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Stability of Archaean cratons and their influence on the global strength of the lithosphere

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It is now well accepted that mantle convection and plate tectonics form an integrated system and cannot be treated independently. Although this is a promising improvement in understanding the Earth, one of the most striking features - the difference between oceans and continents, is still not yet included in self-consistent models of this integrated system.

It has previously been shown that continents can have a first-order effect on the dynamics of Earth's plate-mantle system as they can modulate convective wavelength, surface heat loss and - due to thermal insulation - the internal mantle temperature. Another possible influence concerns the critical yield strength of the lithosphere. So far, convection models with self-consistent plate tectonics but without continents have always required yield strength values that are very much lower than the strength of rocks inferred from laboratory experiments. However, the strong contrasts in physical properties at the boundaries between oceans and continents may well focus convective stresses. That may result in a reduction in the critical yield strength in the presence of continents.

In the present study, these issues are studied in spherical 2-D and 3-D models of mantle convection with self-consistent plate tectonics and continents that are simplified as cratonic roots, the strong Archaean cores of the continents. Continents differ from normal mantle in buoyancy and rheology, but besides that they are treated identically. This allows them to move and/or deform, which is in contrast to most previous studies.

It is well known that cratonic roots are tectonically stable since at least the late Archaean. Stability conditions have been investigated before, but neither for the case of purely internally-heated convection nor in spherical geometry nor in 3-D, which might be important as the topology of subduction zones can be different in 3-D. First results from the present study indicate that the mentioned differences do not significantly change the stability criteria of cratonic roots: if the yield stress and viscosity of the roots are sufficiently higher than those for oceans then cratons are stable, an observation that is basically independent of the root buoyancy.

In a further step, models with and without continents are compared, focusing on the resulting tectonic regime, i.e. whether the lithosphere is mobile (plate-like) or stagnant for a given yield strength. First results show that cratons can cause changes in the tectonic regime and force the lithosphere to remain mobile for yield stress values for which it is normally stagnant – at least episodically. However, this effect depends on the size and perhaps also the number of continental units in the model.