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Characteristics and evolution of the acapulcoite-lodranite parent body

GHYLAINE QUITTÉ[1], ADRIEN NÉRI[2], MARC MONNEREAU[3], JÉRÉMY GUIGNARD[4] AND MICHAEL J. TOPLIS[5]

[1]IRAP / CNRS, Observatoire Midi-Pyrénées
[2]University of Bayreuth
[3]IRAP, CNRS, Observatoire Midi-Pyrénées
[4]IROX Technology
[5]CNRS, IRAP, Observatoire Midi-Pyrénées
Presenting Author: ghylaine.quitte@irap.omp.eu

Acapulcoites and lodranites are partially differentiated meteorites in which metal segregation started but did not reach completion. They are thus samples of choice to get a comprehensive picture of the first stages of metal-silicate separation in the early solar system. To unravel the exact mechanism, timing, and physico-chemical conditions of incipient differentiation processes, we conducted a multidisciplinary study of primitive achondrites, combining mineralogical, chemical and isotopic study with experimental petrology and numerical simulations.

A series of experiments has been conducted on a 3-phase system (metal, silicate liquid, and solid silicate). Due to relative phase fractions and interfacial energies, silicate grains form a touching rigid network. Metal can only segregate if it forms an interconnected network in this silicate matrix. High temperature experiments define an interconnectivity threshold of metal of about 20-25vol%, higher than the initial metal content of chondrites. In this case, migration (and thus local loss) of a silicate liquid is essential to reach the percolation threshold and allow differentiation (Néri et al. 2019, 2020, 2021). The thermal evolution of small bodies has been modelled as a function of their size and accretion age, taking into account the effects of temperature and thermal history on melt viscosity and grain growth (Monnereau et al. 2023). Numerical simulations indicate that the maximum melting degree is 50% in a magma ocean due to rheological threshold effects. In all cases, metal never sinks as isolated droplets in a magma ocean.

In natural samples, equilibrium temperatures have been estimated based on the olivine-chromite and pyroxene-pyroxene thermometers, as well as the oxygen fugacity at which the meteorites formed. The bulk composition of the samples suggests that the precursor was similar to reduced H chondrite material. The isotope composition of the samples has also been measured. Large tungsten nucleosynthetic anomalies have been observed, in particular in GRA95209 (lodranite), compatible with a s-process component. Our new results confirm that the lodranite parent body belongs to the non-carbonaceous reservoir, located in the inner solar system, as already suggested using Mo, Ru and Zr isotopes.

Considering all data together, a global model is proposed to explain the acapulcoite-lodranite suite.