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Viscoelastic modeling of craton stability

M. J. Beuchert, Y. Y. Podladchikov, N. S. C. Simon and L. H. Rupke
Physics of Geological Processes, University of Oslo, Norway

Archean cratons are remarkable features of our planet. Not only has Archean crust avoided continental recycling for several billion years, but it became evident from dating of inclusions in diamonds and thermobarometric measurements on xenoliths from kimberlites that their seismically observed cold and more than 200 km thick lithospheric keels have remained cold and stable ever since their formation.

Yet, some numerical models of craton stability have failed to reproduce this observed stability for billions of years.

In our two-dimensional FEM model, we show that high viscosity contrasts between the convecting upper mantle and the cratonic lithosphere are fully sufficient to account for the long-term stability of cratonic keels. We know from laboratory experiments that for mantle rocks at temperatures as in the cratonic keel, these viscosity contrasts are very high indeed; thus, one should use high viscosity contrasts in modeling of convecting mantle-lithosphere interaction. Furthermore, we suggest that the application of a viscoelastic rheology for the mantle helps to avoid numerical problems associated with high viscosity contrasts in viscous models. With a viscoelastic rheology, there is a transition from viscous to elastic behaviour above a certain threshold of viscosity contrast, resulting in stability of the cratonic keels. This approach is consistent with the viscoelastic nature of rocks. Viscous models are sensitve to the magnitude of viscosity contrasts, which is, in common practice, a free parameter. With a viscoelastic rheology, the effective viscosity contrast is constrained by rheological parameters.

Current parameterizations for the stagnant lid mode of convection, which are to a certain extent applicable to models of lithosphere stability, are yet only available for viscous rheology. We investigate generalization for viscoelastic rheology.