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Core formation in planetesimals: the importance and geochemical legacy of immiscibility in metallic liquids.

GEOFFREY DAVID BROMILEY, FREYA DIBBLE AND LEE SAPER

University of Edinburgh

Presenting Author: geoffrey.bromiley@ed.ac.uk

Core formation, i.e. the physical separation of metallic liquid(s) from silicate, was a key differentiation process in the early, inner solar system. Extensive silicate melting at "high" temperatures and formation of a magma ocean or crystal-rich mush may have been required to effectively segregate core-forming liquids. However, there is evidence that segregation could have initiated in some bodies at lower temperatures before substantial silicate melting, aided by percolation of FeS-rich liquids within solid silicate, following low-degree silicate melting and extraction, under highly reducing conditions, and/or following large impacts and shock heating. These "low-temperature" core-forming mechanisms typically imply segregation of FeS-rich liquids, although an outstanding challenge is identifying robust geochemical signatures. A complicating factor here is that experimental studies indicate immiscibility of FeS-rich and S-poor/Fe-rich liquids during planetesimal differentiation over a broad range of temperatures [1]. This implies that segregation of FeS-rich liquids could also be a feature of high-temperature core formation.

We present new experimental data which demonstrates that the importance of immiscibility of FeS-rich and S-poor/Fe-rich liquids has been overestimated. Carbon-saturation in many experimental studies results in unrealistically high carbon contents in metallic liquids and drives immiscibility, even in low-S systems. In the majority of planetesimals which experienced extensive degassing [2], separation of FeS-rich liquids is only possible during low-temperature core formation and incomplete melting of metallic components. In turn, segregation of immiscible FeS-rich and S-poor/Fe-rich liquids is only likely in volatile-rich (i.e. high C and S) bodies.

This implies that light element content of planetesimal cores is a consequence of both segregation process and composition, the latter including the effects of degassing during planetesimal heating. Using available experimental data we explore geochemical consequences of differentiation processes, including the effects of immiscibility and partial melting of metallic components, for various core-forming scenarios. However, it remains challenging to deconvolve the effects of bulk (volatile) composition, temperature, oxygen fugacity, and segregation process (extent of silicate and metallic melting, and metallic liquid immiscibility) during planetesimal differentiation, and thus identify signatures of low-temperature core formation.

[1] Corgne et al. (2008) *GCA* 72, 2409-2416

[2] Grewal & Asimow (2023) *GCA* 344, 146-159