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Influence of rheology on craton stability – implications from numerical modeling

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Archean cratons belong to the most remarkable features of our planet since they represent continental lithosphere that has avoided continental recycling for several billion years. Dating of inclusions in diamonds and thermobarometric measurements on xenoliths from kimberlites indicate that Archean cratons and their more than 200km thick lithospheric keels have remained cold, but stable ever since their formation. This appears to be a contradiction since coldness would render the lithosphere negatively buoyant and, in consequence, unstable. A hypothesis, first proposed by Jordan (1978), explains this observation qualitatively by a melt extraction event in the early formation of the Archean cratonic lithosphere. The extraction of large amounts of basaltic melts from fertile lherzolitic mantle left a depleted harzburgitic mantle as a residue, which has a significantly lower density. In Jordan's hypothesis, this compositional density decrease balances the density increase due to cooling. Even more, dehydration of the residue due to melt extraction would significantly increase its rigidity, rendering cratonic lithosphere stable. Yet, numerical modeling of craton stability has failed to reproduce the observed stability of cratonic lithosphere over billions of years, even if the suggested stabilizing factors, compositional buoyancy and enhanced rigidity due to melt extraction, are implemented. We suggest that the implementation of more realistic rheologies helps to reconcile the predictions from numerical modeling with observations on craton stability. To test this hypothesis, we explore the influence of rheology on cratonic stability in a new, fully dynamic 2D viscoelastic-plastic FEM model. We use layered lithosphere models that try to mimic the actual compositional features of cratonic lithosphere as suggested from geophysical and petrological evidences and implement the associated mechanical properties into our numerical model. The main focus of this study is to explore the role of rheology in stabilizing cratonic

lithosphere, so that it withstands the erosional forces of subducting slabs at its sides and of the convecting mantle at its base.