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Investigating Eagle Station pallasite formation using silicon isotope signatures of individual olivine grains

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Pallasite meteorites are primarily composed of Fe-Ni metal and silicate (olivine and/or pyroxene). Recent models suggest pallasites formed in the walls and floor of large impact melt basins that penetrated the mantle of their parent asteroid [1]. As such, pallasite metal and silicate are derived from different parent asteroids, where metal was injected by the projectile into the olivine-bearing mantle of the target planetesimal.

Eagle Station pallasites (ESP) are distinct Main Group pallasites (PMG) in their nucleosynthetic makeup and are linked to carbonaceous, outer Solar System planetary objects. Moreover, individual ESP olivine grains record variable mass-independent $^{26}Mg/^{24}Mg$ isotope signatures [2]. These $^{26}Mg/^{24}Mg$ signatures of individual grains have been linked to continuous olivine crystallisation from an evolving magma body during ^{26}Al-to-^{26}Mg decay. Alternatively, this isotopic variability may be inherited from impactor–target mixing. In order to better understand the origin of the mass-independent $^{26}Mg/^{24}Mg$ variability, we selected 11 individual olivine grains from a single slab of Eagle station and measured their Si isotope signatures, which should be invariant if the grains formed through crystallisation from an evolving magma body.

Mass-bias corrected silicon isotope compositions ($\mu^{30}Si$) of individual grains range from -3.1±8.7 ppm to 30.9±3.4 ppm with an average $\mu^{30}Si$ signature of 14.4±6.5 ppm (2SE) encompassing the range of isotope composition of non-carbonaceous and carbonaceous chondrites and distinct from that of PMG [3]. Mass-dependent silicon isotope compositions ($\delta^{30}Si$) have an average composition of -0.24±0.09‰ (2SD), consistent with the bulk solar average value indicating that the $\mu^{30}Si$ variability is not driven by inappropriate mass bias correction. As such, our data show that the observed Mg isotope heterogeneity is also present in silicon isotopes and $\mu^{30}Si$ variability approximates that observed between planetary objects. Thus, silicon isotopes suggest ESP likely represent an impact event that not only injected iron metal into the mantle of an asteroid but also mixed impactor and target silicates that partially equilibrated, whereby either target or impactor was of non-carbonaceous origin.

[1] Mittlefehldt (2024), GCA 383, 92–107.

[2] Larsen et al. (2016), GCA 176, 295–315.

[3] Onyett et al. (2023), Nature 619, 539–544.