CHEMICAL AND MINERALOGICAL SIZE SEGREGATION IN THE IMPACT DISRUPTION OF ANHYDROUS STONE METEORITES. G. J. Flynn[1] and D. D. Durda[2], [1]Dept. of Physics, SUNY-Plattsburgh, 101 Broad St., Plattsburgh, NY 12901 (george.flynn@plattsburgh.edu), [2]Southwest Research Institute, 1050 Walnut St., Suite 426, Boulder, CO, 80302.

Introduction: Interplanetary dust particles (IDPs), which are ~5 to 35 m in size, are enriched in carbon and the moderately volatile elements by factors of 2 to 4 over the CI meteorites [1], while the slightly larger polar micrometeorites, ~50 m to millimeters in size, have significant depletions in Ni and several moderately volatile elements (e.g., S and Se) [2]. To test the idea that this chemical difference might result from the response of an inhomogeneous target, consisting of strong olivine chondrules in a weak, porous matrix, to impact cratering or disruption, we performed impact experiments on seven different chondritic meteorites.

Methods and Samples: The first three meteorites were weathered finds from North Africa -- NWA791, an L6 ordinary chondrite (OC), NWA620, an unclassified OC, and MOR001, an unclassified OC. Because of the potential that terrestrial weathering altered the fragmentation properties of these finds, we then performed disruption experiments on three samples of Mbale (an L5/6 OC), two samples of Gao (an H5 OC), one sample of Saratov (an unusually friable L4 OC), and one sample of Allende (a CV3 carbonaceous chondrite). The mean impact speed for asteroids in the main belt is ~5 km/sec, so we focused on shots with impact speeds in the 4 to 6 km/sec range, firing 1/8- or 1/4-inch Al projectiles at each meteorite using the NASA Ames Vertical Gun Range (AVGR).

To avoid measuring the secondary effects of fragmentation caused by material hitting the walls of the AVGR chamber, we deployed four "passive detector arrays," containing foils to determine the size-frequency distribution, and aerogel capture cells to collect the primary debris fragments. Two passive detector arrays were placed in front of the target, at angles from 30 to 50 degrees off the incoming path of the impactor, positions that were selected to increase the probability of intercepting the debris cone that contains the highest flux of fragments from the impact. Two passive detector arrays were placed behind the target, to compare the debris in these low flux regions to that in the debris cone. Each aerogel capture cell was ~2 to 3 cm thick, allowing us to capture particles up to ~200 m in size. Larger particles completely traverse the aerogel, exiting through the back surface.

The average Ni-concentration of the matrix is significantly higher than the average Ni-concentration of the chondrules for both carbonaceous and ordinary chondrites, while both the matrix and the chondrules have roughly comparable Fe-concentrations. The composition of the chondrules is generally relatively uniform. However, at the 10 m size scale the matrix is inhomogeneous, consisting of individual mineral grains of widely varying compositions, including some olivine grains similar in composition to that of the olivine chondrules. The Ni/Fe ratio of the smallest fragments of matrix varies widely, but it exhibits a mean Ni/Fe value that is significantly greater than the Ni/Fe ratio of the chondrule material. Thus, the distribution of Ni/Fe ratios can be used to identify low-Ni chondrule material and distinguish it from matrix.

Using techniques developed to perform in-situ analysis of particles in aerogel [3], we employed the X-Ray Microprobe on Beamline X26A of the National Synchrotron Light Source at Brookhaven National Laboratory to measure the chemical composition (particularly the Ni/Fe) of the meteorite fragments captured in an aerogel cell from each AVGR shot.

Results: There was a significant change in the average chemical composition of the fragments from the catastrophic disruption of the anhydrous, chondritic meteorites that correlates with the size of the fragments. Figure 1 shows the fraction of particles in each size bin (0 to 10 m, 10 to 20 m, 20 to 30 m, 30 to 40 m, 40 to 50 m, 50 to 100 m, and 100 to 200 m) having Ni/Fe >0.05 (roughly the CI value), with the larger bins required at the larger sizes because of the smaller number of large particles collected.

The small particles (~5 to 35 m in size) are dominated by Ni-rich material while the intermediate size particles (~35 to >150 m) are dominated by Ni-poor material relative to the bulk Ni/Fe (~0.05). Only those fragments that were large compared to the size of the chondrules (which are millimeters in size) were representative of the bulk composition of the target.

Figure 1 shows that simply averaging the chemical composition of many of the ~10 m primary fragments from the disruption of an imhomogeneous, anhydrous meteorite does not reproduce the bulk composition of the target meteorite because these small particles are dominated by Ni- and volatile-rich matrix material. This is true even in the case of Saratov, which, in bulk, contains very little matrix. Similarly, simply averaging the chemical composition of many 50 to 200 m fragments from the disruption of an imhomogeneous, anhydrous meteorite does not reproduce the bulk composition of the target meteorite because these intermediate size particles are dominated by Ni- and volatile-poor chondrule material.

There appear to be small differences in the transition size from high Ni/Fe particles to low Ni/Fe particles

from one meteorite to the next (see Figure 1). Saratov produced high Ni/Fe particles only <10 m in size, while the other two unweathered OCs, Mbale and Gao, produced an abundance of high Ni/Fe particles up to ~25 m in size, and the fragments from Allende were dominated by high Ni/Fe particles up to ~40 m in size. This result may reflect the amount and size of the matrix in each meteorite. Saratov contains very little matrix material, while Mbale and Gao contain more matrix, and, of the meteorites included in this study, Allende contains the largest amount of matrix material.

There is a clear difference in strength between MOR001, a compact, strong rock, and Saratov, which is so friable that pieces come off when the sample is picked up. When these two ~105 gm meteorites were each struck by projectiles having approximately the same kinetic energy the largest fragment from the Saratov disruption was ~11.6 grams, while the largest fragment from MOR001 was only ~4.96 grams. Thus, it requires significantly more energy to produce the same degree of disruption of the more porous meteorite target, consistent with earlier results by Love et al. [4].

Immediately following a disruption event the smallest particles are transported towards 1 AU under the influence of Poynting-Robertson radiation drag. The larger particles may either be broken up by subsequent collisions or transported to 1 AU on a much longer time scale. In either case, the initial flux of ~10 m particles reaching the Earth would be dominated by volatile-rich matrix material from the disruption, while a later flux of Ni- and volatile-poor particles, some in the larger size range (~35 to >200 m in size) and other smaller collisional debris from these larger particles would be expected. This result could explain the differences in chemical composition between IDPs and polar micrometeorites. If the parent body of the IDPs and of the polar micrometeorites is homogeneous, then both the IDPs and the polar micrometeorites should sample that bulk composition. However, if that parent body is an inhomogeneous object at a size-scale >>10 m, like the chondritic meteorites, then our results indicate that the ~10 m IDPs are likely to oversample the volatile-rich matrix material while the larger polar micrometeorites are likely to oversample the Ni- and volatile-poor chondrule material. However, we note that no known chondritic meteorite has a matrix sufficiently carbon- and volatile-rich to match the chemical composition of the anhydrous IDPs, so these primitive, porous IDPs must sample a parent body not represented by any known meteorite.

These results have important implications for the collection and return of samples from extraterrestrial bodies. The simplicity of the Stardust spacecraft, designed to return dust particles from Comet Wild-2 by flying aerogel capture cells through the dust coma, has resulted in ideas to employ a similar design to sample asteroids. A high velocity projectile would be shot into the asteroid and a Stardust-like spacecraft would fly through the resulting debris cloud capturing ~10 m debris in aerogel. Zolensky et al. [5] and references therein suggest that with modern analytical techniques even nanogram samples (~10 m particles) of extraterrestrial bodies might be sufficient to characterize the chemical composition and mineralogy of the object. Implicit in this suggestion is the assumption that cratering or collisional disruption produces a suite of nanogram fragments of the parent that, if added together, reflect the bulk chemical and mineralogical composition of the parent. However, our results indicate that if the asteroid is inhomogeneous, it must be sampled at a size-scale significantly larger than the largest subunit to provide a representative bulk chemical and mineralogical characterization. Simply averaging the composition of tens or even hundreds of ~10 m debris fragments from the hypervelocity disruption of an asteroid similar in structure to a chondritic meteorite would provide an incorrect assessment of the chemistry and the mineralogy of the parent body, since the nanogram samples would be dominated by the matrix material, which may be only one component of an inhomogeneous parent body.

References: [1] Flynn, G.J. et al., (1996) in *Physics, chemistry, & dynamics of interplanetary dust,* Astron. Soc. of the Pacific Conf. Series, **104**, San Francisco, 291-294. [2] Flynn, G. J et al. (1993) *17th Symp. on Antarctic Meteorites,* Nat. Inst. of Polar Research, Tokyo, 304-311. [3] Flynn, G. J. et al (1996) *Lunar & Planet. Sci*., **27,** 369-370. [4] Love, S. G. et al. (1993) *Icarus*, **105**, 216-224. [5] Zolensky, M. E. et al. (2000) *Meteoritics & Planet. Sci.*, **35**, 9-29.

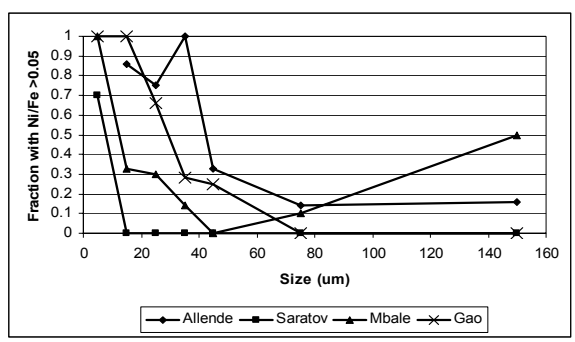

Figure 1: Fraction of particles with Ni/Fe >0.05 vs. size on particles in aerogel capture cells from the Allende, Saratov, Mbale, and Gao disruptions.