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The formation of komatiites by melt accumulation and segregation in the transition zone

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Komatiites are highly magnesian volcanic rocks characteristic of the Archean. There are three types: Al-depleted komatiites, which have low Al/Ti, relatively high concentrations of incompatible elements and depleted HREE; Al-undepleted komatiites, with chondritic Al/Ti and slightly depleted LREE; and Al-enriched komatiites, with high Al/Ti, low concentrations of incompatible elements and extremely depleted LREE. Petrological and geochemical information indicates that these rocks formed by melting in hot mantle plumes at pressures greater than about 13GPa. In a model developed by Robin-Popieul et al (2010 J Petrol 53: 2191), Al-depleted komatiites form by batch melting and segregate at 13GPa leaving a garnet-rich residue while Al-enriched komatiites form by advanced fractional melting at shallower depth.

Two aspects of the model posed problems. First, at the depths where the Al-depleted komatiite is generated, the melt is denser than mantle olivine, and it is unclear how this melt separated from its source. Second, the compositions of melts produced by fractional melting are extremely variable, depending delicately on the degree of partial melting, yet the compositions of packages of erupted Al-enriched komatiites are relatively uniform.

A solution to these problems is provided by the investigation of the physics of melting and melt segregation within hot upwelling mantle described in the companion abstract by Schmeling et al. These studies showed that when the level of neutral buoyancy lies above the depth of onset of melting, the dense melt accumulates behind the solid phases within the rising plume, only to escape as high-degree melt once the plume rises above the neutral buoyancy level. This pattern of melting explains the formation of Al-depleted komatiites. Under other conditions, the melt accumulates within the plume as a series of standing waves that escape upwards as they reach the level of neutral buoyancy. This process progressively depletes the source in incompatible elements. Subsequent batches of melt have compositions that reflect derivation from the depleted source, but are internally uniform. This process explains the Al-enriched komatiites.