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Modeling of craton stability using a viscoelastic rheology

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Archean cratons belong to the most remarkable features of our planet, since they represent continental crust that has avoided reworking for several billions of years. Even more, it has become evident from both geophysical and petrological studies that cratons exhibit deep lithospheric keels which equally remained stable ever since the formation of the cratons in the Archean. Dating of inclusions in diamonds from kimberlite pipes give Archean ages, showing that the Archean lithosphere must have been cold soon after its formation in the Archean, in order to allow for the existence of diamonds, and must have stayed in that state ever since. Yet, whereas the stability of Archean cratonic lithosphere for billions of years is a fact, some numerical models failed to reproduce this observed long-term stability (see review by King, 2005). We devised a viscoelastic mantle convection model for exploring cratonic stability. Our modeling results indicate that the application of sufficiently high temperature-dependent viscosity ratio can provide for the observed cratonic stability for billions of years. From our numerical simulations, we derived a relation between Rayleigh number, viscosity ratio, size of the model craton and time to instability of the cratonic root. The comparison between simulations with viscous and viscoelastic rheology indicates no significant influence of elasticity on craton stability. Yet, stress distributions within the model craton differ significantly between viscous and viscoelastic rheologies. This has important implications for future models that include stress-dependent processes like plasticity, power law creep and shear heating. If those processes are to be modeled accurately in mantle convection models that include the lithosphere, a viscoelastic rheology would have to be applied.