DETERMINING SHOCK LEVELS IN CARBONATE ROCKS AT THE CROOKED CREEK CRATER, MISSOURI USING X-RAY DIFFRACTION.

N. D. Garroni[1,2], G. R. Osinski[1,2] and R. L. Flemming[1,2]. [1]Department of Earth Sciences, University of Western Ontario (1151 Richmond St, London, ON, N6A 3K7, Canada, ngarroni@uwo.ca), [2]Institute for Earth and Planetary Exploration, University of Western Ontario (1151 Richmond St, London, ON, N6A 3K7, Canada, gosinski@uwo.ca).

Introduction: Despite being present in ~40% of target rocks for confirmed hypervelocity impact craters across the globe [1], carbonate rocks are poorly understood as shock indicating minerals. Silicate minerals, such as quartz and feldspar are typically used to qualify shock, as petrographic indicators are more readily preserved (e.g., planar deformation features, planar fractures, diaplectic glass) [2]; whereas carbonates do not display solid-state shock features as observable with optical methods. However, powder X-ray diffraction studies on shocked calcite and dolomite has demonstrated the ability of this technique to determine definitive evidence of shock metamorphism as asymmetric compression of the crystal lattice [e.g., 3].

In this study, samples from the carbonate-rich Crooked Creek impact structure, Missouri were analyzed for changes in shock levels across the width and depth of the crater's target rocks. The Crooked Creek crater is a complex crater ~7 km in diameter with a time of impact between 323 and 470 Ma. Target rock material is primarily bedded dolostone with minor sandstone hosting calcite vugs and chert nodules. Crater modification caused ~400 m of stratigraphic uplift, and later erosion removed all assumed impact-generated breccia and melt rock, exposing the structural central uplift (which includes a circular anticline) and outer annular syncline [4].

Methods: Fourteen samples were collected from the Missouri Geological Survey core CC-02, and from surface outcrops. They were powdered with ethanol to <5 µm in an agate mortar and pestle and reverse mounted onto sandpaper to 2 mm thick. Prepared samples were analyzed using a Rigaku DMAX powder diffractometer with Bragg-Brentano geometry, a graphite monochrometer, and scintillation counter. Operating parameters included Co Kα1 radiation (1.78897 Å wavelength), 40 kV, 35 mA, 0.02°/step, 5 s dwell time per step, and a 2θ range from 5–120°.

Shock, as micro-strain, was first determined using the Williamson and Hall technique [5]: peak full width half maximum (FWHM) is plotted against $\tan\theta$ to determine strain (ε) in the equation, $FWHM = 4\varepsilon\tan\theta + \beta_0$, where 4ε is slope and β_0 is the intercept. Rietveld refinement was carried out using the open-sourced software, Profex to quantify micro-strain and crystallite size in the carbonate minerals.

Results: Because of peak interference from other mineral XRD data, only nine of the fourteen samples provide reliable Williamson and Hall strain values (Fig. 1). Low micro-strain values are observed using this technique, ranging between 0.0249% and 0.1224% for ε. However, when considering the location of each sample, higher strain rates are generally observed in samples that are closer to crater center. The idea here is that the passage of the shockwave at Crooked Creek is recorded in the carbonate rocks as it decayed radially outward from the point of impact. This preliminary data is similar to results from the Haughton crater in the Canadian High Arctic [6] and is being investigated further via Rietveld refinement.
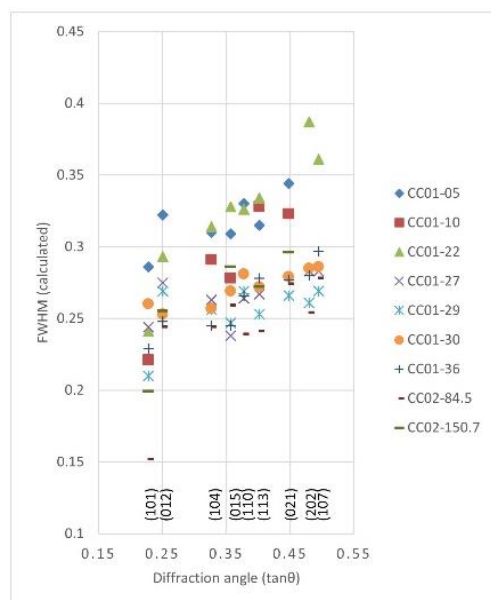

Figure 1: A—Williamson and Hall plot for dolomite powder samples focusing on 9 miller indices. CC01 refers to surface samples, and CC02 to core samples.

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