In the modern Earth, processes such as accretion and continental collision are driven by the combined buoyancy forces of an entire length of subduction zone acting to overcome the resistance in the congested section [Moresi et al, 2014; Betts et al, 2015]. This is a mechanism to amplify the typical stresses one might normally consider would be available to drive accretion and orogeny and this can be helpful in understanding the dynamics interaction of plate tectonics, mantle flow and continental deformation. See Figure 1 for an illustration.

It is interesting to consider how effective this mechanism would have been in the early Earth and consider if it would be a way to supply sufficient stress to construct a long-lived craton. Tectonic origins for the cratonic lithosphere have been favoured in recent discussions [e.g. Lee et al, (2011), McKenzie & Priestley, (2016)] but there are reasons to suspect accretion and crustal thickening would have been more difficult under Archean conditions. We typically expect convective stresses to be lower for the early Earth when internal temperatures were higher and viscosities lower. Furthermore, the actual viability of subduction in the Archean Earth is still a subject of debate due to the need for thinner cold-boundary layers to “outweigh” a thicker oceanic crust formed at high temperatures. Numerical models suggest subduction would have been thermally and mechanically viable in the Archean but slabs would have been weaker and more prone to break-off [van Hunen & Moyen, 2012].

**How do we assemble cratonic lithosphere in the low-stress environment of the young Earth that is strong and resistant to tectonic recycling in the older Earth where higher stresses are available?**

Recent work suggests that, very early in Earth’s evolution, a heat-pipe mode of convection would have been favoured — this is a form of stagnant lid convection in which the internal heat is lost by magmatic pipes by-passing the upper boundary layer and depositing magma at or near the surface. A stagnant lid with the right combination of intrusive and extrusive heat-pipe magmatism, is potentially capable of satisfying the thermal and petrological constraints for the early Archean Earth. [e.g. Moore and Webb (2013), Rozel et al, (2017)]. These models naturally become unstable with respect to mobile-lid convection models as the level of internal heat production decreases.

A possible resolution of this puzzle is to understand whether the transition phase between stagnant lid and a mobile-lid or plate-tectonic style of convection is capable of building or assembling the cratonic lithosphere and not just destroying the stagnant lithosphere. The stresses during the collapse of the thick, stagnant lid can be significantly higher than the convective stresses in either the steady, stagnant lid or the mobile-lid convective regimes (figure 2 B).
We discuss these models and compare the deep lithospheric structure with that which occurs when growth is driven by lateral accretion. This builds upon previous studies by Cooper and Miller (2013), Cooper et al (2016) and Beall (2017).

[Figure 1. Simulations showing the collision of a continental fragment with an ocean-continent subduction zone. The buoyancy available to drive convergence and thickening of the overriding plate comes not only from the congested region of the plate boundary but from continued subduction in the unaffected. Even after slab breakoff, this mechanism can produce continued and significant convergence. Figure from Cooper et al, 2016]

[Figure 2. A collapsing stagnant lid produces an over-thickened, folded structure from an initially thin layer within the upper part of the stagnant lid that is strong enough to resist subsequent convective stresses. An anomalously strong region arbitrarily embedded within the stagnant lid can survive the lid collapse with very little deformation at the surface but with underthrusting and stacking of the lower crust and the mantle lithosphere.]
References


