Deformation-assisted core formation

T. RUSHMER[1] , N. PETFORD[2] AND M.HUMAYUN[3]

[1] University of Vermont; (Tracy.Rushmer@uvm.edu)
[2] Kingston University; (N.Pet@kingston.ac.uk)
[3] Florida State University; (humayun@magnet.fsu.edu)

The segregation and transport of liquid metal in growing planetesimals is a complex problem that requires consideration of multiple processes. We have investigated through deformation experiments, in conjunction with numerical modeling and geochemical analyses, the rates, fluxes and associated composition of core metal migrating by porous flow verses segregation induced by deformation. The mechanical model used to study deformation-assisted rates and fluxes depends on impacts that produce a strain gradient and induce a transient shear dilatant effect that can transport fluid. In comparing the compositions and associated rates of core-forming liquids that can segregate by porous flow alone (driven by buoyancy) we find that deformation-induced migration is several orders of magnitude faster than porous flow. The geochemical results from the experiments show the S content in segregated Fe-rich liquid decreases with increasing degree of melting. As the S content of the liquid metal also strongly affects the partitioning behavior HSE between solid and liquid metal, an increase in liquid metal fraction from 5 to 30% lowers the Dsm/lm by several orders of magnitude. Porous flow depends on interconnectivity and static experiments have shown that interconnectivity is possible at ~5 vol% of liquid metal. Although these liquids can migrate at rates which lie within the constraints of W-Hf estimates the compositions are S-rich and therefore would leave significant HSE in residual metal. At higher degrees of melting, the presence of silicate melt prevents migration of liquid metal by porous flow alone. We propose that while porous flow is important as a background mechanism, for efficient segregation of high fraction liquid metal (and concentrated in HSE), distinct deformation events due to impact are the most effective at driving core formation.

Implications for interaction at the growing CMB

Under appropriate rheological conditions, deformation can create strain gradients that will transiently transport fluid against gravity, so a more dense fluid can be moved upwards into an overlying layer of lower density, once a critical strain rate threshold is reached. We are exploring this mechanism as a possible way to re-introduce HSE into a growing silicate mantle at the core-mantle boundary. Preliminary calculations show that several hundred impacts, each large enough to excite the CMB region for at least 1 minute, are required to transport 10^{21} kg of HSE-bearing core melt upwards into the mantle, sufficient to account for the mantle's observed excess siderophile element abundances.