Title:
Accreting the Earth and Forming its Core: Experimental and Theoretical Constraints

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Abstract:
Earth's accretion and its primitive differentiation are intimately interlinked processes. One way to constrain accretionary processes is by looking at the major differentiation event that took place during accretion: core formation. Understanding core formation and core composition can certainly shed a new light on early and late accretionary processes. On the other hand, testing certain accretionary models and hypothesis (fluxes, chemistries, timing) allows –short of validating them– at the very least to unambiguously refute them, through the "filter"' of core formation and composition.
Earth's core formed during accretion as a result of melting, phase-separation, and segregation of accretionary building blocks (from meteorites to planetesimals). The bulk composition of the core and mantle depends on the evolution (pressure, temperature, composition) of core extraction during accretion. The entire process left a compositional imprint on both reservoirs: (1) in the silicate Earth, in terms of siderophile trace-element (Ni, Co, V, Cr, among others) concentrations and isotopic fractionation (Si, Cu, among others), a record that is observed in present-day mantle rocks; and (2) on the core, in terms of major element composition and light elements dissolved in the metal, a record that is observed by seismology through the core density-deficit. This imprint constitutes actually a fairly impressive set of evidence (siderophile element concentration and fractionation, volatile and siderophile element isotopic fractionation), can be used today to trace back the primordial processes that occurred 4.5 billion years ago.
We are seeking to provide an overhaul of the standard core formation/composition models, by using a new rationale that bridges geophysics and geochemistry. The new ingredients are (1) new laser-heated diamond anvil cell partitioning data, dramatically extending the previous P-T conditions for experimental work, (2) ab initio molecular dynamics calculations to estimate outer-core density and bulk sound velocity, and combine it with seismology to define a range of possible compositions of the core that satisfies the observations, (3) a refined core formation model bringing together the continuousness of the overall process with the discreetness of the final impacts, and equilibrium thermodynamics with the non-equilibrium nature of certain processes (giant impacts, deep magma ocean).
We propose a few strong constraints that come out from our models: (1) the Earth accreted in a rather oxidizing environment, (2) yielding an oxygen-rich core, in a (3) deep magma ocean (~1500 km) that could have (4) never been fully molten or fully equilibrated, at least during core extraction, despite the giant impacts.