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Tectonic controls on magma extraction at mid-ocean ridges at the 100km scale

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The first order segmentation of mid-ocean ridges clearly affects melt extraction, as along-strike variations in crustal thickness are observed at all spreading rate. We focus on two study areas: 1) the ultraslow Southwest Indian Ridge at 10–16°E, where melt is focused towards specific locations – Joseph Mayes Seamount and Narrowgate – at either end of a long, oblique, and essentially amagmatic supersegment; and 2) the ultrafast East Pacific Rise at 8–11°N, which features two transform faults. Gravity anomalies imply an anomalously thick crust at the transtensional Siqueiros transform but not at the transpressional Clipperton transform. Thickened crust at transform zones were observed at all other ridges with a spreading rates in excess of 3cm/yr but not at slower ridges [Gregg et al., 2007].

We model melt extraction over these study areas based on 3D Finite Element models of mantle flow and thermal structure. The models are driven solely by plate divergence, ignoring buoyancy and the feedback between melt delivery and the thermal structure of the lithosphere. Along-strike variations are the results of the imposed segmentation of the spreading center. Melts are assumed to migrate vertically until they enter the thermal boundary layer, where rapid crystallization leads to the formation of a permeability barrier. The barriers shallows and the strength of the crystallization front increases towards the ridge axis. Subsequent melts travel along the base of this barrier and are focused toward the ridge axis. The complex topology of the permeability barrier can focus melt to specific areas. While this can explain the presence of Joseph Mayes Seamount, other features require the implementation of a melt extraction zone associated with plate boundaries. Both the Siqueiros Transform and Narrowgate require that magma traveling along the permeability barrier be extracted by structures such as cracks or faults associated with the plate boundary. These structures may be less efficient at the Clipperton transform due to the transpressional character of this transform. Indeed Clipperton does not feature a crustal thickness anomaly similar to Siqueiros. At slow ridges the thick thermal boundary layer under transform faults may prevent these structures to reach deep enough to enable melt extraction. In summary, we see evidence of melt extraction controlled by plate-scale tectonics in spreading centers at every spreading rate.