THE OBLIQUITY OF THE FLYNN CREEK IMPACT EVENT. K.A. Milam[1] and J. W. Perkins[1], [1]Department of Geological Sciences, Ohio University, 316 Clippinger Laboratories, Athens, Ohio 45701.

Introduction. Most collisions of asteroids and comets with planet occur at angles oblique to the local surface [1-3]. For most impacts at ~30° the surface, this results in a circular (radially symmetrical) crater form. At lower angles, the circularity of the rim, the crater profile, the distribution of the ejecta, and other characteristics are all affected by the lateral transfer of energy in the downrange direction [e.g. 4]. These characteristics can therefore be used to assess the obliquity of ancient impact craters throughout the solar system. On planets such as the Earth and Mars however, active erosion and sedimentation serve to obscure and even obliterate crater landforms. This makes an assessment of obliquity challenging if not precluding it altogether.

Such is the case at the Flynn Creek structure in Jackson County, Tennessee, an impact crater originally suggested to be an oblique impact by [5]. Flynn Creek is a 382 Ma [6], complex crater that formed in a marine environment with a seabed of Middle Ordovician carbonates [6,7]. The crater was quickly buried by Late Devonian and younger sediment [6,7]. Recent stream erosion has exposed both the crater fill and remnant target rocks in the crater rim, floor, and central peak. Although rapid burial would otherwise preserve a pristine crater landform, limited exposures and the erosion from resurge that occurred following this marine impact make an assessment of obliquity quite challenging. For example, re-distribution of ejecta from water column collapse [6] seems to have completely removed most, if not all, ejecta from the crater rim and post-impact erosion has denuded the crater rim [7]. Although our ability to assess impactor obliquity using the ejecta pattern and crater shape is limited, topographic and structural data have provided a means of assessing the impact trajectory, obliquity, and post-impact erosion associated with the Flynn Creek impact event.

Methods. This study involved field work from 2010-2011 in and around the Flynn Creek impact structure in Jackson and Putnam Counties (between 36.2-36.3°N, 85.6-85.7° W. In an effort to assess the potential asymmetry of structural deformation along the crater rim, GPS-recorded (<10m horizontal/$\pm$3m vertical accuracy) and dip measurements were taken of bedding in Ordovician bedrock (Leipers-Catheys and Bigby-Cannon Formations) at all accessible (surface and sub-surface) crater rim exposures excluding those that were in collapsed terrace blocks. Based on previous experimental observations and modeling of a downrange deformation bias in oblique impacts [3,4], we assume that strata with the steepest dips would also occur in the downrange direction of impact and shallowest in the uprange.

In addition, the elevation of the contact between Middle Ordovician carbonate target rock and post-impact, Late Devonian carbonaceous shale was measured at 46 locations both inside and outside of the crater. This data was combined with contact elevations in well data from 30 locations [8] in an effort to use the elevation of the target rock as proxy for uplift and to re-evaluate the shape of the Flynn Creek impact crater.

Dip magnitude and contact elevation maps were produced by contouring (using the Krigging in GIS) data points over the study area. Two contact elevation maps were produced. The 1st included all contact elevations (including those collected within or near the crater rim) and represents the post-impact surface. The 2nd excluded those contact elevations associated with the crater and is a model for the pre-impact surface. The 2nd map was subtracted from the 1st map to indicate the difference between the pre- and post-impact surfaces.

Results. Bedding attitude data from this project are reported in [9]. Data were collected from a total of 184 stations, with an average of 3-5 strikes and dip measurements collected at each station. Data at each station were averaged, contoured, and are shown in Fig. 1. The direction of dip angles shown in Figure 1 are oriented approximately radial to the center of impact.

Fig. 2 shows elevations of the contact between Middle Ordovician carbonates (including those re-deposited by impact) and the Late Devonian Chattanooga Shale. This represents the post-impact surface, which is defined locally by top of the target rock, ejecta, and resurged ejecta. When elevations associated with the crater interior and rim area are excluded, a model for the pre-impact surface can be constructed (Fig. 3), giving a sense of the regional topography prior to the impact event. When the post-impact surface is subtracted from the pre-impact surface (Fig. 4), the effects of impact can be discerned.

Discussion. Data from this study suggests the formation of the Flynn Creek impact crater by the collision of an asteroid or comet at a shallow (~5°) impact angle along an approximately NW to SE present-day trajectory (uprange: ~310-323°; downrange 130-143°). Asymmetric structural and morphological relationships exist around the crater rim that supports this hypothesis.

Largest dip angles (+30°) occur in the SE quadrant of the crater rim along azimuths between 105-185°. Excluding the high dip angles associated with Wave Cave which may be associated with rim collapse [10], the largest dip angles occur between 135-185°, suggesting the downrange portion of the trajectory lies in the present-day SE. This part of the rim also appears to display the most uplift (Fig. 3) between (110-130°), which is consistent with a NW to SE impact. Apparent resurge gullies occur approximately transverse to the proposed impactor trajectory (Fig. 3) and could show evidence for an extremely low angle impact on the order of ~5° along an approximately NW-SE trajectory with transverse ejecta deposition.

Crater cross sections produced across the post-impact surface through the crater center reveal that the greatest slopes along the crater wall exists between azimuths of 310°-270° (NW quadrant) supporting a NW uprange. The opposing part of the crater between 90-130° would thus represent the downrange. This is inconsistent with the observation that the NE crater wall has the shallowest slopes; however, resurge likely scoured the rim and re-deposited ejecta resulting in the shallowest slopes in the NE (Fig. 3).

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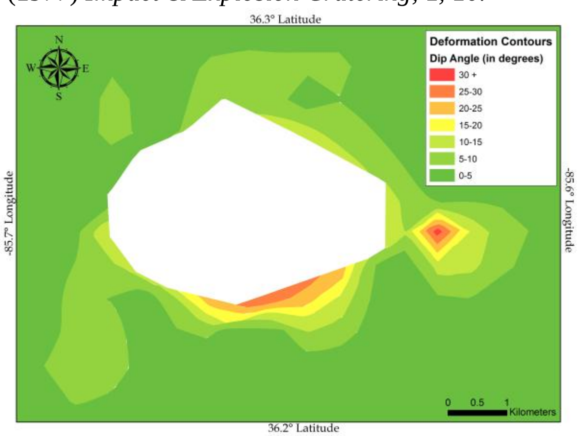

Figure 1. Map showing the spatial distribution and magnitude of dip angles around the Flynn Creek impact crater. The interior of the crater (white area) is excluded from view due to the variability of dip angles and directions that are not related to rim uplift.

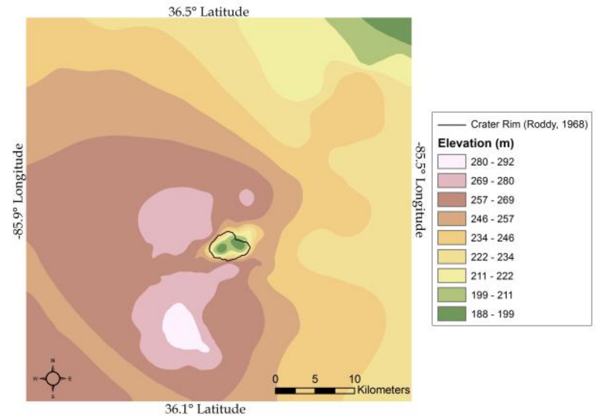

Figure 2. Map showing the elevation of the base of the Chattanooga Shale. This represents the post-impact surface following collapse and resurge.

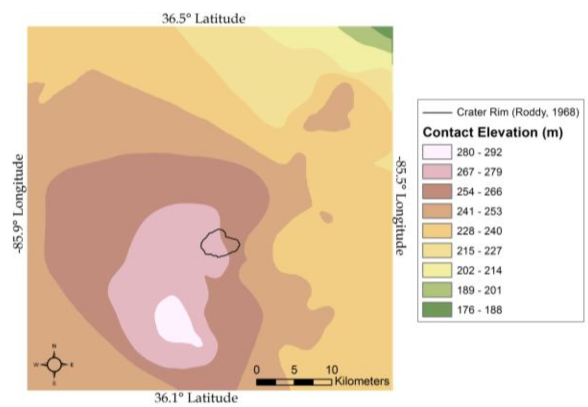

Figure 3. Modeled pre-impact surface using base elevations of the Chattanooga Shale excluding those associated with the Flynn Creek impact crater.

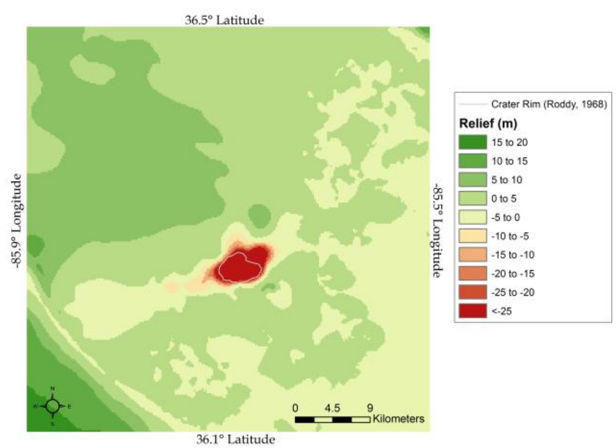

Figure 4. Map showing the relief between pre- (Fig. 3) and post-impact (Fig.2) surfaces.