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Consequences of Earth's Mantle Equilibrating with Nebular Gas During Rapid Accretion for Moderately Siderophile Elements

SETH ANDREW JACOBSON

Michigan State University

The proto-Earth could have grown by pebble accretion to a substantial fraction of its current mass while solar nebula gas was present in the protoplanetary disk. In this case, Earth would have likely accreted a hydrogen-rich primary atmosphere, which would have in-gassed and reacted with the mantle (e.g., Young et al., 2023). The present H2 in the mostly molten mantle would be present during metal-silicate equilibration as core-forming liquids descend to the core. Here, we explore with a numerical model of planetary accretion and differentiation whether this scenario can be made consistent with the moderately siderophile element abundances recorded in Earth's mantle today. In particular, we show that in order for this process to have produced Earth's water content, the conditions during metal-silicate equilibration are generally too reducing to reproduce the mantle abundances of the moderately siderophile elements. Furthermore, even when not considering the role of H2 in setting the redox budget, it is difficult to reconcile the best fit mid-mantle pressure and temperature conditions for metal-silicate equilibration with the likely super-solidus conditions near the base of the mantle. Constraints from the mantle abundances of the moderately siderophile elements established during core formation place significant limits on the rate of Earth's accretion, likely excluding the most rapid accretion scenarios.