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Longevity and thermo-rheological structure of old lithospheres : key constraints form surface and Moho topography.

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Surface topography and Moho are the most robust observables that have been insufficiently exploited for containing the rheological and thermal structure and hence for understanding the longevity and eventual destruction of cratons and “tectons”. Craton longevity has been often explained by their buoyancy and analysed by testing gravitational stability of cratonic mantle “keels” as a function of the hypothesized plate thickness and thermo-rheological structure. Destruction of some cratons (e.g. North China) and data indicating little if no buoyancy of some tectons (e.g., Arabian shield) suggest that buoyancy is not the only factor of their stability, and previous studies show that their mechanical strength is as important as buoyancy. The upper bounds on this strength are provided by flexural studies demonstrating that Te values (equivalent elastic thickness) in cratons are highest in the world and may probably reach 150 km. Yet, the sensitivity of common methods is poor for Te values above 80 km while the lower bounds on the strength and the equivalent elastic thickness of cratons are still matter of debate. How this strength is partitioned between crust and mantle, and which set of rheological parameters pertain, remain major unknowns. We show that smooth low topography and “frozen” heterogeneous crustal structure of cratons represent the missing constraints for understanding of craton longevity. The cratonic crust is characterized by isostatically misbalanced density heterogeneities, suggesting that the lithosphere has to be strong enough to keep them “frozen” through the time without producing major gravitational instabilities and topographic undulations. Hence, to constrain thermo-rheological properties of cratons one should first investigate the stability of their topography and internal structure (constrained from seismic and gravity data). Our thermo-mechanical numerical experiments accounting for free surface boundary condition demonstrate that craton stability cannot be warranted by crustal strength only, and that strong dry olivine mantle rheology and cold thick lithosphere are needed for craton survival. We find fairly robust lower-bound limits on their thermo-rheological structure. In particular, the minimal Te needed for long-term stability of continents (cratons or tectons) is approximately 70 km.