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Reproducing iron-rich phase textures in primitive achondrites: overcoming surface tension in solids

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Primitive achondrites are partially differentiated meteorites originating from parent bodies that accreted around 1.3 Myr after CAIs [1]. Despite a limited heating potential (up to ≈ 1200 °C and 25 vol% of melting for lodranites [2]), the silicate fraction of these specimens shows a high degree of equilibration, based on homogeneous phase compositions and equilibrated textural features.

However, the textures of opaque phases in acapulcoites and lodranites do not reflect an equilibrium defined by interfacial energies. At peak temperatures, the metallic phases most likely featured a Fe-Ni residue and a sulfur-rich melt. In this state, the minimization of interfacial energies dictates that the Fe-Ni residual grains are surrounded by the S-rich melt. Instead, kamacite-taenite and troilite are equally contacting the silicate phases and are spatially sorted within sections of primitive achondrites.

To understand the origin of these textures, an analogue system was designed using olivine and a mixture of troilite and gold to represent the low- and high- surface tension melt and residue, respectively. Samples were enclosed in graphite capsules and compressed to 2.5 GPa using the 500 tons Walker-type multi-anvil press at BGI. From our recovered samples, it appears that a long equilibration in the solid state, after an initial high temperature equilibration, is necessary to reproduce the spatial sorting of opaque phases. The textures of opaque phases in primitive achondrites reflect the cooling history of the parent body rather than high-temperature equilibration.

During the slow cooling of a planetesimal, the high viscosity of solid phases makes the minimization of interfacial energies rather inefficient. Although not energetically favorable, grain-growth occurs over reasonable timescales and controls the small-scale reorganization in the opaque phases by topological re-arrangement of adjacent grains and grain-boundaries. Hence, sub-solidus grain growth results in spatial sorting of the opaque phases. Since such textural features indicate slow cooling, they can be used to place constraints onto the thermal evolution of planetesimals and the possibility and timing of impacts.

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[2] Bild and Wasson (1976), Mineralogical Magazine 40, 721-735