THE EVOLVING CRUST OF 4 VEST FROM COMPOSITIONAL AND THERMAL MODELLING.

J. T. Mitchell[1], A.G. Tomkins[1], C. Newton[2], and T. E. Johnson[3], [1]Dept. of Earth Atmosphere & Environment, Monash University, Clayton VIC 3800, Australia (Jennifer.Mitchell@monash.edu), [2]School of Physics & Astronomy, Monash University, Clayton VIC 3800, Australia, [3]School of Earth & Planetary Sciences, Curtin University, Bentley WA 6102, Australia.

Introduction: A genetic relationship between diogenites and eucrites has long been argued, as has the magmatic evolution of Vesta. In a magma ocean scenario, large-scale mineral settling and fractionation creates an "onion-skin" structure where basaltic eucrites dominate the upper crust and grade down through cumulate eucrites and diogenites in the lower crust and mantle [1]. In a serial magmatism scenario, late-stage diogenite magmas intrude into the older eucrite crust, thickening it and developing a diverse range of lithologies [2]. Therefore, determining the petrogenesis of diogenites and eucrites is a key factor in developing our understanding of differentiated protoplanetary bodies.

We have combined compositional, thermodynamic, and thermal modelling to generate a model for the early evolution of Vesta, allowing us to refine the diogenite-eucrite relationship.

Methods: A continuation of pMELTS [3] modelling presented in [4] was carried out using adjusted bulk Vesta compositions to reflect the removal of 5, 10, 15, and 20% of a mean eucrite component from an initial Vestan mantle composition in order to satisfy the Ca-depletion observed in natural diogenite orthopyroxenes. The bulk composition that generated compositions most similar to natural diogenites was then used to create two P-T pseudosections in THERMOCALC [5] reflecting a primitive and evolved (post-eucrite extraction) Vesta. The above compositional modelling was further used to construct thermal evolution models of Vesta based on the decay of ^{26}Al and ^{60}Fe [6,7] for accretion at 0.5, 1.0, 1.25, 1.5, 1.75, 2.0, and 2.5 Myr after CAIs at T_0.

Results & Discussion: pMELTS modelling finds that the removal of 15-20% of a mean eucrite component from an initial Vestan mantle composition generates diogenites during a second stage of melting that better match natural compositions. THERMOCALC modelling suggests that diogenite melts required considerably hotter temperatures (>1340 °C) than eucrite magmas (<1240 °C). The extraction of an initial eucrite-like melt early in Vesta's history occurred at low % partial melting and would have transported the majority of the available ^{26}Al to the upper regions of Vesta.

We suggest that this forms a hot stagnant lid that cools through convection and insulates Vesta's interior while temperatures increase until diogenite magmatism can begin. The decay of ^{26}Al in the crust and serial eucrite magmatism may have also driven the thermal metamorphism observed in eucrite meteorites [8].

The thermal models also show that there is a delay in the onset of diogenite magmatism of >1 Myr after initial eucrite extraction. This is in keeping with a serial magmatism scenario and previously reported trace element data [9]. Diogenites therefore most likely represent late-stage crustal intrusions emplaced through a network of dykes [10] instead of cumulates from mineral settling in a global magma ocean. These intrusions would thicken the crust [11] and undergo fractional crystallization to produce the wide range of diogenite compositions observed in the meteorite collection.

Thermal models utilizing these temperature and compositional constraints suggest that Vesta accreted 1.5-1.75 Myr after CAI formation and that the timing of accretion is vital in the development and evolution of Vesta due to the changing abundance of ^{26}Al caused by its rapid decay. Earlier accretion results in temperatures high enough to generate a global magma ocean producing komatiite-like lithologies and an anorthosite crust which is not observed. Accretion ages after T_0 + 1.75 Myr are unable to reach temperatures that can produce diogenite lithologies. Our proposed accretion age is seemingly contemporaneous with the ureilite parent body [12], angrite parent body [13], and NWA 011 ungrouped basaltic achondrite parent body [14].

Therefore, the timing of accretion and the relative abundance of ^{26}Al is a controlling factor in the evolution of protoplanetary bodies.

References: [1] Righter, K. & Drake, M.J. (1997), *Meteoritics & Planet. Sci., 32,* 929-944. [2] Yamaguchi A., et al., (2011), *JGR., 116,* E08009. [3] Ghiorso et al., (2002). [4] Mitchell, J.T. & Tomkins, A.G. (2019), *GCA, 258*, 37-49. [5] Powell, R. & Holland, T. (1988), *JMG., 6*, 173-204. [6] Mare, E.R. et al., (2014), *Meteoritics & Planet. Sci., 49*, 636-651. [7] Moskovitz, N. & Gaidos, E. (2011), *Meteoritics & Planet. Sci., 46*, 903-918. [8] Yamaguchi, A., et al., (1996), *Icarus, 124*, 97-112. [9] Barrat J.-A., et al., (2008), *Meteoritics & Planet. Sci., 43*, 1759-1775. [10] Wilson, L. & Keil, K., (2012), *Chemie der Erde, 72*, 289-321. [11] Clenet, H., et al., (2014), *Nature, 511*, 303-306 [12] Budde, G., et al., (2015), *EPSL, 430*, 316-325. [13] Kleine, K., et al., (2012), *GCA, 84*, 186-203. [14] Sugiura, N. & Fujiya, W. (2014), *Meteoritics & Planet. Sci., 49*, 772-787.