ANALYSIS OF DRILL CORE FC77-1 FROM THE FLYNN CREEK IMPACT STRUCTURE, TENNESSEE USA. D.R. Adrian[1], D.T. King Jr.[1], J. Ormö[2], L.W. Petruny[1], J.J. Hagerty[3], T.A. Gaither[3], and S.J. Jaret[4], [1]Geosciences, Auburn University, Auburn, AL 36849-5305 USA. [dra0006@auburn.edu]; [2]Centro de Astrobiología (INTA-CSIC), Madrid, Spain; [3]USGS, Astrogeology Science Center, Flagstaff, AZ; [4]Department of Geosciences, Stony Brook University, Stony Brook, NY 11794

Introduction and Aims: According to Roddy [1-4], the Flynn Creek impact structure is a Late Devonian, 3.8-km diameter, complex, marine-target impact crater, which formed in an epicontinental shelf setting. The Flynn Creek impact structure, located in Jackson County, Tennessee (36° 17' N; 85° 40' W), is situated within the Eastern Highland Rim physiographic province. The crater has an asymmetric outline and displays a central uplift, breccia moat, and terraced crater rim [4-6]. The target stratigraphic section was essentially flat-lying, Upper Ordovician carbonates ranging from Knox Group through Catheys-Leipers Formation [4-6]. Almost all rim exposures consist of Catheys-Leipers Formation, whereas the central uplift exposures consist primarily of Knox and Stones River Groups [4-6]. In a subsequent, post-impact phase, Upper Devonian Chattanooga Shale was deposited in the crater and across the area on what was then a shallow marine shelf [4-7].

Soon after the crater formed, the ejecta blanket, terraced crater rim, moat breccias, and central uplift were substantially eroded, either prior to, or during transgression of the Chattanooga sea. This episode of erosion and transgression produced a distinctive local peneplain [4, 8] with a residuum unit on top that has been recognized for over 100 years [refs. in 8]. This peneplain, which was part of the sub-Kaskaskia regional unconformity U.S. midcontinental area, may have been covered by shallow marine water at the time of impact. However, our study so far indicates that evidence for this shallow marine setting is not as clearly evident as other workers [4, 5, 7] have suggested. An alternative hypothesis is that the impact occurred on this peneplain surface prior to marine transgression.

After Chattanooga Shale was deposited over the area including the crater, several hundreds of meters of other types of sediments were deposited in the area [4, 8]. Regional uplift along the Nashville Dome has promoted erosion in the Flynn Creek area and thus generated an extensive valley network that cuts into, and thus helps expose the terraced rim, breccia fill, and central peak [4, 8]. In addition to surface exposures, a USGS drilling program (1967-1979) extensively cored the Flynn Creek impact structure [6, 10].

For a better assessment of whether or not the Flynn Creek breccia drill cores support a marine impact, in this report, we make a direct comparison of breccia characteristics to craters such as Lockne and Tvären, Sweden [9].

Methods: To better understand the nature and origin of impact breccia at the central peak of Flynn Creek impact structure, drill core from well FC77-1 was described, logged, and analyzed. FC77-1 is well 12 on the map in Gaither et al. [6], which shows all the USGS drilling program sites. This is the first detailed look at this specific drill core since the 1970s (unpublished work by D.J. Roddy). FC77-1 is a continuous drill core that spans 0 to 725 m depth. It is housed at USGS-Flagstaff, and is part of the USGS Flynn Creek drill core collection [6, 10].

Detailed data were collected by observations made directly upon drill core FC77-1 with regard to clast sizes, shapes, and lithologies for depths between 0 and 175 m. We used the line-logging method described by Ormö et al. [9] for the Lockne and Tvären craters and by Ormö et al. [11] for the Chesapeake Bay impact structure. This method was chosen because it is a proven, non-destructive, fast, economic technique, and because it is well-suited for studying breccias in drill cores where the variables are size and composition of constituent clasts. The similar statistical treatment of data as used by [9, 11] also allows direct comparisons with the well-documented resurge breccia deposits of the aforementioned craters. See [9, 11] for more details of the line logging method.

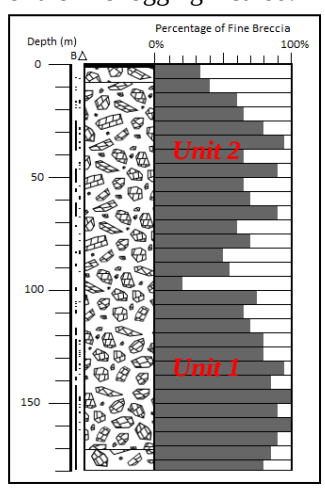

Fig. 1. Percentage of fine-grained breccia in the upper part of drill core FC77-1 (boxes 1-60; depth 0-175m).

Results: Preliminary findings from line logging of FC77-1 reveal a central peak breccia deposit consisting of two units (labeled 1 and 2 in Fig. 1), which can be distinguished by the % of fine-grained breccia. In addition, within units 1 and 2, there are two coarsening upward sequences in each unit (see Fig. 2). Below the drill-core section shown in Fig. 1 (i.e., depths of 175 to

725 m), there are deformed and uplifted basement strata comprising the central peak. We did not complete line logging on that part of the drill core.

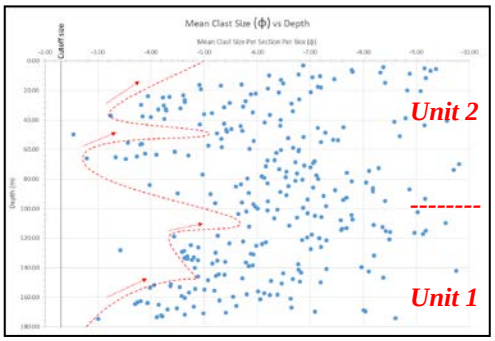

Fig. 2. Mean clast size (in phi, ø) versus depth in meters. Mean clast size (each blue dot) is computed here for each row (or 60-cm 'section') in each core box. Phi is the negative log to the base 2 of the grain size in mm. Therefore, size increases to the right. Red dotted line and related arrows mark main coarsening-upward trends within the data. Minimum measured size (or 'cut off size') is 5 mm. Units 1 and 2 are same as in Fig. 1.

Fig. 3 shows the distribution of clast size (and composition) with depth in the upper 175 m of core FC77-1. Our data show that dolostone is by far the most common type of clast in the Flynn Creek breccia units, which stands to reason considering that the main target layer was the Knox Group, a thick dolostone unit, and that the Upper Ordovician target units above the Knox are mainly dolostones as well. Chert, which is less abundant than dolostone but widely distributed like the dolostone, likely also came from beds within the Knox or younger carbonate units where chert is common in some places. Limestone clasts, in particular, are distributed mainly in two intervals (0-10 m and 155-175 m). Other clasts (e.g., sandstone, shale) are rare in our analysis and are mainly confined to unit 1. It is noteworthy that no crystalline clasts were observed in this drill core. Because it is not possible to say with certainty which formation the dolostone, limestone, chert, and other clasts (e.g., sandstone, shale) came from, we broadly interpret the results as indicating that clasts were sourced from disintegrating target stratigraphic units and, in the process, evidently not much mixing of clasts has occurred. We also plotted number of clasts per meter (1-175 m), which is a type of plot that shows distinctive fining-upward trends in the breccias of Lockne and Tvären craters [9], but for Flynn Creek shows no obvious trends. This finding further suggests that the breccias in FC77-1, boxes 1-60, are not crater-filling, resurge breccia deposits, but rather have another origin related to the central peak.

Conclusions: Preliminary results from line logging suggest that the continuous drill core from well FC77-1 (boxes 1-60; 0-175 m depth) consists of two impact breccia units, which can be subdivided into two coarsening-upward sequences within each unit. The coarsening upward trends are inconsistent with resurge breccia deposits of marine target craters (e.g., Lockne and Tvären craters [9]), wherein a long, fining-upward trends are evident. The coarsening-upward trends in this drill core suggest an origin by slumping or another non-aqueous depositional mechanism. The distribution of clast types indicates lack of mixing processes, which further distinguishes these breccias from resurge breccia deposits. Below 175 m, deformed Upper Ordovician strata with breccia intervals and dikes likely represent the deeper part of the underlying central uplift feature (i.e., boxes 61 through 236 (175-725 m).

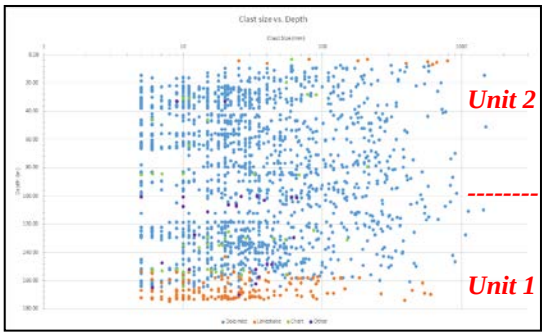

Fig. 3. Clast size (and composition) versus depth in meters. Blue is dolostone, orange is limestone, chert is green, and other clasts are purple. Units 1 and 2 are the same as in Fig. 1. N = ~ 3500 clasts.

References: [1] Roddy D.J. (1966) *The Paleozoic crater at Flynn Creek, Tennessee*. PhD, Cal Tech, Pasadena. [2] Roddy D.J. (1968) In *Shock Metamorphism of Natural Materials*, Mono Book Corp., Baltimore, 291-322. [3] Roddy, D.J. (1977) *Impact and Explosion Cratering*, Pergamon, 277-308. [4] Roddy D.J. (1979) *LPSC X*, 2519-2534. [5] Evenick J.C. (2006) *Field Guide to the Flynn Creek Impact Structure*. U. Tenn., Knoxville. [6] Gaither T.A. et al. (2015) *LPSC XLVI*, Abst. #2089. [7] Schieber J. and Over D.J. (2005) In *Understanding Late Devonian and Permian-Triassic Biotic and Climatic Events: Towards an Integrated Approach*, Elsevier, 51-70. [8] Conant L.C. and Swanson V.E. (1961) USGS Prof. Paper 357, 91. [9] Ormö J. et al. (2007) Met. & Planet. Sci., 42, 1929-1943. [10] Hagerty J.J. et al. (2013) *LPSC XLIV*, Abst. #2122. [11] Ormö et al. (2009) GSA Spec. Paper 458, 617-632.

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