UNUSUAL TINY OBJECTS IN YOUR HED.

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Introduction: Thirty years ago we studied carbonaceous chondrite clasts in HED meteorites [1]. At that time our major conclusion was that the bulk of these lithologies, both in size and total volume, consisted of CM2 material which had been thermally metamorphosed to varying degree during impact onto the HED parent asteroid, widely held to be Vesta. However, some of the smaller clasts of C chondrite material in these same HEDs proved to be more enigmatic. These largely consisted of phyllosilicates but with varying amounts of loose crystals and aggregates olivine and low-Ca pyroxene, lacked chondrules or CAI, and contained significant quantities of magnetite – often framboids and spherulites. We suggested that these lithologies were most similar to the matrix of CR chondrites and CI chondrites, but we could form no firm conclusion as to their true nature. Gounelle et al. [2] even suggested a possible connection to chondritic micrometeorites. In light of our recent discoveries of vaguely similar lithologies in ordinary chondrites [3,4] and ureilites [5], and the march of analytical techniques to finer scales, we have begun to reexamine these HEDs.

Techniques: The samples were imaged and analyzed using a JEOL 7600-FE scanning electron microscope, and JEOL 8530-FE electron microprobe at the E-beam laboratory of the Astromaterials Research and Exploration Science (ARES) section of JSC. Between abstract and meeting time we plan to perform some electron back-scattered diffraction analyses.

Results: Thus far we have reexamined the small, phyllosilicate and magnetite-bearing lithologies in the Jodzie and Y-793497 howardites. Each meteorite contains numerous tiny target clasts, with different mineralogies. Thus our first main result is that these objects are not all the same lithology.

Y-793497: We have examined six tiny (<1mm) clasts in a single section of Y-793497. Three of the clasts are obviously CM2 material. Clasts 3 and 6 are predominantly phyllosilicate with scattered olivine (Fo_{90-72}), high and low-Ca pyroxene ($En_{71}Wo_{1}$ – a single analysis) and magnetite crystals (placquettes and framboids). Fe-Ni sulfides are only present as micron-sized and smaller crystals embedded in phyllosilicates. EPMA analyses of the matrix phyllosilicates indicate compositions nearer to being pure saponite than seen in any other chondritic material we have examined (i.e. CI, CR, CM), save Kaidun. Thus far we have not observed carbonates in these two clasts.

Jodzie: We examined 18 sub-mm clasts in two sections of Jodzie. 14 of these are CM lithologies, heated to varying degree (based on EPMA totals and phyllosilicate textures). Clasts 4 and 12 consist of a phyllosilicate matrix with scattered crystals and aggregates of forsterite (Fo_{100-99}), low-Ca pyroxene ($En_{69}Wo_{3}$ – a single analysis), Ca carbonate, coarse- to fine-grained pyrrhotite and pentlandite, and magnetite (plaquettes, framboids and euhedral crystals). The matrix phyllosilicates are a mixture of saponite and serpentine-type phases with a bulk composition most similar to those observed in CI chondrites. Clasts III-4 and III-5 are very strange. We only have space to describe III-4 briefly here. This lithology consists mainly of matrix-supported, flattened olivine crystals and aggregates (Fo_{98-45}), low-Ca pyroxene (En_{99-37} Wo_{1-5}), and Fe-Ni sulfides. These define a foliation. Sulfides have textures indicating flash heating. The matrix is almost entirely fine-grained, equidimensional crystals of Fe-rich olivine and pyroxene (Fo and En 70s to 40s) – these textures do not resemble heated phyllosilicates we have previously encountered. There are two "veins" of heated phyllosilicates (high EPMA totals) and possible tochilinite. This clast could be a shock-heated CM2, with a texture we have not previously observed.

Preliminary conclusion: With the exception of the obvious CM chips, these tiny objects are not pieces of CR or CI chondrites, but rather appear to be mineralogically distinct.

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References: [1] Zolensky et al. (1996) Meteoritics and Planetary Science **31**, 518-537; [2] Gounelle et al. (2003) Geochimica et Cosmochimica Acta **67**:507–527; [3] Chan et al. (2018) *Science Advances* **4**, eaao3521; [4] Kebukawa et al. (2019) *Nature Scientific Reports* **9**, article number: 3169; [5] Goodrich et al. (2019) *50th Lunar and Planetary Science Conference Abstracts*.