Geophysical Research Abstracts
Vol. 21, EGU2019-6665, 2019
EGU General Assembly 2019

The evolution of trench rollback

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Most subduction zones migrate across the Earth's globe in the direction of the subducting plate, exhibiting trench retreat, which is mostly driven by old, and therefore dense and stiff subducting plates. It is likely that the subduction process operated differently in the early Earth; the mantle was hotter and therefore weaker, and the oceanic crust likely thicker. These differences affect trench retreat, which is the focus of this research project. Here, we use numerical model calculation to investigate the likely evolution of the mobility of subduction zones through geological time.

Our results show that there is a clear feedback mechanism between slab age and speed, mantle viscosity, slab penetration into the lower mantle, and trench retreat. Today, old slabs exhibit rapid trench retreat which links with flattening and stagnation of those slabs in the transition zone, whereas younger slabs penetrate more readily into the lower mantle with less trench retreat. Hotter mantle conditions in the early Earth increased the average plate velocity, reduced the average slab age, and therefore resulted in less trench rollback or slab stagnation. Even a modest mantle temperature increase of only $\sim$50 degrees could make conditions for trench retreat and slab stagnation in the transition zone unfavourable. In addition, such hotter mantle led to more mantle melting at mid-ocean ridges and, hence, a thicker buoyant and relatively weak oceanic crust, which, in turn, can affect slab dynamics (e.g. increased slab break-off, and reduced trench mobility).

These results might have important implications. Firstly, we propose that, unlike commonly assumed, a hotter mantle facilitated slab penetration into the lower mantle, and therefore material exchange between the upper and lower mantle, which is important for the thermal or compositional evolution of the Earth. Secondly, reduced trench mobility may make processes like gravitational orogenic collapse or the formation of back-arc basins less common.