Is the Earth's core still growing? Assessing the fate of molten iron-carbon alloy by investigating its wetting of mantle silicates

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Core-mantle segregation represents one of the most important differentiation events in Earth's history, and likely consists of a series of events, starting as early as 5 million years after the origin of the solar system history and possibly continuing to the present day (Wood et al. 2006). The hypothesis of on-going core growth has become particularly intriguing because recent studies suggested iron-carbon melt may form near the core-mantle boundary (e.g., Liu et al. 2015). If the iron-carbon melt remains trapped in the matrix of solid silicate or oxide, it may be returned to the shallower part of the mantle through global convection. Alternatively, the iron-carbon melt may percolate through the silicate or oxide and drain into the core. The latter scenario implies that the Earth's core is actively growing.

As a separation mechanism, a liquid iron alloy may percolate slowly through the silicate matrix of the Earth's mantle, forming an interconnected network to transport itself to the core (Shannon and Agee, 1998). In the Earth's interior the feasibility of percolation is determined by the ratio of the solid-liquid interfacial energy (γ_{sl}) and the solid-solid interfacial energy (γ_{ss}), which is quantified by the dihedral angle for the silicate/iron-alloy system (θ) (Rubie et al. 2007). A dihedral angle of 60° or less leads to the formation of an interconnected network of iron-alloy, whereas a dihedral angle that is greater than 60° implies that the a significant fraction of iron melt may be stranded as isolated pockets. Previous quench experiments (e.g., Shannon and Agee 1998) and a recent synchrotron transmission x-ray microscopy study (Shi et al. 2013) found a critical reduction in the dihedral angle from the condition of the upper mantle to that of the lower mantle. The results imply that iron-nickel-sulfur alloy is able to percolate through the lower mantle efficiently to join the core.

At 1 bar, the dihedral angle of Fe-C with respect to silicate is about 120°, indicating non-wetting (references in Li and Fei 2014). The wetting behavior of Fe-C melt at high pressure is not known. In this study experiments are conducted at pressures between 10 GPa and 25 GPa to determine the dihedral angel of Fe-C melt in the solid matrix of olivine, wadsleyite, ringwoodite, and/or bridgmanite, using a multi-anvil apparatus. The starting material consists of powder of San Carlos and a powder mixture of iron and graphite with 4 wt% carbon. Recovered run products are analyzed for composition and texture using a JOEL field emission SEM and a CAMECA electron probe microanalyzer. The results will allow an evaluation of the effects of pressure and polymorphic structural transitions on the dihedral angle and the percolative ability of iron-carbon melt in the mantle. The data will be applied to test the hypothesis of subduction-supported core growth.

References

Li, J., & Fei, Y. (2014). Experimental Constraints on Core Composition. *Treatise on Geochemistry*, 527-557.

Liu, J.C., Li, J., Smith, J., Hrubiak, R. (2015) Origins of ultra-low velocity zones through mantle-derived metallic melt, *2015 AGU Fall Meeting.*

Rubie, D., Nimmo, F., & Melosh, H. (2007). Formation of Earth's Core. *Treatise on Geophysics Volume 9: Evolution of the Earth,* 51-90.

Shannon, M. C. (1998). Percolation of Core Melts at Lower Mantle Conditions. *Science, 280*(5366), 1059-1061.

Shi, C. Y., Zhang, L., Yang, W., Liu, Y., Wang, J., Meng, Y., Mao, W. L. (2013). Formation of an interconnected network of iron melt at Earth's lower mantle conditions. *Nature Geoscience Nature Geosci, 6*(11), 971-975.

Wood, B. J., Walter, M. J., & Wade, J. (2006). Accretion of the Earth and segregation of its core. *Nature, 441*(7095), 825-833.