Absolute Pb-Pb age of Dhofar 700 and distinct stages of magmatic evolution of Vesta

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The large collection of howardite–eucrite–diogenite (HED) meteorites represent a unique opportunity to study the initial magmatic differentiation of a small planetesimal, Vesta, that accreted and differentiated during the earliest stages of our Solar Sytem's formation. Most HED meteorites have experienced thermal metamorphism and, consequently, the duration of the initial magmatism on Vesta, resulting from decay of ^{26}Al, is not well constrained. In particular, absolute age information that could link relative ^{26}Al-^{26}Mg ages of diogenite meteorites is still lacking. In an attempt to create an absolute age framework for the ^{26}Al-^{26}Mg decay system for diogenites, we dated the unequilibrated diogenites Dhofar 700 using the Pb-Pb chronometer and measured its Mg isotope composition.

Dhofar 700 has a Pb-Pb age of 4546.4±4.7 Myr, which we interpret to represent the exhumation and cooling age of this meteorite, most likely as the result of an impact. The Pb-Pb age is too young to form an absolute time anchor for the ^{26}Al-^{26}Mg system. However, this young age suggests that magmas capable of producing diogenites were present for at least 20 Myr on Vesta. The ^{26}Mg* excess of Dhofar 700 is 25.5±1.9 ppm, which is similar to eucrites, and is the largest ^{26}Mg* anomaly reported for bulk diogenites. Based on this large excess, we infer that the parent magma of Dhofar 700 formed 1-2 Myr after Solar System formation and experienced little recharge by Mg-rich magmas that would have erased the ^{26}Mg* excess recorded in Dhofar 700 until its crystallization ~20 Myr later. Combined with published ^{26}Mg* and trace element data, our data suggests that diogenites record a two stage magmatic history on Vesta. Diogenites forming a tight cluster of negative ^{26}Mg* and Eu/Eu* ~ 0.2 are interpreted to represent products of an early short-lived magma ocean on Vesta. A second population of diogenites records a trend of decreasing Eu/Eu* with increasing ^{26}Mg*. We interpret this to record diogenite formation from slowly evolving, small magma bodies after the initial, short-lived, shallow magma ocean phase. Based on the age of Dhofar 700, these magmatic bodies resided in the upper mantle of Vesta for at least 20 Myr.