# Melt Rock Reaction in the Mantle and Accretion of the Lower Crust at Slow Spreading Ridges

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## Introduction

Primitive olivine cumulates; dunite, troctolite, and olivine gabbro associated with mantle peridotite are common features of oceanic core complexes away from fracture zones. They are broadly interpreted as from the crust-mantle transition zone, formed where melt transport focused beneath a 2$^{nd}$ order ridge segment. Mapping at Kane Megamullion on the MAR shows local magmatic centers may form anywhere beneath a ridge segment: existing for several hundred thousand years before magmatism focused elsewhere [1].

Olivine-rich troctolites form by melt-rock reaction with the mantle, in a sequential reaction between peridotite and migrating melt, forming first dunite, then troctolite, then olivine gabbro. This occurs due to solidification-by-reaction between melt and the mantle [2]. Such reactions may continue in the lower crust until olivine is eliminated. Ol-rich troctolites in IODP Hole U1309D appear to have this origin [3-5]. Rafting of troctolites to higher levels likely due to tectonic rollover wgeb the lower crust supports a shear stress at low magmatic budgets. Thus a portion of the lower crust may be hybridized mantle.

Ol-rich troctolites also occur within a mantle section at Godzilla Megamullion in the Parece Vela Basin [3]. They include both Ol-rich (Ol > 60 vol.%) and plagioclase-rich (Pl > 60 vol.%) troctolites. The latter likely formed by local dissolution of a plagioclase matrix, and crystallization of olivine, Cpx and new plagioclase by melt produced by mixing high-MgO melt residual to Ol-troctolites formation with melt crystallizing cumulus plagioclase in a melt transport conduit.

We find olivine nickel contents can constrain the formation environment of Ol-rich rocks in the lower crust and mantle, the nature of the formation process, and the magma budget. Comparison to the nickel contents of other troctolite and gabbro occurrences in oceanic and ophiolite settings reveals a set of relationships generally consistent with our interpretations. Notably, the olivine gabbros from the 1500-m Hole 735B Atlantis Bank gabbro section have low nickel contents, while those from the 1400-m Hole U1309D Atlantis Massif gabbro section have high nickel. This is consistent with less-reacted infiltrating melt at the latter, strongly supporting the idea that U1309D represents a deeper section of the lower crust near the crust-mantle transition, while the former have been shown to represent the dike-gabbro transition and underlying gabbros.

Godzilla troctolites and gabbros have clear similarities to EPR troctolites and gabbro segregations drilled in dunites crosscutting mantle peridotites at Site 895 at Hess Deep. These represent multi-stage crystallization of stagnant melts in conduits beneath the EPR. Thus, it appears that the processes that formed the Godzilla troctolites occur beneath ocean rises across the spreading rate spectrum.

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# Thin Crust over the Marion Rise: Melting a Heterogenous Mantle from beneath Gondwana

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The Marion Rise stretches ~ 3100 km along the SWIR from its shoalest point at 850 m, 250-km north of Marion Island, to 5600-m just west of the Rodriguez TJ. By any measure it has essentially the same relief as the Icelandic/Reykjanes Rise, but is twice as long. Cut by numerous large-offset transforms, which would likely dam sub-axial asthenospheric flow, it is unlikely that the rise can be supported by a mantle plume beneath the Marion Hotspot. The hotspot, however, traces back to the Karoo volcanic event at 185 Ma near the time of the breakup of Gondwana, and formation of the SWIR. Hence the mantle substrate beneath the SWIR likely comes from beneath southern Africa, representing the residue of the Karoo event.

We compiled new and existing data on SWIR dredge and dive samples, and find that large peridotite exposures occur throughout, including the Marion Rise crest. In the absence of significant gabbro representative of a lower crustal section, and the presence of near-amagmatic spreading segments along the rise, we conclude that the crust over the Marion Rise, in sharp contrast to the Reykjanes Ridge, is relatively thin and discontinuous. At the same time, analysis of peridotite spinel shows a systematic increase in mantle depletion up the Marion Rise correlating to the composition of spatially associated basalts and ridge depth. Hence the degree of mantle depletion increases towards the rise crest. In the absence of significantly thicker crust, this must be in large part the consequence of an earlier mantle melting event – presumably coinciding with the Karoo volcanism – but possibly including a yet earlier mantle depletion.

This, then, provides an explanation for the Marion Rise other than a simple thermal anomaly attributable to sub-axial asthenospheric flow fed from a mantle plume beneath the Marion Hotspot. Harzburgite in the garnet stability field is significantly less dense than lherzolite, and hence the systematically higher degree of mantle melting required by the Marion Rise basalts and peridotites likely reflects a major density anomaly beneath the SWIR centered on Marion Island 250 km to the south. Thus the Marion Rise may exist due to an isostatic response to an earlier mantle depletion event predating the present day volcanism.

Basalts isotopic compositions along the Marion Rise are highly variable, reflecting a heterogenous mantle consistent with interactions and entrainment of a heterogeneous continental lithosphere and crust in the asthenosphere as Africa migrated northward during the opening of the SW Indiaan Ridge [1-3].

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