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Thermal and chemical consequences of core-mantle differentiation in super-Earth exoplanets

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The formation of a metallic core in Earth released a large amount of heat and redistributed life-essential elements, thus setting the stage for its evolution into the inhabited world. In particular, the core may have reached sufficiently high temperature to dissolve nominally lithophile elements such as magnesium (Mg) and silicon (Si), with implications for sustaining the geodynamo for billions of years [1]. Moreover, the mantle may have melted to sufficient depths to diversify the oxidation states of iron through disproportionation of silicate melt. Subsequent segregation of iron metal would have oxidized the mantle and affected the composition of Earth's early atmospheres [2]. Super-Earths likely experienced core formation and deep magma oceans as well. Here we study the consequences of core-mantle differentiation in super-Earths on their initial thermal and oxidation states, using recent mineral physics and geochemical constraints, including the equations-of-state, heat capacities, and melting curves of relevant phases, as well as the effects of pressure and temperature on iron disproportionation in dense silicate melts. We will quantify the effects of planetary radii, core radius fraction, and heat retention factors on the physical and chemical states super-Earths and discuss the implications for their core dynamos, early atmospheres, and potentials to support life.

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[2] Armstrong et al. (2019) Science 10.1126/science.aax8376, Deng et al. (2020) Nature. Comm. 10.1038/s41467-020-15757-0, Sossi et al. (2020) 10.1126/sciadv.abd1387, Kuwahara et al. (2023) Nat. Geo. 10.1038/s41561-023-01169-4, Hirschmann (2023) 10.1016/j.epsl.2023.118311.