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Origin of pallasites in the interior of terrestrial planetesimals

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Pallasites, a category of stony-iron meteorites, display the following mineralogical composition: Olivine, Fe-Ni, troilite and minor phases, where olivine presents three characteristic forms of well-rounded grains, angular fragments, and polygonal fractured grains, occasionally all present in a single sample (mixed-type pallasites, e.g., Seymchan). Mixing of Fe-Ni-S and olivine caused by a non-destructive collision among planetesimals is indicated as the possible origin of this material. This hypothesis was tested by reproducing simultaneously the presence of olivine, solid Fe-Ni and molten Fe-S experimentally.

We tested an olivine plus partially molten Fe-Ni-S system with variable amounts of Fe and S, and obtained a grain growth rate of olivine surrounded by a matrix of Fe-Ni and molten Fe-S. With a 2D finite-difference numerical model we created a realistic scenario (e.g., time of impact, depth of intrusion of the Fe-Ni-S) for the formation of rounded- and mixed-type pallasites for the first time.

Olivine grain growth rate in partially molten Fe-Ni-S follows: d$\hat{}$n – d0$\hat{}$n = k0 exp(-Ea/RT) t, where, d is the grain size at time t, d0 is the starting grain size, n = 3.70 (61) the growth exponent, k0 = 3.20 μmns-1 a characteristic constant, Ea = 101 (78) kJ/mol the activation energy for a specific growth process, R the gas constant, and T the absolute temperature. This is a substantially slower grain growth than in the case of olivine surrounded by Fe-S melt (i.e. n = 2.42), but significantly faster than for olivine+FeNi or olivine+Ni (n > 4 or 5). We concluded that the grain growth rate limiting factor is the coarsening of solid Fe-Ni, and devised a comprehensive scenario encompassing movement of Fe-S melt, followed by pooling of Fe-Ni to yield an increment of the grain size of both olivine and Fe-Ni.

Numerical models suggest that a $\geq$ 200 km radius body is favorable to form rounded olivine-bearing pallasites, and that early mixing in the planetesimal mantle may yield mixed-type pallasites.