Mantle melting and melt transport beneath oceanic spreading ridges

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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. 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.

Melt focusing to ridges

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. The data can be understood if (a) melt productivity is << 0.1%/GPa beyond cpx-out, and (b) cpx-out occurs > 15 km below the seafloor beneath most ridges.

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.

Underplating of felsic rocks in arcs

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Buoyant, felsic material may be subducted and then returned to the base of evolving crust via (a) relamination, (b) diapirs in the mantle wedge, and/or (c) imbrication (e.g. [1-5]). Subducting crust is carried to conditions (~700°C and P > 1 to 2 GPa) where garnet is stable, rendering some lithologies denser than mantle peridotite at the same PT, and where material is hot enough to flow viscously in response to buoyancy forces [6]. Whereas delamination and foundering can only remove dense lithologies from a narrow, high PT horizon at the base of typical crust, the *entire* subducting crustal section can undergo density sorting in subduction zones. Such efficient density sorting may explain why lower continental crustal compositions, including mafic estimates [7], are less dense than peridotite at the same PT [5, 6, 8].

Sediment subduction and 'subduction erosion' involve intermediate to felsic shale and greywacke. If they are in layers or blobs with dimensions > 100 m, they will rise buoyantly at > 700-800°C in times < 1 Myr [4]. Ascent in a 'subduction channel' involves isothermal decompression to a level of neutral buoyancy (a). Most UHP terrains record re-equilibration at 700°C and 0.5-1 GPa, in accord with this idea [5]. Diapric ascent through the hot mantle wedge (b) will induce extensive melting, producing the 'sediment component' in arc magmas [4]. Some trench sediments may be thrust directly into arc lower crust (c), producing andesitic paragneiss recording typical arc Moho PT (~ 800°C, 1 GPa [9]), as in the North Cascades. Indeed, the 35 km of crust beneath such exposures may itself have been added later, via continued underlplating of buoyant, felsic material. In general, arc magma flux estimates that assume subduction erosion always removes arc crust are overestimates.

Arc-arc or continental collision will also lead to efficient separation of dense, mafic rocks from bouyant, felsic metasediments and plutons that rise to neutral buoyancy [5].

As a result, much of the continental lower crust may be quite felsic, similar to typical granulite terrains. This is consistent with Vp and heat flow data provided that some U, Th and K are extracted via decompression melting [5].

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