EXAMINATION OF SIZES AND SHAPES OF CLASTS IN THE IVUNA CI CHONDRITE. E. M. Riveros[1], J. M. Friedrich[1,2], and D. S. Ebel[2], [1]Department of Chemistry, Fordham University, Bronx, NY 10458, [2]Department of Earth and Planetary Sciences, American Museum of Natural History, New York, NY 10024.

Introduction: The study of meteoritic breccias can yield information on the collisional evolution of planetary bodies [e.g. 1]. Comparisons between chondritic breccias and returned asteroidal samples can help to understand the geologic context of both types of samples. Most chondritic breccias have likely experienced several generations of impact-related cataclasis and lithification. Regolith breccias, which contain solar-wind-implanted noble gases, represent samples from the surfaces of their parent asteroids [2]. In addition to being regolith breccias, CI chondrites represent material that is chemically among the most primitive materials in the solar system [3-5]. CI chondrites also seem to represent material that is akin to samples retrieved by the Hayabusa 2 robotic explorer [6,7] and similarities certainly exist between carbonaceous chondrite regolith breccias and the samples collected by the OSIRIS-Rex mission [8]. In this work, we quantify the three-dimensional (3D) sizes and shapes of clasts within Ivuna to compare with similar data from other breccias, impact breccias, and asteroidal surfaces. These analyses will provide insight into Ivuna's formation and asteroidal context.

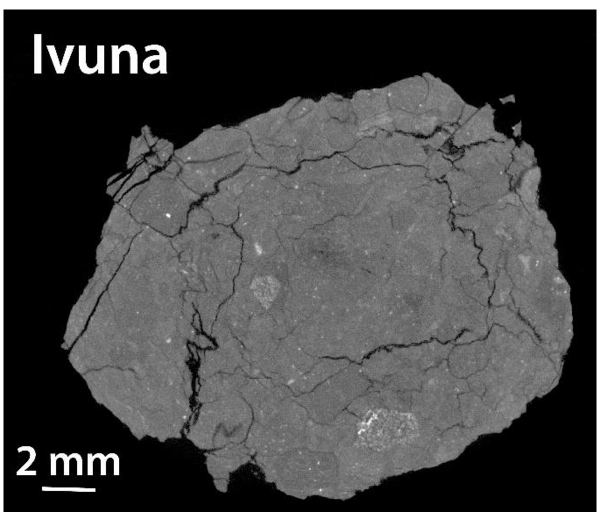

Figure 1. A μCT "slice" of a central portion of the ~3 cm^3 chunk of the Ivuna CI chondrite investigated in this work. Clasts of variable composition can be distinguished from each other and the surrounding material. The air around and the cracks within the sample are represented by the darkest greyscale values while silicates are depicted by lighter greyscale values.

Methods: We used x-ray computed microtomography (μCT) to image a ~3 cm^3 chip of the Ivuna chondrite from the American Museum of Natural History collection (AMNH sample 3963). The scan was performed at the AMNH's Microscopy and Imaging Facility using a 0.2 mm Cu filter, operating at 160 kV and 110 μA. This created a 3D representation of the interior. We then used ImageJ and the TrakEM2 program [9] within it to visually identified and isolate the clasts within the sample, following the methods used in [10].

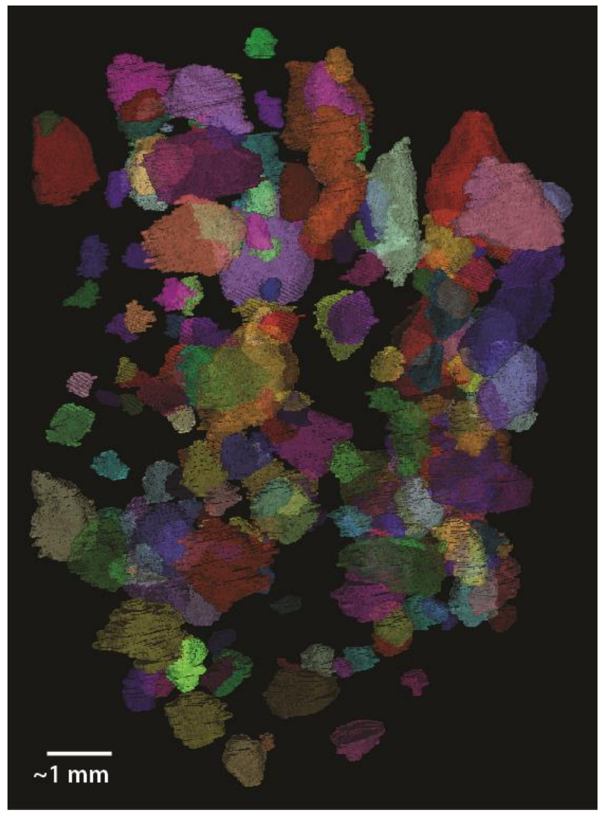

Figure 2. A representation of digitally isolated clasts within the ~ 1 cm diameter Ivuna chunk shown in Figure 1.

Figure 2 shows the resulting data following our digital isolation of identifiable clasts of the Ivuna sample. Once all recognizable clasts were isolated, the data was exported to Blob3D [11]. This software was used to extract quantitative measurements such as clast volume, surface area, and axial dimensions to analyze size and shape trends.

Results: We isolated and measured a total of 213 individual clasts within the ~1 cm diameter roughly spherical sample (Figure 1).

Clast Size. We show clast size in terms of sphere equivalent diameter calculated from the measured clast volumes. Figure 3 shows the clast size distribution. The clasts in our ~3 cm^3 Ivuna sample range in diameter from 0.36-5.07 mm, with most diameters resting between 1.0-2.5 mm.

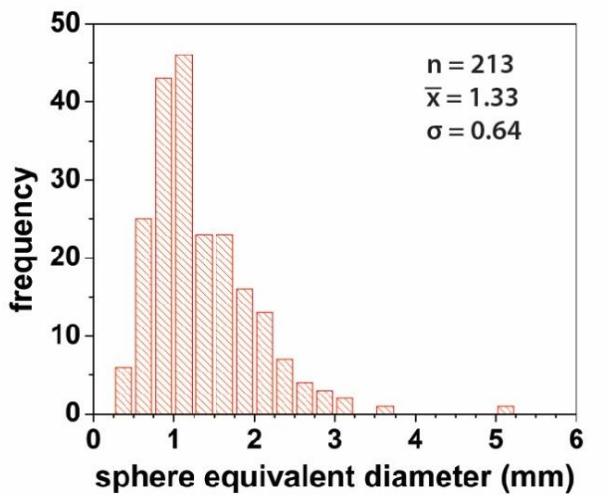

Figure 3. Histogram of the clast size frequency distribution in the Ivuna CI chondrite. Sphere equivalent diameters are calculated from individual clast volumes.

Clast Shape. Using a Zingg diagram [12] and the descriptors of [13] we find that a majority (90.6%) of the clasts are equant to sub-equant in shape, meaning that they are roughly spherical in shape.

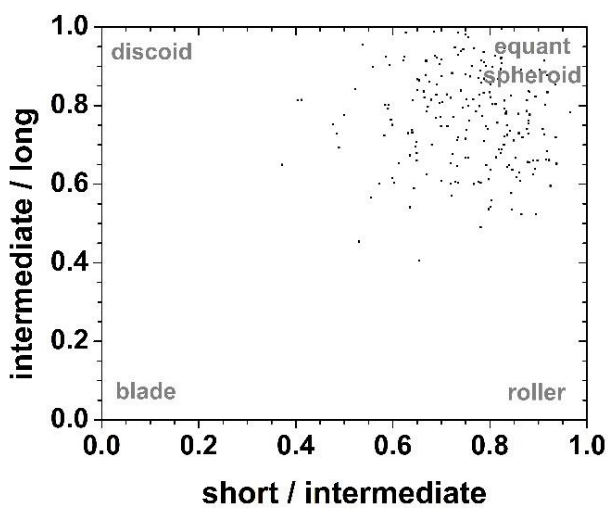

Figure 4. Zingg diagram [12] using axial ratios to examine clast shapes [13] in the Ivuna chondrite.

Discussion: Our clast size distribution (Figure 3) and shape (Figure 4) results are limited based on the size of our ~1 cm diameter sample. Clasts larger than our sample will not be recognized as such and we found no readily recognizable clasts below ~0.36 cm in diameter. These may exist, but we're unable to distinguish them from the surrounding material.

Although not shown, we found no correlation between clast size and shape as supported by the lack of a significant dependent relationship between size and circularity or sphericity.

Few data exist for the direct comparison of our data with asteroidal surface particles. Shapes of particles from the Itokawa asteroid returned by the Hayabusa mission in the ~10-100 µm size range were described by Tsuchiyama et al. [14]. These particles are similar to LL chondrites in composition [see 14 and references therein]; however, the mechanical properties of LL chondrite and CI chondrite materials are certainly different. The differing material properties would yield differing fracturing or impact-related cataclasis properties. Nevertheless, we can compare our shape results with Itokawa particle shapes. Data from Tsuchiyama et al. [14] show that the mean intermediate/long axial ratios were 0.72 and the short/long axial ratios were 0.44 for the Itokawa particles studied. Our respective axial ratio results for the Ivuna clasts in this work are 0.82 and 0.64. Additional analysis and comparisons will be performed.

We will use our data to compare with asteroids and other meteorites to study the relationship between different parent bodies, clast compositions, and clast sizes. Our digitally isolated clasts will also aid in developing machine learning to complete clast identification work in the future.

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