SHOCK METAMORPHISM OF SHATTER-CONED KNOX GROUP DOLOSTONES FROM THE CENTRAL UPLIFTS OF THE FLYNN CREEK AND WELLS CREEK IMPACT STRUCTURES.

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Introduction: Most of what is known about the behavior of target materials during a hypervelocity impact comes from our understanding of silicate-dominated crustal materials. However, a recent survey of confirmed impact sites listed in the Earth Impact Database [1] shows that approximately 39% of terrestrial impact structures contain, in whole or in part, carbonate rocks (i.e. limestone, dolostone, marble, marl). Recent empirical observations of terrestrial impactites [e.g. 2-3] and experimental studies [e.g. 4-5] have shown that shock metamorphism introduces disorder to the calcite and dolomite crystalline lattices. Twinning is a typical response to shock wave propagation [e.g. 6-8]. More specifically, [7] have shown that an increase in twin density and a decrease in twin spacing occurs with correspondingly higher shock pressures. Higher shock pressures may also result in a reduction in grain size [7, 9] or even partial melting of the carbonate target [8]. [2-5,9] have demonstrated that such disruptions to the crystalline lattice may be expressed by peak broadening in X-ray powder diffraction patterns. An experimental study by [5] demonstrated that the level of X-ray peak broadening can be correlated to experimental peak shock pressures. Additional work is required to further resolve the magnitude of shock metamorphism in natural samples. In this study, we examine impactites shocked to low-intermediate pressures in an effort to constrain the range of X-ray peak broadening that occurs in shatter-coned samples.

Geologic Settings and Sample Collection: Specimens utilized in this study were collected from the Flynn Creek and Wells Creek impact structures, both located in northern Tennessee, eastern U.S. These two sites were chosen for this study because both impact events resulted in the uplift of Knox Group dolostones [6,10]. At Flynn Creek, ten shatter cone specimens were collected from the uppermost exposures of shatter-coned dolostone from the Cambro-Ordovician Knox Group, just below the contact with the overlying Early Ordovician Stones River Group. The Flynn Creek impact structure is a 3.8 km diameter complex impact crater formed at 382 Ma [11] and buried beneath Late Devonian and Early Mississippian strata in Jackson County, TN [6, 11]. Twenty shatter-coned dolostones were collected from the uppermost exposures of the Knox group at Wells Creek in a locality known as Central Hill. The Wells Creek impact structure is a ~12 km diameter, post-Paleozoic complex crater located in Wilson County, TN. Two additional samples of unshocked Knox Group dolostones (specifically from the Lockport Dolomite) were collected near Gordonsville, TN for comparison. All of our study samples were collected without the use of the rock hammer in an effort to avoid artificial induction of strain to the dolomite crystalline lattice, which could be expressed as broadened X-ray diffraction peaks [4].

Methods: Samples were processed using techniques thought to minimize processing-induced deformation. Thin strips of samples were initial cut using a Hillquist SF-9 trim saw. These strips were broken, by hand, into small, granules-sized particles. The resulting particles were ground by hand in the presence of ethyl alcohol with a mortar and pestle for the minimum amount of time required to produce approximately 0.5 g/sample of <25 μm powder for X-ray diffraction (XRD) analysis. This size fraction was chosen to minimize peak broadening effects that may occur as a result of larger and variable grain sizes [12]. Aliquots of the >25 μm are being used in the geochemical characterization of each sample using X-ray flurescence. X-ray data was collected using a Rigaku MiniFlex II Diffractometer over a 2θ range of 20-120° at 30 kV and 15mA. This range was chose because it contains all of the prominent and lesser dolomite diffraction peaks and also allows us to identify additional phases that may be present. Powders were held during data collection by a quartz-zero plate to eliminate sample holder signature in diffraction patterns. X-ray diffraction data was refined using the Rietveld peak refinement [13]. One of the outputs of this refinement are the full width-half maximum (FWHM) values calculated across the 20-120° range and fit to a fourth-order polynomial equation. These values provide a means of comparing the peak broadening that occurs in shock metamorphosed samples to those of unshocked specimens.

A representative portion of each sample in this study was also processed into a thin section and examined using a petrographic microscope. Each sample is being observed to determine if textures exist indicating the degree of late stage (post-impact) replacement/recrystallization, which would affect the interpretation of XRD results. Each sample is being searched for twinning and to measure twin density and spacing in individual dolomite grains.

Results: X-ray diffraction data and initial petrographic observations indicate that both Flynn Creek and Wells Creek shatter cones are dominated by dolomite, with some Wells Creek specimens containing minor amounts of calcite and quartz. FWHM values for both Flynn Creek and Wells Creek demonstrate that peak broadening does occur in shatter-coned dolostones of the Knox Group when compared to values for an unshocked analog. The magnitude of peak broadening at Wells Creek is also comparable to that demonstrated for the similar-sized Sierra Madera impact structure in west Texas [3] and Kentland impact structure in northwestern Indiana [15]. When compared to the FWHM values of experimentally-shocked dolomite from [5], initial results suggest that most of the Flynn Creek specimens were shocked below <4.6 GPa, while Wells Creek specimens experienced peak shock pressures below <17 GPa. These results are largely consistent with the range of peak shock pressures proposed in previous work [e.g. 8, 14-16]. Ongoing petrographic examination is expected to provide additional insight into the nature of twinning in these specimens. Differently-sized complex impact structures (13 km vs. 3.8 km for Wells Creek and Flynn Creek respectively) are expected to contain target rocks that have experienced differing peak shock pressures (higher vs. lower for Wells Creek and Flynn Creek respectively). Therefore, we expect to identify differences in twin occurrence, density, and spacing between the two structures.

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