Deformation-assisted core formation

T. Rushmer[1], N. Petford[2], 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 $\sim$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.

1. 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 min, 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.

doi:10.1016/j.gca.2006.06.1009

The once and future battles between Thor and the Midgard Serpent: The Southern Hemisphere Westerlies and the Antarctic Circumpolar Current

J.L. Russell[1], K.W. Dixon[2], A. Gnanadesikan[2], J.R. Toggweiler[2], R.J. Stouffer[2]

[1]Department of Geosciences, University of Arizona, Tucson, AZ, USA (jrussell@geo.arizona.edu)
[2]GFDL/NOAA, P.O. Box 308, Princeton, NJ, USA

Global climate model simulations of the interactions between the Southern Hemisphere Westerlies and the Antarctic Circumpolar Current detail the role of the Southern Ocean in partitioning carbon between the ocean and atmosphere. The coupling of climate, Westerly Wind position and the overturning of deep water in the Southern Ocean explains some of the more puzzling features of glacial-interglacial CO_2 cycles, including the tight correlation between atmospheric CO_2 and Antarctic temperatures, the lead of Antarctic temperatures over CO_2 at terminations and the shift of the ocean's $\delta^{13}C$ minimum from the North Pacific to the Southern Ocean. Cold glacial climates seem to have equatorward-shifted Westerlies which allow more respired CO_2 to accumulate in the deep ocean. Warm climates like the present have poleward-shifted Westerlies that flush respired CO_2 out of the deep ocean.

In global warming simulations of future climate, poleward-intensified Westerlies maintain a robust deep water overturn around Antarctica even as rising atmospheric greenhouse gas levels induce warming that reduces the density of surface waters in the Southern Ocean. These results imply that the future poleward-intensification of the Southern Hemisphere Westerlies may prop open the Southern Ocean door to the deep ocean, allowing the ocean to remove relatively more heat and anthropogenic carbon dioxide from the atmosphere.

doi:10.1016/j.gca.2006.06.1010