Sink or Swim? The role of intracrustal differentiation in the generation of compositional diversity and crustal delamination in the Archean

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Significant debate exists regarding the processes of crustal formation and stabilization in the Archean, with some researchers advocating for continuous subduction-like processes throughout earth history, and others advocating crustal recycling by lithospheric delamination or ‘drip tectonics’. Much of the debate hinges on whether Archean mantle potential temperatures (Tp) were significantly hotter than the present day. The rock record of non-arc Archean primary magma compositions (Herzberg et al., 2010) has been used to infer higher ambient Tp (Tp = 1500-1650°C) during the Archean, causing high melt fractions during decompression melting, and leading to extreme primary (oceanic) crustal thicknesses of 30-40 km (Herzberg and Rudnick, 2012). Such crustal thicknesses might inhibit subduction, in which case an alternative mechanism of crustal recycling would be required.

In their recent paper, Johnson et al. (2014) showed that at Tp > 1500°C, the lower portions of a thick homogenous Archean primary crust generated would be density unstable with respect to the ambient mantle. Additionally, they showed that given realistic rheological constraints, large-scale lower crustal delamination is a very efficient crustal recycling mechanism at Tp >1600°C. The Archean crust, however, is likely to be internally differentiated. I will present updated pMELTS and Perple_X modeling results on two possible scenarios for intracrustal differentiation of Archean primary crust. In the “Super Penrose” model, the primary crust is differentiated by fractional crystallization within the lower crust. In the “Stacked Lavas” model, the crust is differentiated by partial melting of the lower primary crust. The two models have radically different chemical and density structures. Using the composition and density profiles generated by intracrustal differentiation in the two different scenarios, our geodynamic modeling extends the Tp over which efficient crustal delamination will occur to lower values, consistent with those likely throughout the Archean. Efficient crustal differentiation and delamination of dense mafic residues throughout the Archean may explain the apparent paucity of mafic lithologies relative to TTGs that characterize the preserved Archean rock record. I will compare the predicted crustal lithologies to those observed within the Archean rock record and the modern day in an attempt to place further constraints on the viability of the Super-Penrose versus Stacked Lavas scenarios for crustal accretion and differentiation in the Archean.