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Making a Chemically Habitable Earth during Accretion and Early Differentiation

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Earth became habitable because its formative years laid the foundation for life. Such a foundation involved the acquisition and distribution of chemical ingredients essential for the formation of simple forms of life as we know them. At an elemental level, the key ingredients are carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur – the life-essential elements (LEEs).

The LEE inventory of Earth is linked to the chemistry of planetesimals and planetary embryos that built it, and to the processes in the planetesimal-to-planetary interiors that shaped the distribution of LEEs early in its history. Earth's surface habitability could subsequently be maintained for billions of years, via interior-surface communication aided by magmatism and tectonic rock cycles through geologic history. Therefore, inquiry into the onset of Earth's habitable conditions needs to consider processes that shape the planet-scale inventories and distributions of LEEs. Earth is a rocky planet with a layered structure: a central metallic core, surrounding silicate layers separated into the mantle and crust, and an overlying atmosphere. The initial conditions for Earth's habitability require tracking the fates of all life-essential ingredients as Earth forms and differentiates to achieve such an internal structure. An investigation into Earth's LEEs, or more specifically volatile-LEEs in Earth's degassable layers (mantle + crust + atmosphere), reveals a story of loss, distribution, and redistribution through the formation and early differentiation of Earth. In this presentation, we will attempt to tell that story.

Different styles of differentiation and magma ocean episodes on accreting bodies and in a growing Earth distributed LEEs to various interior reservoirs and established the secondary atmosphere. Subsequent mantle melting released LEEs to the surface reservoirs further. We will compare and contrast the fates of LEEs during accretion and early differentiation processes at different conditions and show that Earth was unique among all inner Solar System bodies. The key deep processes we will interrogate are (a) metal melt-silicate melt differentiation in accreting planetesimals, planetary embryos, and in growing Earth, (b) elemental exchanges during percolative core formation, (c) magma ocean degassing during Earth's growth, and (d) partial melting of early planetary mantles.