Pre-, Syn-, and Post Formation Controls on Earth Composition

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Our current Earth is the end product of 4.5 Ga of chemical and physical differentiation. Results obtained over just the last decade, however, provide increasing evidence that events that occurred during the terrestrial planet forming process determined major compositional features of Earth. Nucleosynthetic isotopic variability in meteorites shows that carbonaceous chondrites, long used as the starting point for estimating bulk-Earth composition, cannot form a major mass proportion of the Earth, or even an important component of the late accreted material proposed to account for mantle abundances of the highly siderophile elements. Enstatite chondrites show substantial isotopic overlap with Earth. If Earth was built primarily from enstatite chondrites, their very reduced nature and compositional features imply a bulk-Earth composition dramatically different than that observed, at least in the upper mantle. Evidence for global melting and differentiation of planetesimals occuring within 1-4 Ma of Solar System formation suggests that Earth grew primarily from differentiated planetismals, with consequences for its initial volatile abundances, metal-silicate ratio, and perhaps even refractory lithophile element abundances. Evidence from the short-lived radionuclides ^{129}I, ^{146}Sm, ^{182}Hf and ^{244}Pu documents differentiation events occurring within the first 100 Ma of Earth history. The isotopic imprint of this differentiation, however, is surprisingly small, suggesting either that extensive differentiation of a terrestrial magma ocean did not occur, or that it occurred relatively late in Solar System history, perhaps as late as circa 4.4 Ga, a suggested age for the Moon-forming giant impact. By 4.3 Ga, Earth's surface appears to have cooled to the point where it could host liquid water, and differentiation of the solid Earth was occuring via the type of melting processes we associate today with plate tectonics.