Laboratory experiments on metal fragmentation in a magma ocean

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Understanding the physics of metal-silicate differentiation provides constraints on metal-silicate chemical equilibration during Earth's formation. According to solar system formation models, much of the Earth mass accreted as a result of high-speed collisions between planetary embryos consisting of a silicate mantle and a metallic core. Energy release during such impacts resulted in widespread melting, where dense liquid metal blobs fell and subsequently fragmented into droplets within fully liquid silicate magma oceans.

We present experiments on the instability and fragmentation of blobs of a heavy liquid released into a lighter immiscible liquid. We characterize the different flow regimes as a function of the Weber number, which measures inertia versus surface tension. At sufficiently high Weber numbers, the relevant regime for core formation, the heavy liquid is contained inside a coherent structure that grows by turbulent entrainment of ambient liquid and whose shape remains self-similar during the fall. The turbulent entrainment assumption is consistent with our experimental data and provides a simple parameterization for the volume of silicates that can equilibrate with metal in magma oceans. Extrapolating, breakup into droplets starts within a few initial proto-core diameters and occurs as a single and global event, facilitating metal-silicate equilibration.