Goldschmidt 2023 Abstract
https://doi.org/10.7185/gold2023.20310

Iron isotope evidence of an impact origin for main-group pallasites

CORLISS KIN I SIO[1], NEIL R BENNETT[1], EDWIN SCHAUBLE[2], CHARLES LESHER[3], JOSH WIMPENNY[4] AND ANAT SHAHAR[5]

[1]University of Toronto
[2]University of California, Los Angeles
[3]University of California, Davis
[4]Lawrence Livermore National Laboratory
[5]Carnegie Institution of Washington

Presenting Author: Corliss.sio@utoronto.ca

Main-group pallasites (MGP) are traditionally thought to represent materials from the core-mantle boundary of a differentiated planetesimal. Paleomagnetic data, however, have suggested a shallower origin in which metal was sourced from an impactor [1,2]. Complementary geochemical evidence in support of this model has been harder to find. Recent results, however, appear to point more convincingly toward an impact model [3,4,5].

The origin of MGP can be inferred from their thermal history: a core-mantle boundary necessitates prolonged cooling from high temperature, whereas a shallow origin does not. We performed numerical models of planetary cooling with simultaneous diffusive exchange between olivine and metal. Under all modelled scenarios, olivine and metal achieve Fe isotopic equilibration at or near the core-mantle boundary. To determine whether MGP carry this equilibrium Fe isotopic signature, we analyzed olivine and metal in eleven MGP. We then compared this result to the equilibrium Fe isotope fractionation derived from piston cylinder experiments and density function theory (DFT) calculations [4].

The $D^{56}Fe_{olivine\text{-}metal}$ fractionation determined from our equilibration experiments is +0.054 ±0.027‰, whereas that from our DFT calculation is +0.026 ±0.017‰ (at 1400 °C). These values agree with those predicted using nuclear resonant inelastic X-ray scattering data from the literature, which gives $D^{56}Fe_{olivine\text{-}metal}$ of +0.052‰ at the same temperature [6]. Thus, these different approaches all suggest that, at equilibrium, olivine should be isotopically heavier than metal. However, we found the opposite sense of fractionation in MGP, where $D^{56}Fe_{olivine\text{-}metal}$ = -0.49 ±0.016 ‰ (n = 11). The difference in the polarity of fractionation suggests that olivine and metal were never in equilibrium with respect to Fe isotopes. This disequilibrium signature is only compatible with MGP having cooled at shallow- to mid-mantle depths in a planetesimal, definitively ruling out a core-mantle boundary origin and instead implicating an impact process for their formation.

[1] Tarduno et al. (2012) Science, 338(6109), 939-942.
[2] Bryson et al. (2015) Nature, 517(7535), 472-475.
[3] Windmill et al. (2022) PNAS Nexus 1, pgac015.
[4] Kruijer et al. (2022) EPSL, 584, 117440.
[5] Bennett et al. (2022) GPL, 23, 6-10.
[6] Dauphas et al. (2014) EPSL, 398, 127-140.