# peridotites with much lower modal Opx. Such low Opx compositions could be residual from high degrees of polybaric, decompression melting, ending in the spinel lherzolite stability field at pressures of 30 to 20 kbar (Bernstein et al., 1998). Similarly, based on Mg# and trace element evidence, we infer that the great majority of both spinel- and garnet-bearing xenoliths are also residues of polybaric melting that ended at pressures ≤ 30 kbar. Where xenoliths record equilibration pressures > 30 kbar, this must result from tectonic transport of peridotites to greater depth after melting (Kelemen et al., 1998).

Proposed mechanisms for producing the high Mg#, high Opx compositions include metamorphic differentiation of high pressure residues, mixtures of residual peridotites and high pressure igneous cumulates from ultramafic magmas, and addition of SiO_2 to low Opx peridotites via melt/rock reaction. A positive correlation between Ni contents of olivine and modal proportions of Opx in mantle xenoliths (Kelemen et al., 1998) is probably not produced by partial melting, metamorphic differentation, or formation of igneous cumulates. It can be produced by reaction between SiO_2-rich liquids (e.g., small degree melts of subducted eclogite) and previously depleted, low Opx peridotites.

Kelemen et al. (1998) proposed a two step process. First, high Mg#, low Opx peridotites were created by large degrees of polybaric melting ending at pressures < 30 kbar. Later, these depleted residues were enriched in Opx by interaction with SiO_2-rich melts generated mainly by partial melting of eclogitic basalt and sediment in a subduction zone. Magmas modified by such a process could have formed a major component of the continental crust. Thus, this hypothesis provides a genetic link between cratonic upper mantle and continental crust.

We are now conducting isotopic and trace element investigations of several suites of cratonic peridotites, with the following goals:

(1) The hypothesis that high Opx peridotites with high Ni in olivine (e.g., xenoliths from the Premier kimberlite, Boyd, pers. comm. 1998) gained SiO_2 via reaction with SiO_2-rich partial melts of eclogite implies that high Opx peridotites should have mineral compositions in equilibrium with light rare earth element (REE) enriched melts, and probably should be depleted in Nb and enriched in Sr relative to light REE. Kelley and Kelemen are attempting to measure REE contents of Opx via ion probe and laser ICP-MS to determine whether this is the case.

(2) The hypothesis that low Opx peridotites (e.g., xenoliths from East Greenland, Bernstein et al., 1998) represent true residual compositions, which have not been modified by subsequent major element metasomatism, would be strengthened if it could be shown that some or all of these also have trace element contents indicative of a residual origin. Hanghøj and Kelemen are using microbeam techniques to evaluate this.

(3) The inference that highly depleted, low Opx peridotites, such as those from East Greenland, are Archean must be evaluated. Hanghøj, Blustajn and Frei have completed preliminary Os isotope measurements which give Archean “Re depletion ages”. Efforts to produce a true isochron have met with failure, and we have documented substantial, recent Re addition to most or all samples.

(4) Modeling by Kelemen et al. (1998) presented a single melt/rock reaction scenario, involving a high SiO_2 melt composition produced by experimental melting of eclogite at 30 kbar by Rapp and co-workers. This forward model fit the observed variation of Ni in olivine vs. modal Opx in cratonic peridotites. However, we were uncertain about the uniqueness of this model. Kelemen is conducting similar modeling using a variety of different initial melt compositions to evaluate alternative possibilities.

(5) Jordan (e.g., 1988) proposed that the cratonic upper mantle is neutrally buoyant with respect to the convecting, oceanic upper mantle, suggesting that the lower temperature of the cratonic upper mantle is offset by compositional differences (mainly, lower Fe). We have noticed that the data set for the Kapvaal craton (e.g., Boyd, pers. comm. 1998) suggests instead that “low temperature” peridotites of the cratonic upper mantle are compositionally buoyant compared to the convecting upper mantle.This supports the idea that even diamond-bearing low temperature peridotite xenoliths were residues of partial melting which ended at pressures less than 30 kbar. Kelley and Kelemen are making calculations to support this alternative idea, for Kapvaal data from Boyd (pers. comm. 1998) and also for an extensive data set from Eggler (pers. comm. 1998).

We will report on the progress of most or all of these efforts at the Lherzolite Conference.

REFERENCES

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