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Viability of Archean Subduction Initiation from Gravitational Spreading

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The development of plate tectonics and Earth's early tectonic environment are currently not well understood. Modern plate tectonics is characterized by the sinking of dense lithosphere at subduction zones; however this process may not have been feasible if Earth's interior was hotter in the Archean, resulting in thicker and more buoyant oceanic lithosphere than observed at present (van Hunen and van den Berg, 2008). Previous studies have proposed gravitational spreading of early continents at passive margins as a mechanism to trigger early episodes of plate subduction (Rey et al., 2014). The numerical models used in this study employed a viscoplastic rheology and a free-slip upper boundary condition.

In our study, we investigate the impact of a free surface upper boundary condition and elasticity on the viability of subduction initiation due to gravitational spreading using the finite element code MVEP2 (Kaus, 2010; Thielmann et al., 2014). Subduction initiation by gravitational spreading was found to occur only for models with free-slip boundary conditions and lithospheric yield stresses less than 200 MPa. Because lithospheric stresses are a critical factor for subduction initiation, we investigated the effects of continental buoyancy and the resistance of the oceanic lithosphere to lateral forces from a spreading continent on the initial stress field. Results show that different density-viscosity combinations produce maximum lithospheric stresses which may vary over 1000 MPa and average stresses which range between 100-200 MPa in both the continent and the oceanic lithosphere. The use of a free-surface boundary condition allows the development of isostatic topography, which was not considered previously. Results indicate that the magnitude and location of lithospheric stresses vary for cases with and without isostatic uplift, and that subduction initiation is less likely to occur in cases with lithospheric elasticity and continental uplift due to intra-lithospheric gravitational stresses from a spreading continent being insufficient to initiate subduction.