Convection-assisted metal segregation in early accreted planetesimals

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Meteorites preserve a record of accretion and evolution of primitive bodies in the early Solar System. They exhibit different degrees of differentiation from the most primitive, with mixed metal and silicates (chondrites), to the most evolved, composed only of metal or silicates (achondrites). Such objects indicate that metal-silicate segregation occurred in planetesimals that were heated sufficiently to – at least partially – melt their silicate and metal phases. Primitive achondrites that have melting degree up to 20 vol.% show poor metal segregation while achondrites (e.g., iron meteorites, pallasites, HED) have reached higher temperatures with melt contents allowing the formation of magma oceans, i.e. > 40 vol.% silicate melt.

In this latter case, the generally accepted idea is that metal particles simply sink into the magma ocean and form the core. However, the Rayleigh number of such magma oceans indicates that a convective regime occurs. Sinking of a particle is controlled by its size and density but also by the vigor of convection. We calculated that metal particles must be cm in size to escape convective motion and sink. Although the meteoritic record shows evidence of complete differentiation for parent bodies that went through a magma ocean stage, regular grain growth mechanisms are not efficient enough to allow metallic grains to escape convective motions. To solve this paradox, experiments were performed to determine how metal can segregate in a turbulent environment.

High temperature time series experiments have been performed in a 1-atmosphere controlled furnace to follow textural evolution and to constrain timescales of metal coalescence in a partially molten and turbulent environment. Samples are composed of a mixture of forsterite, nickel and silicate melt. Post-mortem samples have been analysed using 3D microtomography and show that turbulent motions formed an interconnected network in samples with low nickel (5 vol.%) and high melt contents on an extremely short timescale (< 1 day). Such features indicate that convection promotes coalescence of nickel and would form grains larger than a centimeter if applied to a larger scale, *i.e.* that of a planetesimal.