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Effects of differentiation on the geodynamics of the early Earth

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Archean geodynamic processes are not well understood, but there is general agreement that the mantle potential temperature was higher than present, and that as a consequence significant amounts of melt were produced both in the mantle and any overlying crust. This has likely resulted in crustal differentiation. An early attempt to model the geodynamic effects of differentiation was made by Johnson et al. (2014), who used numerical modeling to investigate the crust production and recycling in conjunction with representative phase diagrams (based on the inferred chemical composition of the primary melt in accordance with the Archean temperature field). The results of the simulations show that the base of the over-thickened primary basaltic crust becomes gravitational unstable due to the mineral assemblage changes. This instability leads to the dripping of dense material into the mantle, which causes an asthenospheric return flow, local partial melting and new primary crust generation that is rapidly recycled in to mantle. Whereas they gave important insights, the previous simulations were simplified in a number of aspects: 1) the rheology employed was viscous, and both elasticity and pressure-dependent plasticity were not considered; 2) extracted mantle melts were 100% transformed into volcanic rocks, whereas on the present day Earth only about 20-30% are volcanic and the remainder is plutonic; 3) the effect of a free surface was not studied in a systematic manner. In order to better understand how these simplifications affect the geodynamic models, we here present additional simulations to study the effects of each of these parameters.

Johnson, T.E., Brown, M., Kaus, B., and VanTongeren, J.A., 2014, Delamination and recycling of Archaean crust caused by gravitational instabilities: Nature Geoscience, v. 7, no. 1, p. 47–52, doi: 10.1038/NGEO$_2$019.