LOW-TEMPERATURE HEAT CAPACITY AND THERMAL CYCLING OF CI SIMULANT MATERIAL

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Introduction: Due to their rarity and friability, whole-stone CI carbonaceous chondrites are generally not available for study of physical properties. Our extensive database of over 1700 meteorite densities and porosities contains just two CI specimens, one of Orgueil (Vatican #718) and the other of Ivuna (Southwest Meteorite Laboratory #95.1), measured by 3D laser scanning and ideal-gas pycnometry. If the measurement techniques involve placement in liquid nitrogen, the options become even more restrictive. As such, the use of simulated CI chondrite material with similar composition and structure to the original meteorites becomes the best available substitute. In this study, we subjected a 36-gm specimen of CI simulant material manufactured by Dan Britt and the University of Central Florida to heat capacity (C_p) measurement by the technique of liquid nitrogen immersion.

In addition, it has been proposed that diurnal thermal cycling of asteroids may be a cause of surface-layer disintegration and pulverization [cf. 1]. The thermal stresses of the diurnal cycle are reproduced to some degree in our experiment, but we have not observed any appreciable weathering of this sort in our work with ordinary chondrites. The CI simulant, being about as friable as most CI specimens, ought to be particularly vulnerable to this process. By comparing the volume of the specimen after measurement with its starting volume, we attempted to estimate an upper limit for the rate of disintegration by this process.

Measurement Technique: Before commencing the work, we measured volume, density, and porosity using non-destructive, non-contaminating techniques. Bulk volume and density were determined using a NextEngine model 2020i 3d laser scanner. Grain volume and density were measured by ideal gas pycnometry using a Quantachrome 1200e Ultrapycnometer [cf. 2]. Heat capacity was measured via the technique of liquid nitrogen (LN2) immersion, in which heat capacity is determined by the mass of liquid nitrogen vaporized as the meteorite cools from room temperature to 77 K [3]. C_p is a strong function of temperature over this range, but the results corresponds well to Cp at 175 K. We conducted four drops of the specimen into a thermos of LN2 resting on a scale, which recorded the mass at 10 sec intervals. Between each drop, we allowed all LN2 to vaporize and the specimen to return to room temperature before repeating the experiment. After heat capacity measurements were completed, we remeasured bulk volume and mass using the laser scanning technique.

Results: The simulant has a bulk density of 1.80 ± 0.01 g cm^{-3}, a grain density of 2.74 ± 0.01 g cm^{-3}, and a porosity of (34.3 ± 0.4)%. This compares well to the bulk densities of Ivuna (1.95 ± 0.01 g cm^{-3}) and Orgueil (1.61 ± 0.01 g cm^{-3}), and has a slightly higher grain density than the two CI meteorites (Ivuna: 2.55 ± 0.02 g cm^{-3}; Orgueil: 2.44 ± 0.01 g cm^{-3}), and a comparable porosity (Ivuna 23.7% ± 0.7%; Orgueil 33.8 % ± 0.5%).

The simulant's heat capacity at 175 K is 629.0 ± 1.1 J kg^{-1} K^{-1}. We have no other CI data with which to compare it, but it is substantially higher than what we measure for other carbonaceous chondrites (2 CO, 1 CR, and 2 CV), which range from 502-535 J kg^{-1} K^{-1} [3]. The very low grain density of CI chondrites compared to other carbonaceous chondrites may contribute to its higher C_p due to a lower wt% metal. However, a significant additional factor may be the adsorption of atmospheric water, the C_p of which is nearly an order of magnitude higher than that of most chondrites.

We attempted to determine an upper limit of thermal weathering based on the volume lost during the four thermal cycles to which we subjected the specimen. (Mass is unreliable due to how easily the specimen adsorbs moisture from the air.) The measured volumes were within uncertainties of each other. If we assume the actual volumes were at their extremes, this would mean a maximum volume loss over the four cycles of 0.009 cm^3 (0.015 gm). Averaged over the surface area of the specimen (measured from the laser scan data) this means a maximum loss of 4.7 x 10^{-5} cm per diurnal cycle. In order for an asteroid of this composition and structure to pulverize a surface layer to a depth of 1 mm, we estimate a lower limit of 2100 diurnal cycles are required. A further, more extensive study is planned.

References: [1] Molar J. L. et al. 2015. *J. of Geophys. Res. Planets* 120: 255-277. [2] Macke R. J. 2010. *Survey of Meteorite Physical Properties: Density, Porosity and Magnetic Susceptibility*. Ph.D. Thesis, University of Central Florida. [3] Consolmagno G. J. et al. (2013) *Planet. & Space Sci.* 87: 146-156.