Silicate melt ferric/ferrous iron speciation and the redox state of a deep magma ocean

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During the accretion and differentiation of the Earth one or more phases of global mantle melting probably occurred, forming a magma ocean that likely extended into the lower mantle. Metallic core forming liquid would separate and sink through this ocean and collect at the base before sinking further to assimilate with the core. The final phase of equilibration with metallic liquid would have been at the base of this ocean, where the redox state would have consequently been below the iron-wüstite oxygen buffer. The extent of equilibration and the final compositional state of the magma ocean were likely decisive to the further evolution of the Earth.

At low pressures silicate magmas in equilibrium with metallic Fe contain practically no ferric iron. We have examined this relationship as a function of pressure by equilibrating silicate melts with a coexisting Ru-RuO_2 buffer between 5 and 24 GPa. Further experiments were performed on the same melt in equilibrium with iron metal and a basaltic melt has also been examined. In situ x-ray diffraction measurements on Ru and RuO_2 were necessary to determine the oxygen fugacity of this buffer at high pressure and a number of phase transformations of RuO_2 were observed. The results show that for a fixed relative oxygen fugacity, the melt ferric iron content initially decreases with pressure but above 15 GPa this trend reverses and the ferric iron content increases

This behaviour would drive the oxygen fugacity of a deep magma ocean with a fixed ferric/ferrous ratio down with increasing depth, creating a redox gradient. As a result the magma ocean could have been in equilibrium with metallic iron at its base but more oxidised in its shallower regions. Crystallisation of this magma ocean could render an upper mantle oxygen fugacity similar to that in the Earth's accessible mantle today.