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A reevaluation of the petrogenetic relationships among HED meteorites with Ca isotopes

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The nature of howardite, eucrite, and diogenite (HED) petrogenesis and the magmatic evolution of Vesta, the asteroid from which HEDs are believed to originate, remain contentious. Most models propose that either 1) eucrites and diogenites formed from primary partial melting: in this case, eucrites crystallize from a basaltic magma and their extraction leaves behind an ultramafic residue from which diogenites crystallize [1]; or that 2) Vesta experienced a magma ocean stage and underwent fractional crystallization: in this case, diogenites formed by crystal accumulation and most eucrites by crystallization of residual melts [2].

To date, no model respects all physical, chemical, petrological, thermal, and isotopic constraints provided by observations. The magma ocean scenario has become particularly problematic since O isotope data has revealed deviations of some eucrites and howardites from the common mass fractionation line, suggesting that these meteorites derive from different parent bodies or that Vesta experienced incomplete convective homogenization during differentiation [3].

To investigate the nature of HED relationships, we aim to quantify the effects of differentiation processes on Ca isotopes. Recent studies have started evaluating Ca isotope variability related to partial melting and fractional crystallization in the terrestrial mantle [4-6]. Results suggest that these processes are sources of mass-dependent Ca isotope heterogeneity in the products of differentiated bodies.

We have measured the Ca isotope compositions of 13 monomict HED samples sourced from the meteorite collection at the Field Museum using the Neptune XT MC-ICP-MS at The University of Chicago. Preliminary data show that most samples have Ca isotopic compositions similar to BSE; however, there is some variation which does not systematically correlate with mineralogy or elemental concentration. Among the howardites, there is larger Ca isotopic variation than within other groups. This is expected as they are mechanical mixtures of impact-derived material from eucrites and diogenites and may also contain a xenolithic component.

[1] Stolper (1977) GCA 41, 587-611. [2] Greenwood et al. (2005) Nature 435, 916-918. [3] Wiechert et al. (2004) EPSL 22, 373-382. [4] Kang et al. (2017) EPSL 474, 128-137. [5] Valdes et al. (2019) Chem. Geol. 509, 77-91. [6] Wang et al. (2019) 259, 37-52.