FIRST RESULTS OF A MULTIDISCIPLINARY ANALYSIS OF THE HAUGHTON IMPACT CRATER, DEVON ISLAND, CANADA. III PETROGRAPHY AND SHOCK METAMORPHISM;

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Composition of the allochthonous polymict breccia:

The polymict breccia is composed of lithic fragments of Cambrian, Ordovician, and Silurian sediments (limestone, dolomite, quartzite, gypsum, anhydrite, conglomerates and shales) embedded in a fine-grained clastic matrix of limestone, gypsum, and silicate mineral fragments. A minor but important component are clasts of Precambrian crystalline rocks (acidic gneisses and some more basic lithologies) which were derived from a depth of more than 1700 m. The polymict breccia is not uniform -in contrast to earlier reports (1)- but two types can be distinguished which differ in clast population and matrix composition. Along the "inner ring" are outcrops of polymict breccias consisting of a dense, medium-grey, gypsum-bearing matrix in which cm- to dm-sized angular fragments of sediments (limestone, dolomite, shale) are incorporated. The outcrops in general are associated with uplifted gypsum beds of the Bay Fiord Formation. The gypsum-rich breccias are covered by light grey polymict breccias which are volumetrically far more abundant. The light breccia consists of a carbonate-rich matrix enclosing mineral and lithic clasts (sediments and crystalline basement rocks) of highly variable size. Stratigraphic considerations lead to the contention that the matrix compositions and clast populations of the two breccias reflect an inversion of the stratigraphic position of their respective source lithologies, the Middle Ordovician Bay Fiord gypsum and the Lower Ordovician Eleanor River limestone and dolomite. This is supported by the observation that the largest clasts of Precambrian crystalline rocks are found near the very top of breccia hills, several tens of meters above the outcrops of uplifted sediments.

Shock metamorphism:

The most prominent macroscopic shock features are shatter cones in limestones, dolomites, conglomerates, quartzites, gypsum and even volcanic rocks. While the existence of shatter cones, selectively shock-fused feldspars, and solid-state shock effects in quartz and sillimanite have been reported before from the gneisses (2,3,4), more highly shocked sediments and completely shock-melted crystalline rocks were previously unknown. All crystalline clasts from the breccia along the northeastern section of the inner ring show shock effects. The least shocked display several sets of planar elements in quartz and beginning isotropization of feldspars (shock pressure: 25-30 GPa). More highly shocked samples consist of selectively shock-melted K-feldspar (50 GPa) along with diaplectic quartz glass and kinked biotite. Apatite, present in large crystals, shows no shock effects. Crystalline clasts from a breccia near the crater's geometric center (Anomaly Hill) are more highly shocked. Quartzo-feldspathic rocks show shock metamorphism which approaches whole-rock melting. These melts were produced by selective melting of particular lithological varieties, whereas fragment-laden melt rocks derived from an extended, homogenized pool of melt (as in the case of melt sheets at craters in crystalline rocks or of glass "bombs" or melt splashes in suevite breccias) are not observed. This limits the maximum shock pressures experienced by the Precambrian rocks in the crater basement to 60 to 70 GPa. Evidently a breccia lens containing the most highly shocked crystalline clasts covers the central uplift but no homogeneous melt sheet formed.

The Anomaly Hill breccia of the central basin also contains shocked carbonates, quartzites and shales derived from the sediments which covered the Precambrian basement. The source of the shocked quartzites, limestones and dolomites most probably was the Eleanor River Formation, whereas shales could be derived from the underlying but ill-defined Cambrian sediments. Highly shocked carbonates are unique to the Haughton impact structure and are described for the first time. Shocked limestones, dolomites and shales are highly vesicular resulting in an unusually low density (Table 1). Sedimentary textures are still observable although some samples show evidence of flow, e.g., elongated vesicles. Thin sections show a pumice-like texture of the rocks which consist largely of submicroscopic, dark material and of colorless, and optically isotropic material, some of which may be shock-fused quartz. X-ray diffraction analyses yielded quartz, calcite, dolomite, gypsum, and a 10 A mineral, probably illite. Calcite and gypsum may be in part of secondary origin. The existence of portlandite ($CA(OH)_2$) is indicated in two samples. The high porosity of the shocked carbonates is probably caused by degassing of CO_2 as the result of the high shock- and post-shock temperatures, and by degassing of shales by dehydration of (OH)-bearing sheet silicates.

Shock melted quartzites are highly vesicular (Table 1) with spherical vesicles from < 1 µm to 1 cm. These samples are almost completely isotropic. X-ray analyses yielded considerable amounts of coesite in at least one sample (HAH 6) which also contains liquid-filled vesicles. The highly shocked quartzites and some of the shocked carbonate rocks and shales belong to shock stage IV (5) and therefore represent the most highly shocked samples from Haughton crater.

The shock-produced mineral and rock glasses from the crater center have been quenched and show remarkably little evidence of devitrification and no secondary hydrothermal alteration. Quartz and feldspar glasses, and glasses formed from shaly sediments are fresh throughout the sampled breccia unit. This is in contrast to similar materials in suevite breccia lenses of the Ries crater which is about the same size and had target lithologies similar to Haughton crater. However, the sedimentary layers at Haughton are about 1000 m thicker than those of the Ries target area. Consequently a smaller volume of crystalline rocks were shock-melted and no hot suevite layer developed. It appears that the amount of shock-melted crystalline rocks may largely determine the post-impact cooling history of crater deposits.

References: (1) Frisch, T. and Thorsteinsson, R. (1978) Arctic 31, 108-134. (2) Robertson, P.B. and Sweeney, J.F. (1983) Can. J. Earth Sci. 20, 1134-1151. (3) Robertson, P.B. and Mason, G.D. (1975) Nature 255, 393-394. (4) Robertson, P.B. and Plant, A.G. (1981) Contrib. Mineral. Petrol. 78, 12-20. (5) Stöffler, D. (1971) J. Geophys. Res. 76, 5541-5551.

Table 1: Density and mineralogical composition of highly shocked sediments from the center of the Haughton impact structure (Anomaly Hill).

Sample	density	mineral content (x-ray analyses)
carbonate-rich sediments and shales		
HAH 5	1.53 g/cm^3	quartz, calcite, illite (?), portlandite, glass
HAH 41	1.37 "	quartz, illite, montmorillonite, portlandite
HAH 42	1.39 "	calcite, quartz, glass
quartzose sediments		
HAH 6	1.19 g/cm^3	coesite, quartz, gypsum, calcite, glass
HAH 8	1.09 "	quartz, calcite, gypsum, illite (?), glass
HAH 43	1.04 "	quartz, calcite, dolomite, gypsum, glass
HAH 46	0.56 "	glass, calcite