



A NEW MODEL FOR EARLY DIFFERENTIATION AND CHEMICAL STRATIFICATION OF THE EARTH'S MANTLE

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New experimental data on the solubility of oxygen in liquid Fe-rich alloy enable the geochemical consequences of core formation and the early geochemical evolution of the Earth's mantle to be better constrained. We have studied oxygen solubility in liquid Fe-alloy at 5-23 GPa, 2100–2700 K and variable oxygen fugacities using a multianvil apparatus. At constant oxygen fugacity, O solubility increases with increasing temperature but decreases with increasing pressure. Thus, along a high temperature adiabat (e.g. after formation of a deep magma ocean), oxygen solubility is high at relatively shallow depths (e.g. <1000 km) but decreases strongly at greater depths where the effect of high pressure dominates. Applying these results to models of metal-silicate separation in a magma ocean leads to the conclusion that the silicate component of relatively oxidized chondritic material will be reduced by reaction with liquid Fe due to the high solubility of O in the metal if the temperature is sufficiently high. Metal-silicate separation in a magma ocean ~1500 km deep can thus explain the reduced nature of the Earth's upper mantle compared to that of the Martian mantle (the magma ocean on Mars would have been shallower and therefore colder – see abstract by Rubie et al.). However, as metal migrates to greater depths, the solubility of O decreases strongly, which could lead to precipitation of FeO and the enrichment of the lower part of the mantle in this component. Alternatively, if all or part of the dissolved oxygen is transported to the core (e.g. as a disequilibrium component), the consequences would include the presence of significant amounts of oxygen as a light element in the core and/or the formation of a FeO-rich layer at the CMB due to exsolution of the excess oxygen. Such models may also predict a small degree of chemical stratification of the mantle with respect to silica content. High temperatures (>3000 K) in a magma ocean

result in significant Si being dissolved in liquid Fe-alloy whereas at depths >800–1000 km the solubility starts to decrease again and becomes close to zero at the CMB (Gessmann et al. 2001, EPSL 184, 367). Thus migration of liquid metal during core formation provides a mechanism for enriching the lower part of the mantle in the FeO component, and possibly also in SiO₂, relative to the upper part.