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Stratification of the Outermost Core by Reaction with a Basally Molten Mantle

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Recent experimental work on equilibrium between silicates and metals at pressures and temperatures near those expected at Earth's core-mantle boundary (CMB) supports earlier studies that consistently indicate a propensity for dissolution of iron-bearing silicates and oxides into predominantly iron metal at CMB conditions. Due to this high solubility of silicon and oxygen in metal, which for reasonable ranges of CMB temperatures appears to be well in excess of the amount that would account for the light element budget in the bulk of the outer core, metallic oxygen and silicon are expected to enter the top of the core following reaction with the base of the mantle. However, owing to the large density deficit of this Si/O-enriched metal relative to the underlying core, the buoyancy of these reaction products will be too great to allow for significant degrees of downward entrainment and mixing into the underlying convecting liquid outer core, and instead a gravity stratified layer is expected to form in which radial transport of species is controlled by chemical diffusion alone. We propose that this disequilibrium at the CMB has existed since Earth's formation, predict that a diffusion boundary layer accounting for gradients in chemical potential will have been able to grow to a thickness of order 10-100 km over Earth's history, and test the dynamical stability of the layer over geological time. An upper bound on the thickness is given by geomagnetic secular variation constraints that permit magnetic diffusion times no longer than permitted by an outermost core stratified layer of maximum thickness 100 km. A lower bound is obtained from a diffusion length scale of several tens of km over the age of the Earth. The strength of the compositional stratification atop the core depends critically on whether or not the bottom of the mantle was more extensively molten in the past than at present, however, the length scale is not sensitive to the state of the mantle. Such a variation in composition at the top of the core may also explain variations in the seismic structure inferred in the uppermost core.