

Application of MELTS to Pyroxenite Partial Melting in Basalt Source Regions

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Although pyroxenites are likely to host some portion of the heterogeneous geochemical components present in basalt source regions, relatively little is known about their partial melting behavior. Key unresolved questions include the melting behavior of pyroxenites compared to that of peridotites, the compositions of partial melts of pyroxenite and the residual mineralogy of pyroxenites during partial melting. Here we apply MELTS to partial melting of pyroxenites.

The MELTS algorithm has proved to be a powerful tool for understanding partial melting of the mantle. Perhaps unique among chemical models of magma genesis, MELTS has made several correct predictions regarding features of peridotite phase equilibria that have later been verified either by experiment or by rigorous thermodynamic analysis of simple systems. There are a number of important inaccuracies in MELTS reproduction of experimentally determined peridotite melting relationships, but MELTS success has derived from its internal consistency, which allows exploration of processes and scenarios not easily investigated by other means, and from judicious comparison to experiments and simple models.

We have performed MELTS calculations at 3 GPa for two anhydrous pyroxenite compositions, MIX1 G, and GERM2, for which we also have high pressure experimental results. MIX1 G is close to the compiled average composition of pyroxenite reported from xenoliths and orogenic massifs (Hirschmann and Stolper, 1996). GERM2 is similar to the composition of average subducted oceanic crust (Pertermann and Hirschmann, 1999).

For MIX1 G, the calculated near-solidus mineral assemblage consists primarily of aluminous clinopyroxene and garnet, a small amount (~2%) of olivine, and a trace of spinel. Substantial melt production does not occur until temperatures similar to the peridotite solidus are achieved; e.g. at 1500 °C, the calculated melt fraction is 7%. Liquid compositions are strongly undersaturated for much of the calculated melting interval. These results accord with our experimental results, which also yield strongly *ne*-normative liquids and have substantial liquid present only at temperatures near the peridotite solidus.

For GERM2, the calculated near-solidus mineral assemblage also consists primarily of aluminous clinopyroxene and garnet, with small amounts of quartz, rutile, and a trace of spinel. Substantial melting is predicted at temperatures approaching the likely peridotite solidus; e.g., F=45% at 1500°C. Liquids are

silica-enriched at small-to moderate degrees of melting, but are basaltic at high (F>60%) degrees of melting. These results again accord with experimental results, which define the liquidus of GERM2 at near 1510 °C at 3 GPa and which produce liquids with SiO₂52% from the solidus up to 50% melting.

Calculated melting relations with mixtures of MIX1 G and GERM2 at 3GPa are consistent with the presence of a thermal divide between two broad categories of pyroxenite, which we term "silica-excess" and "silica-deficient". A survey of pyroxenite layer and xenolith bulk compositions (Hirschmann and Stolper, 1996) suggest that both types could be common in the mantle. Near their solidus, mixtures with more than 20% GERM2 are silica-excess pyroxenites, which produce silicic liquids and have quartz in the residue. Those with less than 20% GERM2 are silica-deficient pyroxenites, which produce undersaturated liquids and have olivine in the residue. At constant temperature, calculated melt fraction is minimal near 20% GERM2 and increases towards the end members, but increases more rapidly on the silica-excess side. The thermal divide corresponds to compositions consisting solely of garnet and clinopyroxene. High expected degrees of melting of silica-excess pyroxenite near the peridotite solidus will produce basaltic liquids, which presents difficulties for the hypothesis that pyroxenite-derived components in basalts could be associated with silica-enrichments.

The mode of garnet at 3 GPa for GERM2 is no greater than 25% in calculations and 18% in experiments. This garnet mode is lower than that of metamorphic eclogites of similar bulk composition owing to strong Al-enrichments in clinopyroxene at high temperatures and pressures. Thus, widely-assumed trace element models that invoke "eclogite" with ~50% garnet modes in basalt source regions require revision and potential garnet signatures from partial melts of pyroxenite may be weaker than are sometimes assumed. Maximum calculated garnet modes for MIX1 G are up to 35%, suggesting that garnet signatures in partial melts of silica-deficient pyroxenites (which also melt to lesser extent) may be stronger than those of silica-excess pyroxenites.

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