CARBONACEOUS CHONDRITE-RICH HOWARDITES; THE POTENTIAL FOR HYDROUS LITHOLOGIES ON THE HED PARENT. J. S. Herrin[1,2], M. E. Zolensky[2], J. A. Cartwright[3], D. W. Mittlefehldt[2], and D. K. Ross[1,2]. [1]ESCG Astromaterials Research Group, Houston, Texas, USA (jason.s.herrin@nasa.gov), [2]NASA Johnson Space Center, Houston, Texas, USA, [3]Max Planck Institut für Chemie, Mainz, Germany.

Introduction: Howardites, eucrites, and diogenites, collectively referred to as the "HED's", are a clan of meteorites thought to represent three different lithologies from a common parent body. Collectively they are the most abundant type of achondrites in terrestrial collections [1]. Eucrites are crustal basalts and gabbros, diogenites are mostly orthopyroxenites and are taken to represent lower crust or upper mantle materials, and howardites are mixed breccias containing both lithologies and are generally regarded as derived from the regolith or near-surface.

The presence of exogenous chondritic material in howardite breccias has long been recognized [2,3]. As a group, howardites exhibit divergence in bulk chemistry from what would be produced by mixing of diogenite and eucrite end-members exclusively, a phenomenon most evident in elevated concentrations of siderophile elements [4]. Despite this chemical evidence for chondritic input in howardite breccias, chondritic clasts have only been identified in a minority of samples, and typically at levels of only a few percent [2,5,6].

Three recent Antarctic howardite finds, the paired Mt. Pratt (PRA) 04401 and PRA 04402 and Scott Glacier (SCO) 06040, are notable for their high proportion of carbonaceous chondrite clasts. PRA 04401 is particularly well-endowed, with large chondritic clasts occupying more than half of the modal area of the sections we examined. Previously only a few percent chondritic clasts had been observed to occur in howardites. PRA 04401 is the most chondrite-rich howardite known.

Petrography: We examined thin and thick sections of PRA 04401 (,10 ,11 & ,12), PRA 04402 (,6 &,7), and SCO 06040 (,11) using optical and E-beam techniques to characterize their petrography. Chondrite clasts in all of the specimens we examined are composed mostly of a matrix of fine-grained opaque phyllosilicates intermixed with fine iron sulfide and iron nickel sulfide. Within this matrix are embedded 10-300 µm clumps of coarser mineralogy including high-mg# olivine and pyroxene, coarse pyrhotite, pentlandite, calcium carbonate and calcium sulfate. Most of these clasts appear to be texturally consistent with CM2 classification [3,7,8]. Relict chondrules are common and often contain high-mg# olivine with metal inclusions. Reaction or alteration textures are not apparent in the surrounding howardite matrix.

PRA 04401 is a very coarse clastic howardite breccia containing large angular carbonaceous chondrite clasts texturally resembling CM2 up to 7mm occupying nearly half of the sample area accompanied 1-5 mm subangular impact melt clasts containing relict eucritic fragments. The remaining medium and fine fraction of the specimen consists of mm-to-sub-mm angular-to-subrounded eucritic, diogenitic, carbonaceous chondrite clasts set in a medium-to-coarse angular matrix of same materials. The eucrite/diogenite ratio of identifiable clasts is approximately 50/50. The total modal abundance of visible carbonaceous chondrite fragments is ~60%.

PRA 04402 is a howardite breccia consisting of mm-to-sub-mm subrounded-to-subangular diogenite and eucritic clasts in roughly equal proportions set in a medium-to-coarse matrix. Millimeter to submillimeter carbonaceous chondrite clasts resembling CM2 occupy 3-5% of the sections. A few submillimeter impact melt clasts are also present. Although this meteorite is paired with PRA 04401, the two are not petrologically identical. This likely reflects heterogeneity on the cm-scale.

SCO 06040 is a coarse howardite breccia containing large rounded eucrite clasts up to 5 mm and many rounded carbonaceous chondrite clasts up to 2 mm set in a medium subangular matrix. Eucritic clasts are the most common component. The eucrite/diogenite ratio of identifiable clasts is approximately 80/20. Visible chondritic clasts occupy approximately 10% of this sample. The majority of large clasts resemble CM2 but a few smaller clasts appear to have experienced some degree of thermal metamorphism resulting in textural coarsening. Impact melt clasts and remobilized breccia clasts are also present.

Low EPMA totals: Phyllosilicates can contain both structural OH- as well as adsorbed water [9]. Consistently low totals from electron microprobe (EPMA) analyses of matrices of these clasts can give us some impression of the amount of water they contain. Grain size of matrix minerals is typically smaller than EPMA beam size so correction must be applied to account for host phase density effects [10]. Since the relative contributions of individual phases within each analysis would be impossible to determine, we used a simplified approach considering only two phases, serpentine and Fe-Ni-sulfide, assigning all S first to NiS and then FeS until exhausted. Carbonaceous chondrite clasts in the paired PRA 04401 and PRA 04402 are similar in composition and their matrices yield similar EPMA totals of 85-90 wt%. SCO 06040 contains several thermally metamorphosed clasts whose matrices yield totals up to 90-95 wt%. The contribution of water from Anarctic weathering is assumed minimal since surrounding howardite material appears unaltered, even the fine-grained material in the matrix.

Using EPMA estimates of the water content of chondritic matrices, a simple algebraic extrapolation can be used to estimate the bulk howardite water content by taking into account the modal proproportion matrix within chondritic clasts, the modal proportions of chondritic/diogenitic/eucritic material in the howardite, and the relative densities of all of the above [11]. From this we estimate PRA 04401, PRA 04402, and SCO 06040 to contain approximately 6 wt%, ½ wt%, and 1 wt% water, respectively. For comparison, the loss on ignition (LOI) determined from fusion of bulk samples of PRA 04401 and SCO 06040 were 7.4 wt% and ~0 wt% [12]. The LOI will include water and CO_2 derived from the phyllosilicates, carbonates, and sulfates. From bulk Ni content in these same data, we can estimate a chondritic contribution of ~35 wt% and ~5 wt% chondritic material for PRA 04401 and SCO 06040, respectively – in good agreement with our estimates of modal abundance in thin section once density contrasts are taken into account [11].

Trace element fingerprinting: We analyzed trace elements in two chondritic clasts in PRA 04401by laser ablation ICP-MS in an attempt to link them to one of the known carbonaceous chondrite groups. In order to obtain representative analyses, we performed linescans 1-3 mm in length across the clasts. We performed the same analyses on the chondrites Mighei (CM) and Renazzo (CR).These preliminary data seem to comfirm that at least some of the carbonaceous chondrite clasts are chemically indistinguishable from CM, but distinct from CR showing lesser enrichment in refractory elements relative to moderately volatile elements.

Conclusions: Recent chondrite-rich Antarctic howardite finds further document the contribution of CM chondrite impactors to the HED parent surface, and indicate that local concentrations of hydrous material may exist on the nominally anhydrous HED parent. The coarse size, angular shapes, and pristine chondritic textures suggest that these clasts are latecomers to the breccia assemblage relative to coexisting diogenitic and eucritic clasts, many of which are rounded. These textures also suggest that this CM material was delivered by relatively low velocity impact(s). Since these materials are exogenic, they are likely to be concentrated in near-surface lithologies and therefore potentially observable by remote sensing techniques or perhaps likely to be plucked from the surface by robotic sampling missions.

References: [1] Mittlefehldt et al., 1998. Planetary Materials, RiM 36, Ch. 4. [2] Zolensky et al.,1996. MAPS 31:518-537. [3] Zolensky et al., 1993. GCA 57:3123-3148. [4] Warren et al., 2009. GCA 73:5918-5943. [5] Gounelle et al., 2003. GCA 67:507-527. [6] Lorenz et al., 2002. LPSC Abs#1570. [7] McCoy & Reynolds, 2007. Ant. Met. News. [8] Scott & Krott, 2004. In Vol. 1 Treatise on Geochemistry, Elsevier Pergamon, Oxford, pp143-200. [9] Beck et al., 2010. GCA 74:4881-4892. [10] Warren (1997) LPSC XXVIII, Abstract # 1406. [11] Britt & Consolmagno, 2003. MAPS 38(8):1161-1180. [12] Mittlefehldt et al., 2010. LPSC Abs#2655.

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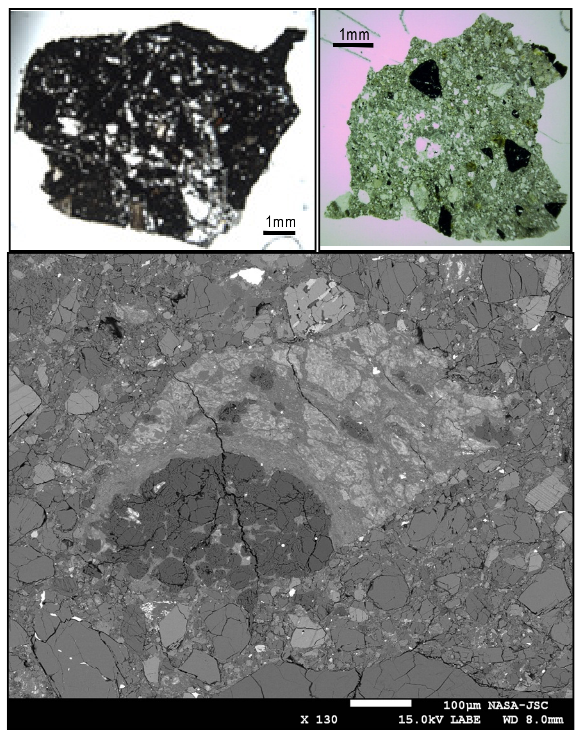

Top: Transmitted light images of PRA 04401 (left) and SCO 06040 (right). Chondritic clasts appear dark. **Bottom:** Backscattered electron image of chondritic clast in PRA 04402 surrounded by howardite matrix. Clast appears to contain a broken chondrule consisting mainly of forsteritic olivine with minor metal surrounded by a predominantly phyllosilicate matrix. Variation in brightness of matrix is due primarily to variation in density of fine-grained sulfides.