Magma oceans, lakes or ponds?

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The mantle abundances of moderately siderophile elements are currently interpreted as due to partitioning between segregating metallic core and silicate liquid at the base of a deep magma ocean. This model, first developed in the 1990's [1, 2], is based on the observed pressure-dependence of the metal-silicate partitioning of a number of transition elements, in particular Ni. The abundances of these elements in the silicate mantle were established during the last ~20% of accretion and these abundances appear to require high pressure (40-50 GPa) of metal-silicate equilibration ie at mid-mantle depths. There is an evident problem with this model, however; it requires high degrees of metal:silicate equilibration just when dynamical models suggest this is least likely. That is, at the end of accretion where models suggest direct merging of impactor cores with that of the protoEarth.

We have re-modelled terrestrial accretion and mantle abundances of a number of elements (inc. W, Nb, Co & Ni) and find that they can all, with the exception of Ni be explained by metal-silicate equilibration at relatively low pressure (<10 GPa), thus in a shallow magma lake or pond. Only Ni requires the extreme pressures of equilibration currently accepted. Given the importance of this one element, we considered that it was time to re-investigate the deep magma ocean model of core formation. Our findings are that elemental mantle abundances may be set by early differentiation in small, oxidised and reduced bodies, with only a low degree of metal:silicate equilibration subsequently occuring in the growing Earth. Ni can be fit into this model provided the reduced bodies are sulfur-rich or "mercury-like". A low pressure model of core formation is consistent with the volatile depletion of the Earth, and reconciles dynamical models of accretion with metal:silicate partitioning data without having to resort to equilibration in ever deeper models of magma oceans.

1. Li, J. & Agee, C. B. *Nature* **381**, 686-689 (1996)
2. Walter, M. J. & Thibault, Y. *Science*, 1186 (1995)