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Editorial: The Early Earth Crust and Its Formation

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Editorial on the Research Topic

The Early Earth Crust and Its Formation

The geochemical and petrological nature of the early Earth crust, and the processes involved in its formation and stabilization, are critical questions to understand the earliest evolution of our planet, and have yet to be resolved. The ancient rock archives in stable cratons provide the foundation for our understanding of the early formation and evolution of Earth's crust, but it is unlikely that these archives are representative of average early crustal composition or its evolution. Geodynamic modeling and isotope tracers provide key complementary constraints, as well as tests for hypotheses proposed based on the rock record.

One of the most fundamental questions that is still unresolved is *the timing of the onset of plate tectonics*, which is a feature that is unique to the Earth among the known rocky planets. Subduction zones represent the geological environment in which crustal fractionation currently takes place, but it could be argued that this particular setting is not conducive to the long-term preservation of crust due to recycling. Moreover, the style of subduction, or horizontal tectonics more broadly, may have changed during early Earth history, and hence the nature of crusts generated over time. Additionally, the onset of subduction could well have pre-dated global plate tectonics, as the required assemblage of global plates may not have been a stable configuration on the hot young Earth. Interpretations of the ancient rock record are strongly debated and divided among those who support horizontal plate tectonic processes throughout the Archean Eon, and those who invoke a plume-dominated, stagnant lid scenario and infracrustal differentiation with a transition (gradual or abrupt) to modern-style plate tectonics, likely towards the end of the Archean.

This Research Topic brings together articles that explore the earliest part of Earth's geological history; from mantle-derived magmas and their fractionation, all the way through partial melting and crustal differentiation to form stable continental crust. The invited review by Hawkesworth et al. comprehensively combines observations from metamorphism, tectonics, geochemistry, petrology and geophysics to infer the nature and secular evolution of the continental crust, and its implications for the onset of plate tectonics. They purposely provide a global picture, which advocates for a transition in the nature of the crust towards a more felsic flavor, coincidental with a proposed onset of plate tectonics at ~3.0 Ga.

The formation and evolution of the early Earth's crust is further evaluated by Garde et al. who reviewed the geological history of the North Atlantic craton of West Greenland and present their conclusions regarding the geodynamical context of its construction from the Eoarchean to Mesoarchean. The authors conclusions advocate for the existence of horizontal tectonics since the Eoarchean.

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The article by Sawada addresses the secular evolution of the size of continental blocks through the study of terrigenous clastic sediments, a key topic still under-investigated. The author proposes a non-linear evolution for the size of continents with largely submerged and small continents in early Archean times that progressively emerge and grow by sequential amalgamation thereafter. From 2.5 Ga, supercontinent cycles enhance the size increase of continental blocks to the present day. Continental size and volume estimates remain poorly constrained, as mentioned by the author, but future development in understanding clastic sediment deposition in relation to continent sizes should shed new light of this key issue.

Wyman presents an alternative view for the origin of komatiites, which are ultramafic volcanic rocks peculiar to the Archean and commonly form the cornerstone of Archean greenstone belts. He proposes that they originate from the mantle transition zone (660 km) in response to local subduction and stagnation of subducted plates within a "basalt barrier". The geodynamic scenario of komatiite formation presented in this study combines subduction and plume processes, whereas these are commonly considered as being separate and represented by felsic magmatism and mafic magmatism, respectively.

Close temporal association of mafic and felsic magmatism is also discussed by Waterton et al. who present a multi-element and isotope study of the 3.0 Ga Maniitsoq norite belt in West Greenland and its implications for the geological context of its formation. These authors propose the coeval formation of norite and TTG (i.e., tonalite-trondhjemite-granodiorite) through an ultra-hot orogen due to magmatism being quickly followed by low-pressure/high-temperature metamorphism. In this scenario, the heat influx for TTG formation and mafic magmatism is provided by lithospheric mantle delamination in response to shallow subduction of thin crusts.

Halla's contribution explores extensive outcrops of migmatites in the Fennoscandia shield that expose *in-situ* formation of granitoids of typical TTG composition. TTGs are a crucial component of Archean cratons and are generally viewed as what provided early crust with the buoyancy to be preserved. This article highlights the petrogenetic and magmatic peculiarities of Archean granitoid formation compared to Phanerozoic granites, and discusses the petrological mechanisms of TTG formation to account for its geochemical signatures.

This Research Topic does not resolve the long-standing debates of secular changes in continental crust evolution and the onset of plate tectonics, but it does provide a timely review of the current state-of-the-art on these key questions. Moreover, contributions to this Research Topic propose key future directions to explore, including a better understanding of the links between the metamorphic and magmatic records in different tectonic environments, developing methods to more accurately reconstruct past continental topography from sediments, and determining global links between compression and extension at lithospheric plate boundaries. Linking the different types of data on the early Earth crust, merging local and global constraints, and promoting inter-disciplinarity in general will provide the breakthroughs about the early Earth crust and its formation that will build towards a consensus of this hugely important topic.

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