

## Geologic history of asteroid 4 Vesta

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Some types of meteorites – most irons, stony irons, some achondrites - hail from asteroids that were heated to the point where magmatism occurred within a very few million years of the formation of the earliest solids in the solar system. The largest clan of achondrites, the howardite, eucrite and diogenite (HED) meteorites, represent the crust of their parent asteroid [1]. Diogenites are cumulate harzburgites and orthopyroxenites from the lower crust whilst eucrites are basalts, diabases and cumulate gabbros from the upper crust. Howardites are impact-engendered breccias mostly of diogenites and eucrites. There remains only one large asteroid with a basaltic crust, 4 Vesta, which is thought to be the source of the HED clan [2].

Differentiation models for Vesta are based on HED compositions [e.g., 3]. Proto-Vesta consisted of chondritic materials containing  $^{26}\text{Al}$ , a potent, short-lived heat source. Inferences from compositional data are that Vesta was melted to high degree ( $\geq 50\%$ ) allowing homogenization of the silicate phase and separation of a metallic core. Convection of the silicate magma ocean allowed equilibrium crystallization, forming a harzburgitic mantle. After convective lockup occurred, melt collected between the mantle and the cool thermal boundary layer and underwent fractional crystallization forming an orthopyroxene-rich (diogenite) lower crust. The initial thermal boundary layer of chondritic material was replaced by a mafic upper crust through impact disruption and foundering. The mafic crust thickened over time as additional residual magma intrudes and penetrates the mafic crust forming plutons, dikes, sills and flows of cumulate and basaltic eucrite composition. This magmatic history may have taken only 2-3 Myr [4].

This magma ocean scenario is at odds with a model of heat and magma transport that indicates that small degrees of melt would be rapidly expelled from source regions, precluding development of a magma ocean [5]. Constraints from radiogenic  $^{26}\text{Mg}$  distributions suggest that the parent asteroid of HEDs was much smaller than Vesta [4]. Thus, first-order questions regarding asteroid differentiation remain.

[1] Mittlefehldt (2014) *Chem. Erde-Geochem.*, submitted. [2] McSween *et al.* (2013) *Meteoritics Planet. Sci.* 48, 2090-2104. [3] Mandler and Elkins-Tanton (2013) *Meteoritics Planet. Sci.* 48, 2333-2349. [4] Schiller *et al.* (2011) *Ap. J. Lett.* 740, L22-L27. [5] Wilson and Keil (2012) *Chem. Erde-Geochem.* 72, 289-321.