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Two stage self-consistent growth of primordial continental crust without the initiation of subduction and plate tectonics

Charitra Jain, Antoine Rozel, Taras Gerya, Patrick Sanan, and Paul Tackley
ETH Zurich, Institute of Geophysics, Department of Earth Sciences, Zurich, Switzerland (charitra.jain@erdw.ethz.ch)

It is widely accepted that the majority of continental crust formed during the hotter Archean was composed of Tonalite-Trondhjemite-Granodiorite (TTG) rocks. In contrast to the present-day loci of crust formation around subduction zones and intra-plate tectonic settings, TTGs are formed when hydrated basalt melts at garnet-amphibolite, granulite or eclogite facies conditions. The feasibility of identifying the P-T formative conditions for TTG (Moyen, 2011) in global models has been demonstrated recently by Rozel et al. (2017). Here we parameterise the melt production and melt extraction processes and show the self-consistent generation of primordial continental crust using evolutionary thermochemical mantle convection models, for the first time on a global scale. A pyrolytic mantle melts to generate basaltic magma, which gets hydrated, and then partially melts to form continental crust.

To study the growth of TTG and the geodynamic regime of early Earth, we systematically vary the ratio of intrusive (plutonism) and eruptive (volcanism) magmatism, initial core temperature, and internal friction coefficient. Corroborated by scaling laws, our simulations show two distinct stages of TTG production, similar to the proposal of Dhuime et al. (2012): a period of continuous linear growth with time and intense recycling that lasts for 1 Gyr akin to 'plume-lid' tectonics, followed by a stage with the TTG growth proportional to cubic root of time and moderate recycling. Most importantly, we report that TTG production can suddenly decrease without a major shift in the convection regime. Such a drop in crust production rate is often interpreted as the onset of subduction-driven plate tectonics (e.g., Cawood et al., 2006; Shirey and Richardson, 2011; Dhuime et al., 2012; Hawkesworth et al., 2016a,b).

The resolution of our simulations allow us to see lower crustal delamination and dripping, formation of stacked terranes, and recycling of the continental crust. However, dome and keel structures, which are typical of some Archean cratons (Van Kranendonk et al., 2015), are not resolvable in our global models. Furthermore, our results reaffirm the significant role of plutonism in shaping our planet's lithosphere (Crisp, 1984; Cawood et al., 2013). Future improvements will include magmatic weakening (Sizova et al., 2010; Vogt et al., 2012; Sizova et al., 2015) and the coeval formation of strong, depleted, and viscous cratonic roots (e.g., Herzberg, 1993; Arndt et al., 2009; Lee et al., 2011).