Chemical Exchange between Earth's Core and Mantle

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Abstract

Transfer of mass across the core-mantle boundary (CMB) is a consequence of chemical disequilibrium. Initial departures from equilibrium are established by the process of core formation during the accretion of the planet. Measured concentrations of moderately siderophile elements in the mantle are compatible with separation of metal and silicates at the bottom of a mid-mantle magma ocean (P 50 GPa and T 3300 K). Subsequent delivery of liquid metal to the core is thought to occur in large diapirs with limited chemical exchange. This material arrives at the CMB well out of equilibrium with the surrounding mantle. Adjustments toward equilibrium are expected to drive Si and/or O from the mantle into the core. The rates of mass flux are initially limited by chemical diffusion through the core, but solid-state diffusion through the mantle quickly becomes the rate-limiting process. Small amounts of partial melt can lower this barrier, so quantitative estimates for the delivery of light element to the core depend on the longevity of partial melt at the base of the mantle. Diffusion of Si or O into the core is capable of producing a 60-km to 120-km stratified layer over the age of the Earth, independent of how mass is transferred to the core. By comparison, estimates for the strength of the density stratification are sensitive to factors such as degree of partial melt in the mantle. Gradual cooling of the core shifts the state of chemical equilibrium with the mantle and may cause other dissolved constituents (like Mg) to become oversaturated. Exsolution of Mg promotes compositional convection in the core and tends to erase any stratification. We distinguish between these possibilities at the present time by looking for the influence of fluid stratification on flow at the top of the core. Recent evidence for magnetic waves in the core supports the existence of a 140-km stratified layer. The strength of stratification is broadly consistent with a thermal origin, although a compositional origin is also possible if transport into the core is limited by small volumes of partial melt in the mantle. In order to explain the thickness of the layer with compositional gradients, we favor O as the main additive to the core after its initial formation.

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