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Paradise Lost: Interpreting peridotites from oceanic ridges

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Summary: In many ways, polybaric decompression melting, focused melt transport and accretion of igneous crust at oceanic spreading ridges is the simplest and best understood igneous process on Earth. However, in this presentation we focus on remaining - in some cases, increasing - uncertainties in understanding melting and melt transport beneath oceanic spreading ridges from the perspective of studies of residual mantle peridotites.

Degree of melting & potential temperature: Reaction of cooling melt with shallow peridotite can reset indicators of degree of melting and potential temperature in both melt and residual peridotite. Yb concentration and spinel Cr# in peridotite are affected by (a) small scale variations in reactive melt transport, (b) variable extents of melt extraction, and (c) *impregnation*, i.e. partial crystallization of cooling melt in pore space. Comparison of abyssal peridotite bulk compositions to residual trends indicate that roughly 3/4 of abyssal peridotites have undergone major element refertilization. Also, many peridotites at ridges may have undergone several extensive partial melting events over Earth history, while others could be residues of extensive melt extraction from mafic heterogeneities in the mantle source. For all of these reasons, estimates of the *degree of melting* based on peridotite compositions should be viewed with increasing skepticism.

Melt focusing to ridges: Dissolution channels (dunites) within residual peridotite are predicted to coalesce downstream, but so far numerical models have not produced sufficient focusing to explain why $> 95\%$ of oceanic crustal accretion takes place in a zone < 5 km wide. Modeled crystallization of cooling melt in the shallow mantle can create a permeability barrier guiding underlying melt diagonally toward the ridge, but field studies have not identified such barriers. Permeable *shear bands* may guide melt to the ridge, but the nature of shear bands in open systems at natural grain size and strain rates is uncertain. 2D and 3D focused solid upwelling due to melt buoyancy and weakening as a function of permeability - especially increasing permeability with decreasing pyroxene content during melting - may warrant more attention.

Crustal thickness, spreading rate & melt productivity: The following three statements are inconsistent: (1) Modelled peridotite melt productivity beyond cpx exhaustion is $> 0.11\%$/GPa. (2) Crustal thickness is independent of spreading rate. (3) Thermal models predict, and observations confirm, thick thermal boundary layers beneath slow spreading ridges. Most sampled peridotites from ridges melted beyond cpx-out. Cpx in these rocks formed via impregnation and/or exsolution during cooling. When abyssal peridotite data are filtered to remove refertilized samples, and pyroxene compositions are recalcalated at ˜ 1300 C, more than half contain no residual clinopyroxene. Thus, most or maybe all abyssal peridotites undergo cpx exhaustion during polybaric decompression melting. If (a) melt productivity is $<< 0.1\%$/GPa beyond cpx-out, and (b) cpx-out occurs > 15 km below the seafloor beneath most ridges, then the independence of crustal thickness with spreading rate can be understood.

Conduit generation and geometry: Dunites, formed by pyroxene dissolution in olivine-saturated melt ascending by porous flow, are conduits for focused porous flow of melt, preserving disequilbrium between melt and pyroxene in surrounding peridotite at $P < 1.5$ GPa. Perturbations in permeability grow into dunite conduits because incongruent dissolution increases porosity and permeability. Perturbations may arise from *shear bands* and/or heterogeneities in the mantle source. Conduits may also involve mechanical instabilities, if it is easier to open a pore than to close it. Most models and experiments do not produce the power law distribution of dunites at a given depth observed in peridotites, except for some shear band experiments.

Keywords: Mid-Ocean Ridge, Melting, Melt migration, Peridotite, Clinopyroxene