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Geochemical Weirdness of the Early Earth and Implications for Earth Evolution

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Advances in isotopic measurement capabilities have allowed the characterization of rocks and minerals formed during the first half of Earth history in ways that were only dreamed of 30 years ago. In particular, high precision measurement of both mass dependent (e.g., Pt), and radiogenic and non-radiogenic mass independent (e.g., ^{142}Nd, ^{182}W, ^{100}Ru) isotopic compositions of certain elements in ancient rocks has revealed an early Earth that in some ways resembles a different planet from the one on which we reside. For example, the anomalous mass dependent isotopic composition of Pt in certain Archean rocks may indicate the survival of mantle nearly devoid of late accreted planetesimals for >1 billion years into Earth history (Creech et al., 2017). Short-lived radiogenic isotope systems have been particularly valuable in revealing processes that occurred during the first 500 Myr of Earth history. For example, positive and negative anomalies in ^{142}Nd in early Earth rocks require substantial early fractionations of Sm/Nd to have occurred in the mantle, perhaps by magma ocean processes (e.g., Rizo et al., 2013), despite limited survival of chemical evidence for such processes. Similarly, ^{182}W anomalies in ancient rocks must reflect processes, such as core segregation and magma ocean fractionation, that occurred during the first ~60 Myr of the Solar System while the parent isotope ^{182}Hf was extant (e.g., Willbold et al., 2011). The preservation of isotopic anomalies in the rock record must also reflect subsequent sluggish mixing processes, possibly including of late accreted components within the mantle, as well as possible mixing between the mantle and core. The discovery of nucleosynthetic heterogeneities documented in early Earth rocks, e.g., ^{100}Ru in rocks from Isua, Greenland (Fischer-Gödde et al., 2019), provides new insights to the genetic diversity of Earth's building blocks and mantle mixing processes. Likely processes leading to the transition of Earth from the isotopically anomalous version of the planet recorded in ancient rocks to the modern version would probably have had severe consequences for the development of Earth's atmosphere and ultimately the origin of life.