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The geochemical constraints on Earth's accretion and core formation

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A wide range of geochemical observations can be used to place constraints on Earth's accretion and core formation. Isotopic observations, such as Hf-W and U-Pb, potentially constrain the timing of Earth's accretion. Siderophile element abundances, combined with partitioning experiments, potentially constrain the temperature, pressure, and oxygen fugacity conditions of metal-silicate segregation during core formation. Here we present a simple geochemical box model that can be used to understand these observations and provide constraints. A key parameter in the model is the degree of equilibration during metal-silicate segregation. Existing models have shown that the siderophile element abundances are consistent with full equilibration in a deep magma ocean, with an increase in oxygen fugacity during accretion. Here we show that the siderophile element abundances are equally consistent with scenarios involving partial equilibration. The Hf-W isotopic observations constrain the degree of equilibration to be at least 36%. In partial equilibration scenarios, the conditions of metal-silicate differentiation in planetary embryos is important. If conditions in the embryos are suitably reducing compared with those on Earth, an increase in oxygen fugacity during accretion is not required. The timing constraints also depend strongly on the degree of equilibration. With full equilibration, the Hf-W observations imply a rapid early accretion stage (at least 80% of Earth accreting within 35 Myr), but with partial equilibration accretion may be much more protracted. If Pb partitions into Earth's core, the U-Pb observations can constrain the late stages of accretion, and are consistent with the final 10% of Earth's accretion occurring during the Moon-forming giant impact at $\sim$4.45Ga.