PRELIMINARY INVESTIGATION OF SHOCKED CARBONATES FROM THE HAUGHTON IMPACT STRUCTURE, DEVON ISLAND, NU, USING X-RAY DIFFRACTION AND RIETVELD REFINEMENT.

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Introduction: Observation of shock metamorphism in rocks is the primary method of determining if they have been exposed to a hypervelocity impact. This is necessary to confirm any proposed new impact structure [1]. Shatter cones are the only macroscopic evidence of shock and they may not be generated in all rock types or even preserved in every crater. Microscopic evidence of shock metamorphism can be identified as planar fractures (PFs) or planar deformation features (PDFs), diaplectic glasses, or high-pressure mineral phases [1]. These diagnostic features are typical of the silicate minerals quartz and feldspar and signify shock pressures greater than 5-10 GPa [2] generated during hypervelocity events; however, these minerals are not ubiquitous among all rock types. Sedimentary target sequences that are rich in carbonates may have limited to no occurrences of these diagnostic shocked silicate minerals.

Carbonates are present in one third of known impacts [3] so developing a reliable technique to identify signs of shock in whole rock samples of these rock types would be a valuable resource. Investigation of shock effects in calcite from the Kara and Steinheim [4] and Ries [5] impact structures and calcite and dolomite from the Sierra Madera impact structure [6] have been previously reported. In these investigations, Rietveld refinement was applied to the shocked samples from each impact site. This method of crystallographic analysis [7,8] can be performed on whole rock samples and enables mineral modal analysis as well as refinement of crystal structural parameters such as unit cell dimensions, cation positions, as well as size and strain analysis. To continue exploring the concept of identifying shock effects in carbonates by XRD, samples of shatter cones from the Haughton impact structure have been investigated using the Rietveld method.

Geologic setting. Located on Devon Island, NU in the Canadian Arctic, the Haughton impact structure is a well-preserved complex crater with a diameter of 23 km and is found in a sedimentary target sequence. Target rocks comprise primarily of limestone, dolostone, gypsum/anhydrite, and sandstone. Some of the crystalline basement gneiss has been excavated to the surface and can be found as shocked clasts within the impact melt breccia. Shock features known from the Haughton impact structure include shatter cones, PDFs, diaplectic glass, and the high-pressure quartz polymorph coesite [2]. Shatter cones are the only one of these shock features directly associated with carbonates.

The aim of this study is to examine dolomite and calcite in whole rock samples from the Haughton impact structure to determine if similar effects are seen as reported by [4,5,6]. The approach to detecting microscopic shock effects in Haughton carbonates will be through X-ray diffraction (XRD)/ Rietveld refinement of shatter cone and low to unshocked target samples.

Samples and Methods: *Sample selection:* Ten shatter cone samples were selected from an extensive sample suite previously collected during multiple field seasons, to represent various locations within the impact structure (Fig. 1). The presence of shatter cones indicates that the rocks have been shocked, but, moreover, that the samples have remained in the solid state, with no melting and recrystallization of the minerals. The composition of these samples includes dolomite, calcite and mixtures of the two carbonates. Many samples contained minor quartz and two contained minor gypsum. Three additional samples, one from the rim, one 2.5 km

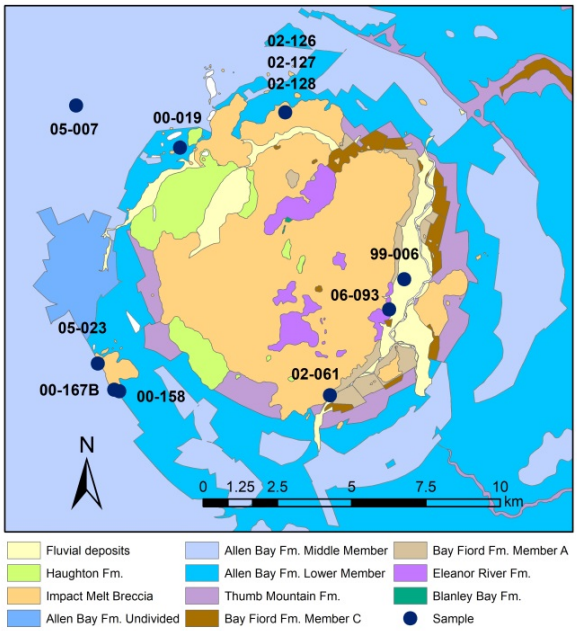

Fig. 1. Geologic map of the Haughton impact structure and locations of samples. Samples not shown are 06-108 which was collected 8 km north of 05-007 and 05-010 collected 160 km east of the impact structure.

beyond the rim, and a final sample 160 km away from the impact site were analyzed to provide low shock, low to no shock, and zero influence, respectively, to the hypervelocity event. These three samples are all from the same dolostone target unit, the Allen Bay Fm. Middle Member and do not contain shatter cones.

Sample preparation: Ten shatter cone samples were sieved to <45 µm size. Six samples were split and ground for 30 min under ethanol to reduce the grain size to ~5 µm. Allen Bay target samples were also ground for 30 min under ethanol to achieve ~5 µm.

Powder X-ray diffraction (XRD): Used a Rigaku DMAX powder diffractometer, with Bragg-Brentano geometry, graphite monochrometer and scintillation counter. XRD patterns were collected using Cu Kα (λ = 1.5418 Å) and/or Co $K\alpha_1$ (λ = 1.7889 Å), step size 0.02º /step, 5 s per step count time, at 40 kV and 35 mA. Minerals were identified using the International Centre for Diffraction Data (ICDD) database. Selected samples were examined on a Bruker D8 Discover XRD [9].

Rietveld Refinement/Modal Analysis: Rietveld refinement was performed using TOPAS (v 4.2 or 5.0) (Bruker-AXS). Refined parameters were background, scale, sample displacement, unit cell parameters, atomic positions, occupancy, thermal parameters, and grain size and strain. Whole patterns were fitted using a Thompson Cox Hastings Pseudo-Voigt profile. Gaussian size and strain algorithms performed better than Lorentzian. Starting structures were obtained from the American Mineralogist Crystallographic Database or the Inorganic Crystal Structural Database (ICSD). Calcite and dolomite are hexagonal ($R\bar{3}c$ and $R\bar{3}$, respectively). Preferred orientation was also refined.

Results and Discussion: For sieved samples (unground), grain size was variable. Some were inherently fine grained (e.g. 02-128), while others were coarse grained (e.g. 05-023) (Fig. 2). Rietveld refinement could be performed on the inherently fine grained material without grinding as grain size is independent of particle size. Coarse-grained minerals require grinding.

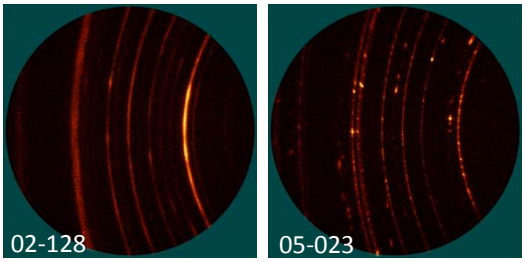

Fig. 2. Bruker D8 Micro-XRD 2D diffraction patterns for unground samples 02-128 (dolomite) and 05-023 (calcite). Texture indicates grain size. Left: Fine-grained dolomite (02-128) shows Debye rings. Right: Coarse-grained calcite (05-023) shows X-ray spots and spotty rings, indicating larger grains.

XRD patterns for the six ground Haughton samples and the Allen Bay target sample from the crater rim are shown in Fig. 3.

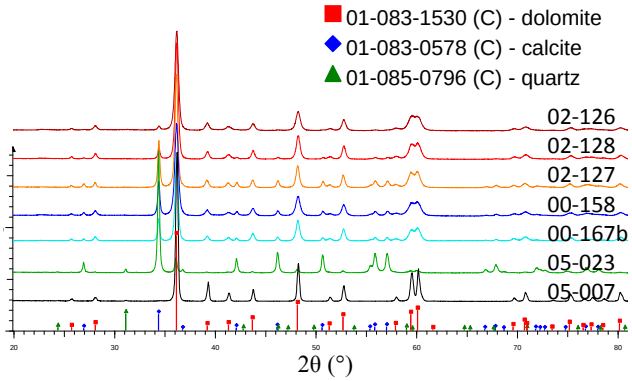

Fig. 3. Powder XRD patterns of the six ground shatter cone samples and Allen Bay crater rim target dolostone (05-007). Dolomite is the dominant phase in these samples, except 05-023 which is calcite. Narrow diffraction lines indicate unshocked material, and line broadening correlates with shock.

Line broadening is evident in the samples from within the Haughton impact (Fig 3.), which is consistent with results found by [4,5,6]. Rietveld refinement yielded quantitative strain values (% ε) and whenever dolomite and calcite occurred together, the dolomite was always about twice as strained as calcite.

A correlation was also seen between unit cell size and strain for dolomite. In dolomite, unit cell size decreased (both lattice parameters and volume decreased) as strain increased. This is consistent with a similar observation made for calcite [4,5].

Conclusions: Whole rock analysis by Rietveld refinement is a convenient method of getting modal mineral proportions as well as unit cell size and grain size/strain relationships.

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