Formation of Plagioclase bearing peridotites by Mantle Assimilation-Fractional Crystallization

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The mechanism of formation of plagioclase bearing peridotites is debated: current models include fractional crystallization, melt-rock reaction and assimilation in the crust and shallow mantle. We have studied Cr-spinels from plagioclase peridotites recovered from Hess Deep (equatorial Pacific Ocean), which show clear evidence for a reactive origin.

The evidence for melt-rock reaction in the genesis of the Hess Deep plagioclase peridotites is in the form of symplectitic intergrowths of spinel and plagioclase with associated compositional zonation. Compositionally, the spinels extend to very high TiO_2 concentrations (0.2-4 wt %), at modest Cr# (0.28-0.42), forming a separate cluster from spinels in the associated refractory harzburgite (TiO_2 < 0.1wt%; Cr# 0.5-0.6). Enrichment in TiO_2 is spatially associated with the reaction interfaces within the spinel grains.

We modelled the evolution of the Hess Deep spinels by mantle assimilation-fractional crystallization (AFC) using MELTS. We found that AFC reaction of a peridotite (residue of ~20% partial melting of fertile mantle) with a primitive MORB (MgO 9.8-12.2 wt%) melt leads to progressive TiO_2-enrichment in spinels. There is a remarkable increase in the concentration of TiO_2 after plagioclase joins the AFC liquidus, which matches the compositional data from the Hess Deep spinels. These models are robust to changes in initial magma composition, fO_2 in the range of FMQ 0 to –1, and activity of H_2O in the magma source (assuming 125ppm in the source).

An intriguing finding is that the models predict the appearance of orthopyroxene early in the AFC crystallization sequence. Early saturation of orthopyroxene (Mg# > 80) has been observed in the lower oceanic crust but has remained enigmatic because the low SiO_2 and water contents of mid-ocean ridge basalts should suppress orthopyroxene. Our results indicate that reaction of ascending mid-ocean ridge basalts with mantle peridotites may account for this phenomenon.