SEDIMENTOLOGICAL AND PETROGRAPHIC ANALYSIS OF DRILL CORE FC77-1 FROM THE FLANK OF THE CENTRAL UPLIFT, FLYNN CREEK IMPACT STRUCTURE, TENNESSEE.

D. R. Adrian[1], D. T. King Jr.[1], S. J. Jaret[2], J. Ormö[3], L. W. Petruny[1], J. J. Hagerty[4], and T. A. Gaither[4], [1]Department of Geosciences, Auburn University, Auburn, Alabama 36849. [dra0006@auburn.edu]; [2]Department of Geosciences, Stony Brook University, Stony Brook, New York 11794; [3]Centro de Astrobiología (INTA-CSIC), Madrid, Spain; [4]USGS, Astrogeology Science Center, Flagstaff, Arizona 86001

Introduction: The Flynn Creek impact structure, located in Jackson County, Tennessee (36° 17' N; 85° 40' W), is a ~ 3.8 km diameter, marine-target impact crater which has an asymmetric outline, central uplift, breccia moat, and terraced crater rim (Fig. 1) [1-4]. The target stratigraphic section was essentially flat-lying Ordovician carbonates, ranging from Lower Ordovician Knox Group through Upper Ordovician Catheys-Leipers Formation [1, 2, 4, 5]. In a subsequent, post-impact phase, Upper Devonian Chattanooga Shale was deposited within the impact structure and across the area on what was then a shallow marine shelf [1-5].

The present research examines the upper 175 m of the drill core FC77-1, which was drilled in 1977 to a total depth of 725 m into the flank of the central peak of Flynn Creek impact structure (Fig. 1). Drill core FC77-1 is part of the Flynn Creek drill core collection at the U.S. Geological Survey Astrogeology Science Center in Flagstaff, Arizona [5, 6]. We think that the upper 175 m of this well represents the interval above the top of underlying broken and uplifted target formations (Stones River and Knox Groups) and below the present erosional surface of the central uplift. Thus, this interval encompasses the extant impact breccia lying upon the flank of the central uplift area of the impact structure. The overall objective of this study was to determine what the characteristics of these impact-derived sediments could tell us about impact processes in general at Flynn Creek and around the central uplift's flank in particular.

Methods: *Sedimentological (Grain-size) Analysis.* Data regarding the clast sizes of various constituent lithologies in the central uplift breccias were collected in drill core FC77-1 from depths of 0 to 175 m by using the line-logging method described by [7, 8]. Clast size is first recorded in millimeters and then converted to phi (Φ) values following the formula: $\Phi = -\log_2(d)$, where d is the grain diameter in millimeters [9]. Positive phi values (i.e., $-1*\Phi$) are used for convenience as well as to stay consistent with comparable data presented by [7, 8, 10]. Therefore, as our positive phi values increase, the grain size is greater. Other than analyzing the mean $-\Phi$ value per box (φ) instead of per meter, our analysis technique was the same as [7, 8].

Petrographic (Thin-section) Analysis. A total of 103 standard thin sections that span the interval of 0 to 175 m depth were made to examine the nature of the breccia matrix and breccia constituent clast types. Thin sections were examined using standard petrographic techniques and a description was made of the petrology of each thin section. Volume percentages of components were estimated using grain-density visual comparison charts and constituent minerals were identified petrographically, and in some instances supplemented by micro-FTIR and micro-Raman spectroscopy.

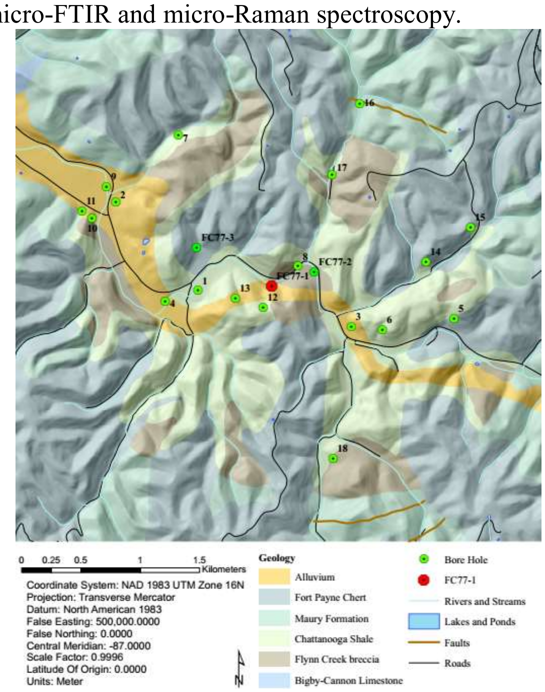

Figure 1. Geologic map of Flynn Creek impact structure. Colors show the main stratigraphic units. The outcrops of Catheys-Leipers Formation in the crater-rim and Stones River and Knox Groups in the central peak are too small to show at this scale. Modified from the Flynn Creek map on the U.S. Geological Survey Mineral Resources On-Line Spatial Database (mrdata.usgs.gov).

Results: *Sedimentological Analysis.* The plot of the vertical distribution of mean $-\Phi$ values per box (φ) and standard deviations (σ_φ) per box versus depth revealed that there are three distinctive sedimentological units (numbered 1 through 3 in Fig. 2) within the 175 m-thick impact breccia unit in the FC77-1 drill core.

Sedimentological unit 1 displays an overall coarsening-upward sequence from 175 to approximately 109 m, approximately 4.7 φ to a terminal peak of approximately 8.7 φ, and standard deviation (i.e., size sorting σ_φ) values ranging from approximately 1.2 to 2.5. Out of the three units, unit 1 has the most limestone, although it is confined to the lower 20 m, and above that, dolomite prevails. Other clasts, such as chert and shale, occur throughout the unit. The top of unit 1 is coarser and more poorly sorted than the lower part of the unit.

Unit 2, which is found between 109 to 32 m, is a fining-upward sequence from approximately 8.7 φ to a terminally low of approximately 4.7 φ. It also displays σ_φ values (i.e., size sorting) ranging from approximately 2.5 to approximately 1.2. The value of 2.5 σ_φ at the top of the unit coincides with the grain-size low of approximately 4.7 φ. It is dominated by dolomite clasts, with a few “other” clasts (mainly shale) near the base of the unit. Chert is found throughout the unit. It is evident that the top of sedimentological unit 2 is more fine-grained and better sorted than the lower part of the unit.

Sedimentological unit 3 displays a truncated coarsening-upward sequence that peaks at approximately 8.4 φ near the top of the drill core. Standard deviation shifts between about 1.2 and 2.2. Unit 3 is dominated by dolomite clasts, but a few limestone clasts occur mainly in the upper few meters of the unit. The top of unit 3 is 0 meters in the FC77-1 drill core, which is an erosional surface at ground level, and its base is approximately at 32 m. Grain support increases over the span of unit 3.

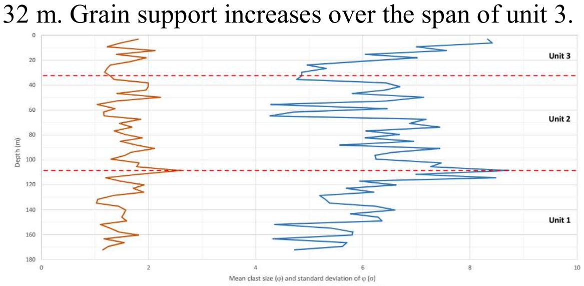

Figure 2. Mean clast size per box (φ) and standard deviation per box (σ_φ) versus depth. The interpreted boundaries between sedimentological units 1, 2, and 3 are indicated.

Petrographic Analysis. Overall, the Flynn Creek breccia in the upper 175 m of the FC77-1 drill core is a carbonate breccia composed mainly of fine to medium clasts, which consist mainly of grey dolomite clasts and a minor component of other kinds of clasts. These clasts occur within a grey to grey-brown matrix of fine-grained dolomite, limestone, chert, minor amounts of dark clay, and traces of opaque materials including some pyrite. The overall matrix content was about 25 percent for the entire 175 m interval studied. Based on megascopic core descriptions, the sizes of clasts in this breccia range from approximately 5 mm to 1.6 m, but most observed clasts are between 5 to 130 mm.

Cryptocrystalline melt clasts (Fig. 3), which have not been reported previously at Flynn Creek impact structure, include 1-5 cm, irregular to subrounded masses of extremely fine-grained quartz. In cross-polarized light, the melt clasts appear to be isotropic, except for a few fine- to medium-sized dolomite crystal inclusions. However, micro-FTIR and micro-Raman spectroscopic analysis reveals that the melt clasts are in fact made of crystalline quartz. Despite the clasts being nearly optically isotropic, micro-FTIR and micro-Raman spectroscopy indicate that the clast matrix is crystalline. The clast matrix exhibits strong infrared peaks at 1080 cm^{-1} and 1172 cm^{-1} consistent with SiO_2 phases. In effect, the crystal size is so minute in the cryptocrystalline melt that even though the optical behavior overall mimics glass, the crystal structure is intact at a very small scale. In plane light, cryptocrystalline melt clasts are clear, pinkish, greenish, or brown-ish and they contain wavy bands and unique inclusions. These characteristics contrast with chert present in the breccia matrix, which do not have the colors and crystallinity of the cryptocrystalline melt.

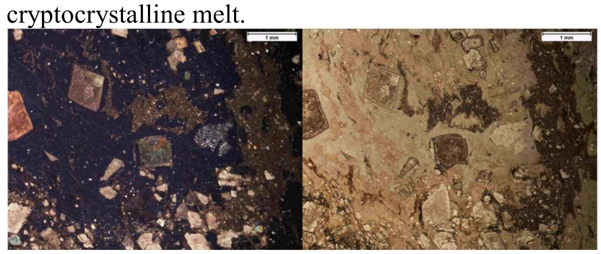

Figure 3. Photomicrograph of cryptocrystalline melt with flow features and dolomitic inclusions. Scale bar (1 mm) is given on each image. Cross-polarized view (left); plane light (right). Sample FC77-1-45-D.

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