Core formation in terrestrial planets without magma oceans: the role of deformation in melt segregation

M. BERG[1], G. D. BROMILEY[1]*, I. B. BUTLER[1], S. A. T. REDFERN[2], Y. LE GODEC[3] AND J. CARR[4]

[1]School of GeoSceinces, University of Edinburgh, UK geoffrey.bromiley@ed.ac.uk*
[2]Dept. Earth Sciences, University of Cambridge, UK
[3]Inst. De Minéralogie et de Physique Condensés, Université Pierre et Marie Curie, Paris, France.
[4]School of Materials, University of Manchester, UK

It is assumed that efficient core formation in rocky bodies in the early solar system was dependent on extensive silicate melting and 'ponding' of core-forming melts at the base of a silicate 'magma ocean'. Despite the attractiveness of this hypothesis it has remained difficult to model the chemistry of Earth's mantle based on iron-silicate partitioning at the base of a deep magma ocean, and recent iron isotope analysis appears inconsistent with the effects of high-PT fractionation (Halliday 2013, Nature 497:43-45). It has been suggested that core formation could have been initiated prior to the onset of silicate melting due to the influence of deformation in promoting development of networks of metallic melt in solid silicate matrices. However, in one of the only studies performed under high PT conditions it was concluded that the influence of strain rate on deformation mechanisms indicated that such deformation-aided melt segregation was not relevant to conditions prevalent in the early solar system (Walte *et al.* 2011, *EPSL* 305:124-134).

Using a combination of novel in-situ and ex-situ high PT deformation experiments, 2D microanalysis and 3D nano-CT imaging we demonstrate that deformation has a fundamental influence of textural development, resulting in channelisation of melts as nm-tick sheets which otherwise remain trapped at silicate grain junctions in static systems. These features are difficult to resolve using traditional microscopy, highlighting the usefulness of recent advances in nano-CT imagining.

We see no influence of strain rate on strain partitioning, with similar textures observed in samples deformed over a wide parameter space. It appears likely that deformation due to convection led to early core formation prior to silicate melting in newly accreted planetessimals. Core formation was likely a complex, multistage process dependent on planet size and heating rate, and unless overprinted by later melting events, likely resulted in only partial silicate-metal equilibration.