Deep mantle melting in the past and at present

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Recently a series of melting experiments has been performed in a laser-heated diamond-anvil cell (DAC) under deep lower mantle conditions. Synchrotron X-rays are useful for the characterization of small DAC samples in-situ at high pressure. Complementary to X-ray studies, ex-situ characterization, in particular using focused ion beam (FIB) techniques, is also important for three-dimensional textural observations and chemical analyses with high spatial resolution and high precision.

Solidification of a magma ocean is a key process that determined the initial conditions and later evolution of the solid mantle. We have recently determined the crystallization sequence of solid phases and the compositional evolution of melts upon solidification in the deep magma ocean. Results show that brigmanite is the liquidus (first crystallizing) phase in a middle to deep lower mantle and that iron partitions preferentially into melts relative to bridgmanite (Nomura et al., 2011 Nature; Tateno et al., 2014 JGR), indicating that the deep magma ocean should have evolved towards Si-poor and Fe-rich composition. Also, if fractional crystallization occurred, strong compositional stratification should have developped, forming brifgmanite single-phase layer in the lower mantle with iron-enriched magnesiowüstite-dominant layer at its bottom.

At present, the interpretaion of ultralow-velocity zone (ULVZ) is important to understand thermal and compositional strcutures near the CMB. Since it is not globally observed, the solidus temperature of pyrolite may give the upper bound for temperature at the CMB. Our data based on ex-situ sample characterization (Nomura et al., 2014 Science) showed that pyrolite starts to melt at 3600 K at the CMB, lower than previous estimates using in-situ X-ray observations. The possible presence of melt at the ULVZ is likely to be attributed to melting of materials with lower solidus temperatures such as MORB. Our experiments also show the important consequences of MORB melting in the lowermost mantle.