Survey of primordial and altered carbonaceous chondrite clasts in Howardites

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A large variety of foreign clasts were found in HED meteorites and yet the most common type of exotic clasts in HEDs are CM-like chondritic material [5] that contains, on average, 10 wt.% water and complex organics. Such observations confirms that a large flux of CM chondrite material impacted small differentiated rocky bodies, e.g., Vesta, at sufficiently low speed (<1000 m/s or even slower than 300 m/s) [1-4], without major heating or total disintegration. Those existing clasts indicate that the chondritic material had been gently incorporated into the regolith before the lithification of the rocks and later could have delivered volatile gases to the HED parent body. Indeed, the presence of H_2O fluid mineral interactions with regolith has been proposed [6-8], and the volatile source of these fluids is suggested to be CM chondrite clasts. However, significantly heated CM chondrite clasts or other altered chondritic materials are absent from howardites, so the interpretation that secondary phases represent textual evidence of water-bearing fluids is still controversial. In order to better understand the contribution of such volatile rock interactions, we have investigated textures and compositions of the carbonaceous chondrite clasts found in howardites. We also investigated Raman spectra to determine the thermal history recorded within organics.

We investigated 20 howardites: A-881170, ALH 78006, Y 000426, Y 000428, Y 000523, Y 000527, Y 000528, Y 000577, Y 000596, Y 000605, Y 000705, Y 000706, Y 001380, Y 002797, Y 002895, Y 003125, Y 791192, Y 793173, Y-984079, and NWA 6695. And, carbonaceous chondrite clasts are located in 13 out of the 20 howardites' thin sections/thick sections. A total of 28 clasts were investigated by Raman spectroscopy. We obtained Raman spectra of selected spots on the matrix in the clasts. Several carbonaceous chondrites (Allende, ALH 77307, Y 980115, and Y 82162) as references and artificially heated Murchison samples (600°C and 900°C) were analyzed under the same settings used for the CC clasts in order to estimate the peak temperatures. The peak position and full-width, half-maximum (FWHM) of the D1- and GL-bands were determined.

The carbonaceous chondrite clasts often have sharp boundaries with the host rock. The clasts we examined exhibit original carbonaceous chondritic texture and obvious secondary thermal metamorphism features such as reaction rims (c.f. PV3 clast in Plainview (1917) H5) are absent from the clasts in a few tens of micrometer level.

On the D-band position versus FWHM diagram, most Raman data of the clasts fell between the heated-Murchison standards, indicating that the clasts experienced temperatures from 600℃ to 900℃. However, a few clasts appear to have been much more highly heated as they have D-band spectra similar to those of Allende matrix. These heated carbon features suggests that secondary metamorphism may have occurred on the HED parent body after incorporating CC clasts. If so, the surrounding minerals may have experienced chemical exchange with the gas produced by the heated carbonaceous chondrite clasts. Nevertheless, the secondary features were absent at the level of the SEM observation.

We investigated an impact melt clast as an example of extremely heated conditions on the HED parent body. We confirmed carbon peaks, which G-band or D-band shapes are distinct from organics in carbonaceous chondrite materials, within the impact melt clast. In the impact melt clast, we also confirmed relict chondritic olivine phenocryst (Fe/Mn values from 38 to 45; Mg# from 84.7 to 87.3). The carbon peaks are likely inorganic carbon that was initially organic prior to the impacting of the chondritic material.

Through the observations, we did not confirm direct petrological evidence that depicts the source of volatile fluids, such as reaction rims around the clasts. However, we located carbonaceous chondrite materials that experienced a range of thermal histories within howardite meteorites and the likely remnants chondritic carbon. Our results are inconsistent with previously reported carbonaceous chondrite clasts in Howardites (from 50℃ to 70℃ [9]). In fact, primordial clasts are much more easily found when using the optical microscope than thermally metamorphosed clasts. It would be very challenging to locate them once they were melted. Thus, it might lead to the apparent high occurrences of primordial chondritic materials. Because of observational biases, one should expect thermally altered clasts at a relatively higher frequency than we previously thought in the howardites and similar rocks such as polymict eucrites.

References

[1] Warren, Personal Communication. [2] Vedder 1998 Icarus 131 283-290. [3] Vedder 1996 Icarus 123(2), 436-449. [4] Bottke et al. 2005 Icarus 179(1), 63-94. [5] Zolensky et al. 1996 MAPS 3 1(4), 518-537. [6] Barrat et al. 2011 GCA 75(13), 3839-3852. [7] Warren et al. 2017 MAPS. [8] Shisseh et al. 2023 GCA 340, 51-64. [9] Visser et al. 2018 GCA 241, 38-55.