The impact of temporal stress variations, dynamic disequilibrium, and asthenospheric channels on the initiation of plate tectonics

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We use 3-D numerical experiments and 1-D thermal history models to study the impact of dynamic thermal disequilibrium, asthenospheric channels, and large temporal variations of normal and shear stresses on the initiation of plate tectonics. Previous models that explored plate tectonics initiation from a steady state, single plate mode of convection concluded that normal stresses govern the initiation of plate tectonics. Using 3-D spherical shell mantle convection models in an episodic regime allows us to explore larger temporal stress variations than can be addressed by considering plate failure from a steady state stagnant lid configuration. The episodic models show that an increase in convective mantle shear stress at the lithospheric base initiates plate failure. In this out-of-equilibrium and strongly time-dependent stress scenario, the onset of lithospheric overturn events cannot be explained by boundary layer thickening and normal stresses alone.

Moreover, we empirically find that the period increases with a decrease in "channel number MN", which we define as $MN=eta_A/(d_A)^3$ (here eta_A is the non-dimensional channel viscosity and d_A the ratio between channel thickness and mantle depth). Therefore, decreasing values of MN move the system toward stagnant lid convection.

At this stage, our results indicate that a decreasing channel number is associated with lower basal shear stress on the plate above, and in that sense, our results are consistent with the idea that basal shear stress, asthenospheric channels, the temporal variation of stresses, and dynamic disequilibrium are critical for initiating plate tectonics.

References. Stamenkovic, V., Höink, T., Lenardic, T. (2016) JGR Planets, 121, 1–20, doi:10.1002/2016JE004994.

Additional Information. This work was supported by a fellowship from the Simons Foundation (award 338555, VS) and by the NSF grant EAR-0944156 (A.L. and T.H.).

Keywords: Plate tectonics, Asthenosphere, Stresses, Non Equilibrium, Mantle Convection

