FURTHER HED ANALYSIS TO INVESTIGATE THE BOMBARDMENT HISTORY OF VESTA J. A. Cartwright[1] & I. Kouvatsis[1]. [1]Department of Geological Sciences, University of Alabama, Box 870338, Tuscaloosa, AL 35487, USA; E-mail: jacartwright@ua.edu

Introduction: The howardite, eucrite and diogenite (HED) achondrite meteorite clan are likely sourced from the asteroid (4) Vesta: the second largest in the asteroid belt, and the only known differentiated (and intact) body with a metallic core, ultramafic mantle and basaltic crust (e.g. [1-3]). Of these materials, the howardites represent materials from the vestan regolith, containing fragments of clasts of eucritic and diogeneitic material distributed heterogeneously. They can be separated into two subtypes – 'fragmental', which are simple polymict breccias, and 'regolithic', which are typically heavily brecciated and represent lithified remains of the active vestan regolith (e.g. [4]). Among the regolithic features observed in howardites, melt clasts are particularly interesting, not only for their compositional variability and appearance, but because they likely formed through shock processes linked to impacts.

The impact history of the Solar System has been heavily modelled on the Moon, where crater counting and absolute dating of returned samples yielded a significant age cluser between 3.8-4.0 Ga, thought to represent either a sudden 'Lunar Cataclysm' or an epoch of declining bombardment [5-9]. While no true consensus has been reached regading either scenario, the extent of the impact flux or period should also be preserved in materials other than those that are lunar derived, including Vesta.

Previous HED chronological studies have focused on eucritic material, revealing an apparent age range of 2-4.5 Ga, with clusters at ~3.5, 3.7-3.8 and ~4.5 Ga, with most authors suggesting consistency with the lunar model (e.g. [10-15]). Only a few previous studies have targeted melt clasts in howardites, where extracted material yielded ages of 3.7-4.2 Ga (16-19) and 3.2-3.7 [20], and consistency with the lunar model was favoured. In a study to expand the dataset for howardite materials, Cartwright et al., [21] performed in-situ chronological analyses on targeted clasts within two howardites using the argon-argon (Ar-Ar) technique, yielding a broad age range of 2.5-4.5 Ga with multiple clusters that do not correlate with findings from the lunar model. They concluded that the vestan surface highlights a broader impact flux, and that the lunar model may require refinement.

In this study, we are continuing on from the work of [21] by selecting a further four howardite samples GRO 95535, GRO 95602, LEW 87004 and QUE 94200 for targeted in-situ analysis using Ar-Ar. Here, we will describe the samples, and the melt clasts observed, in preparation for the chronometric data that will be acquired later in the year.

Samples: The four samples described below were loaned to us from the Meteorite Working Group (MWG). In order to satisfy material requirements for our future chronometric work, the MWG team prepared a thick section (~150 um) mounted in cyanoacrylic and mirrored thin section in standard epoxy were prepared for each sample, to reduce background and contamination issues for Ar-Ar analyses.

GRO 95535: Paired with a number of GRO howardites (except GRO 95602), it contains angular diogenitic and eucritic clasts, and rare chondritic material. Though melt clasts are not in as high abundance as for other howardites, GRO 95535 was previously analysed for noble gas composition, and found to be rich in solar wind (SW), suggestive of a SW origin [22]. Given this history, we expect melt clasts present to show evidence of resetting from impacts on Vesta.

GRO 95602: With medium/fine grained sub-angular sub-rounded grains of mainly eucritic composition, this howardite, also showed evidence of SW composition in previous analyses [22], suggestive of a regolithic origin.

QUE 94200: Paired with QUE 97001, this howardite has a light grey matrix, and is dominated by orthopyroxene, which may hint at a high diogenitic content. A number of dark melt clasts are observed [23]. This howardite was analysed previously for noble gas composition, and found to be dominated by cosmogenic components [24]. While not showing evidence of a SW component, this sample is an interesting comparison to the GRO materials studied here.

LEW 87004: While the MetBull classification for this sample is that of a polymict eucrite, it shows a strong resemblance to howarditic textures. It has a light grey/brown groundmass that contains larger subangular clasts of plagioclase and pyroxene. This sample has not been analysed previously for noble gas composition.

Methods: The four samples were examined using standard microscopy observations within the Cartwright Cosmochemistry Lab (CCL) at the University of Alabama (UA), where transmitted (if possible) and reflected light image mosaics were obtained. The thick sections were studied further using the the field-emission scanning electron microscope (FE-SEM) *Thermo Scientific Apreo*, at the Alabama Analytical Research Center (AARC) at UA. Large-scale high-resolution mosaics of the samples were obtained to aid examination and location of suitable melt clasts for chronometric studies.

Observational Data: In order to obtain sufficient Ar to determine a date, So far, we have identified ~13 suitable melt clasts within GRO 95535, ~28 in GRO

95602, ~12 in QUE 94200 and ~34 in LEW 87004. Figure 1 shows examples of two types of clast – an impact melt clast and recrystallised melt clast, are shown in QUE 94200 and GRO 95602 respectively. Given the high number of clasts observed so far, and with previous experience analysing similar materials [21], we are confident that these samples will yield data that will further expand on the impact history of Vesta.

Future Work: We are working through the images collected using our microscopy techniques to further identify suitable clasts for analysis. Selected regions of our samples are being irradiated for future Ar analysis, which will be performed in the Group 18 Noble Gas Laboratory of Arizona State Univeristy (PI: K. V. Hodges). We expect to perform these analyses later this year.

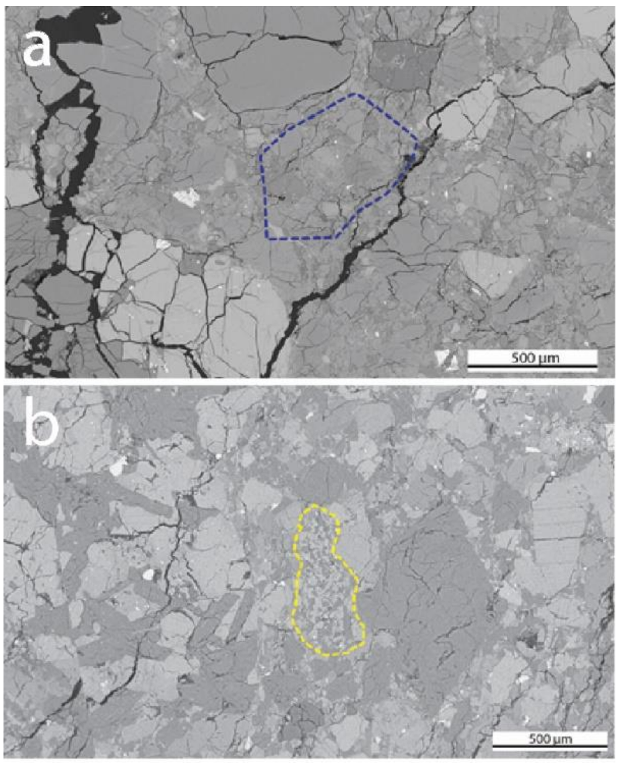

Fig.1: *SEM images of a) QUE 94200 and b) GRO 95602 with two melt clasts highlighted. In a) this clast shows a similar texture to an impact melt clast, while the melt clast in b) resembles a recrystallized melt clast [21].*

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