An integrated isotopic-geologic view of early continental crust formation from the oldest rock record

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A cornerstone of Earth sciences for many years was the assumed complementary of mantle and crustal chemical evolution, with extraction and recycling of continental crust through time thought to be the main processes controlling the composition of the upper mantle. This view has been brought into question following discoveries of extinct nuclide signatures in Archean rocks (e.g. ^{142}Nd, ^{182}W) requiring early differentiation and/or a non-chondritic Earth. Linked to this are questions of which isotopic and geochemical monitors of continental crust formation processes and continental mass are most reliable.

Here we present an integrated geochemical and geologic examination of Archean continent formation with an emphasis on the patterns of ^{176}Hf and ^{143}Nd isotopic variations. Focus is on the largest extent of early crust located within the 3000 km^2 Eoarchean Itsaq Gneiss Complex of SW Greenland. This complex preserves evidence of several temporally and spatially distinct episodes of juvenile crust formation between ~3.89 Ga and 3.66 Ga, which are dominated by TTG rocks. In each event, TTG suites were emplaced into slightly older gabbros, basalts and andesites, which have geochemical signatures consistent with fluid-fluxing of upper mantle sources. The TTG suites are characterized by magmatic zircon with initial εHf of ~0 and positive whole rock initial εNd of +4 to +2. The most likely geodynamic settings for generation of this early crust were convergent plate boundary environments analogous with, but not identical to, modern island arcs. The pattern of near constant εHf values in primitive granitoids for >300 m.y. argues against derivation of these magmas by repeated sampling of a mafic crustal source, from reworking of older crustal material, or from a mantle source previously experiencing large amounts of Hadean crustal extraction. Starting at 3.66 Ga, granitic rocks first begin to show Hf isotopic evidence for reworking of older crust. Varying ^{143}Nd isotopic compositions of Eoarchean rocks likely reflect early Sm/Nd fractionation unrelated to crustal extraction. We propose that the shift to correlated ^{176}Hf-^{143}Nd isotopic temporal trends, as typify Phanerozoic style arc accretion processes, began as early as ~3.5 Ga.

Geochemistry and Carbon Management

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Without a doubt, meeting human energy needs while dramatically reducing greenhouse has emmissions is one of the grand challenges of our time. Geochemistry plays a critical role in assessing both the impacts of changing the chemical composition of the atmosphere due to emission of greenhouse gases and designing solutions. Over the coming decades, a radical transformation of our energy system is needed to reduce global greenhouse gas emissions by over 80%. Solutions for achieving needed emission reductions include improving enegy efficiency, shifting to renewable energy resources for producing electricity, reducing emissions from fossil fuel by capturing and storing CO_2, switching from coal to natural gas for power generation, and sustaining use of nuclear power, In this paper, the critical role that geochemistry plays in developing and evaluating solutions is highlighted. Examples from carbon dioxide capture and storage, nuclear waste disposal, shale gas development, and providing the critical materials for renewable energy and storage systems are provided. Over the coming decades, Earth's resources will be taxed in new and unforseen ways. The discipine of geochemisty will play a crucial role in anticipating and responding to these challenges.

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