Geophysical Research Abstracts
Vol. 20, EGU2018-9290, 2018
EGU General Assembly 2018

What controlled the style of subduction and evolution of Plate Tectonics on Earth since the mid-Mesoarchean?

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While plate tectonics (PT) is the most important geological process operating on Earth, an understanding of how PT was initiated and which factors controlled its evolution over Earth's history still remains incomplete. It has been suggested that secular cooling of the Earth is one key factor. We support this idea but emphasize the importance of the rise of continents and the availability of continental margin sediments as underappreciated but important factors in the development and evolution of PT.

It is broadly accepted that the necessary condition for initiation and stable operation of PT is maintaining low strength along plate boundaries, particularly along the subduction zone interfaces. Examples from the South American Andes and other subduction zones show that unconsolidated continental sediments filling the trenches serve as an efficient lubricant for subduction. If these sediments are lacking, friction in the subduction channel and strength of the plate boundary is significantly increased. Here we suggest that lubrication of subduction by accumulation of sediments at continental edges and in trenches played a crucial role during the evolution of PT on Earth since the mid-Mesoarchean. We posit that the rise of continents and the formation of supercratons/supercontinents generated enhanced surface erosion and caused an increasing flux of continental sediments into the oceans, which in turn lubricated subduction channels and intensified PT.

The rise of continents in the Mesoarchean is indicated by multiple geochemical proxies and evidence of subduction since that time is preserved in the records of magmatism and metamorphism. Subsequently, there are two significant intervals during which the continental lithosphere was reorganized into a different geography: during the breakup of the supercratons and the assembly of Columbia and during the breakup of Rodinia and the assembly of Pangea. Each of these two major reorganizations occurred over several hundreds of millions of years, and was associated with significant rises in oxygen, significant positive and negative excursions in $\partial 13C$ associated with global glaciations, and rises in the thermal gradient of high dT/dP metamorphism. Periods of supercraton/supercontinent assembly represent periods of intense subduction, volcanic activity and continental sedimentation in trenches prior to terminal collision. Conversely, a decrease in plate boundary length and a reduction in volcanic activity and continental sediment accumulation during periods of stability after supercraton/supercontinent assembly was the likely reason for periods of PT hiatus and environmental stability, including the so called 'boring billion' between 1.8 and 0.8 Ga.

The largest surface erosion and subduction-lubrication event occurred at the end of the 'snowball' Earth epoch in the Neoproterozoic and likely switched-on the most recent episode of active PT. Based on analysis of various geological observations, we suggest that the cyclic behavior of PT on Earth since the mid-Mesoarchean (the so-called 'supercontinent cycle') can be interpreted in terms of the balance of power between PT, driven by slab pull and controlled by the temperature of the upper mantle, and the efficiency of lubrication in the subduction zones, controlled by accumulation of continental sediment in the trenches.