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Formation of cratonic lithosphere during the initiation of plate tectonics

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Cratonic lithospheric mantle preserved from ∼3 Ga is anomalously thick (>200km) and has a large influence on continental deformation and heat-flow. As modern lithosphere is thickened in regions of high tectonic compressional stress, the preserved cratonic lithosphere appears to be evidence of higher mantle stresses in the past. This conflicts with the stress scaling for mobile-lid convection of a hotter Archean mantle, which would predict cratonic lithosphere to instead be anomalously thin and increasingly unstable through time. We reconcile this paradox by proposing that the cratonic lithosphere records a catastrophic transition in mantle regime, from heat-pipe to mobile-lid convection, as plate tectonics initiated. Anomalous stresses are generated at a continental scale by mantle downwellings, as the heat-pipe boundary layer is destabilised and rapidly recycled. Numerical calculations are used to demonstrate that an existing buoyant and strong layer, representing harzburgite and felsic proto-crust, can thicken and stabilise during a lid-breaking event. The peak compressional stress experienced by the lithosphere is 3-4x higher than for the heat-pipe or mobile lid regimes immediately before and after. It is plausible that the cratonic lithosphere has not been subjected to this high stress-state since, explaining its long-term stability. The lid-breaking thickening event reproduces features observed in typical Neoarchean cratons, such as lithospheric seismological reflectors and the formation of low angle shear zones. Paleoarchean 'pre-tectonic' structures can also survive the lid-breaking event, acting as strong rafts, that are assembled during the compressive event. Together, the results indicate that the signature of an important switch in mantle regime, from a stagnant lid Earth to the initiation of plate tectonics, has been captured and preserved in the characteristics of cratonic crust and lithosphere.