IMPACTITES OF THE HAUGHTON IMPACT STRUCTURE, DEVON ISLAND, NUNAVUT, CANADA.

G. R. Osinski[1,2], J. G. Spray[2] and P. Lee[3]. [1]Dept. of Planetary Sciences, University of Arizona, Tucson, AZ 85721-0077, USA. [2]Dept. of Geology, University of New Brunswick, Fredericton, NB E3B 5A3, Canada. [3]SETI Institute/NASA Ames Research Center, Moffett Field, CA 94035-1000, USA. (osinski@lycos.com).

Introduction: The presence, distribution and characteristics of impact melt rocks have provided valuable information on the cratering process [e.g., 1, 2]. Coherent impact melt rocks are known from a number of well-studied impact sites such as the West Clearwater Lake, Manicouagan, and Mistastin structures in Canada (see 3, for a review). These lithologies often display classic igneous features (e.g., columnar jointing) and textures (e.g., glassy or fine-grained crystalline groundmass), and are easily recognizable as products of crystallization from a melt. It is widely accepted that coherent impact melt rocks only form in impact structures developed in predominantly crystalline (e.g., Manicouagan, Mistastin, West Clearwater) or mixed crystalline–sedimentary targets (e.g., Popigai, Russia). In the latter case, the impact melt rocks and glasses are apparently derived entirely from the crystalline basement [4].

In impact structures formed in predominantly sedimentary (principally carbonate-rich) target rocks, impact melt rocks have not generally been recognized. The resultant impactites have been referred to as lithic breccias, clastic matrix breccias, or fragmental breccias that are supposedly melt free [e.g., 5-7]. Indeed, it has been widely documented that the volume of impact melt rocks found in sedimentary targets is about two orders of magnitude less than for crystalline targets in comparably sized impact structures [5]. This anomaly has been attributed to the generation and/or release of enormous quantities of sediment-derived volatiles (e.g., H_2O, CO_2, SO_x), resulting in the wide dispersion of the shock-melted sedimentary rocks [5].

However, Osinski and Spray [8,9] have recently presented evidence from the Haughton impact structure that conflicts with previous models of the response of sedimentary rocks to hypervelocity impact. Combined field and analytical SEM studies reveal that the calcite, silicate glass, and anhydrite in the groundmass of crater-fill impactites at Haughton represent a series of impact-generated melts that were molten at the time of, and following, deposition [8,9].

The purpose of this study is to extend earlier investigations of the groundmass of the crater-fill impactites at Haughton. New data on the modal abundance and composition of groundmass phases will be presented. Detailed field work has also revealed the presence of a series of additional impactite types, including previously unrecognized ejecta deposits, that provide insight into the processes and products of hypervelocity impact into sedimentary targets.

Geological Setting: The ~23 Ma, ~24 km diameter Haughton impact structure is a well preserved complex impact structure situated on Devon Island in the Canadian Arctic Archipelago (75° 22' N, 89° 41' W). The target rocks at Haughton comprise a ~1880 m thick series of Lower Paleozoic sedimentary rocks of the Arctic Platform, overlying Precambrian metamorphic basement of the Canadian Shield. The unmetamorphosed sedimentary succession consists of thick units of dolomite and limestone, with subordinate evaporite horizons and minor shales and sandstones. This stratigraphically conformable sequence of early Cambrian to Siluro–Devonian rocks lies in a gently west-dipping homoclinal succession, which exposes approximately north–south striking layers that young to the west.

Impactites: Light grey-weathering crater-fill impactites currently form a discontinuous ~60 km^2 layer in the central area of the structure. Seismic reflection data [10] and field studies reveal that the crater-fill has a maximum current thickness of ~125 m, with a present volume of ~7 km^3. The presence of crater-fill impactites up to ~140 m above the central topographic low area suggests that the original thickness was >200 m.

Detailed mapping reveals that several different types of impactites are present at Haughton. A distinction is made here between impactites in the interior of the crater (radial range from crater center <6–7 km; i.e., crater-fill lithologies within the collapsed transient cavity), and those of the near-surface crater rim region (radial range from crater center >7 km; i.e., lithologies that have been transported from their place of origin in the original transient cavity).

Crater interior. There is a consistent upward sequence of lithologies from target rocks to crater-fill impact melt breccias:

(1) Shallow to steeply dipping (~10–80°) parautochthonous target rocks with an increase in the intensity of fracturing upwards.
(2) Parautochthonous lithic breccia (monomict) up to ~10 m thick derived from underlying target rocks.
(3) Friable, allochthonous lithic breccia (polymict) with clasts derived from a wide range of target lithologies, set in a fine-grained clastic matrix.
(4) Allochthonous impact melt breccias with a sharp and typically irregular contact with the underlying allochthonous and/or parautochthonous lithic

breccias. The lower levels of the impact melt breccias are clast-rich, with above average (i.e., meter length) clast sizes. SEM studies reveal that the groundmass of these impactites comprises three main components: (1) microcrystalline calcite (4–52 vol%); (2) silicate impact glass (up to ~67 vol%); (3) anhydrite (up to ~60 vol%). The various groundmass phases typically comprise ~50–60 vol% of the crater-fill impactites.

Near-surface crater rim region. Detailed mapping has revealed the existence of a series of impactites in the near-surface crater rim area of Haughton. Two principal impactites have been recognized (from the base upwards):

(1) Allochthonous impact melt breccia and megablocks with a microscopic, pale yellow groundmass. These impactites are polymict, in as much as different clast types are present; however, at a single locality, all clasts are derived from the same formation. The groundmass comprises microcrystalline calcite and an SiO_2-rich glass.

(2) Pale grey-weathering impact melt breccias. The largest occurrence of these impactites is preserved in a down faulted graben structure in the southwest of the Haughton structure. These pale grey-weathering impact melt breccias resemble the crater-fill impact melt breccias in hand specimen; however, there are important differences. Firstly, the groundmass of these lithologies is dominated by calcite (up to ~55 vol%), with impact melt glass comprising <10 vol%.

Origin of groundmass phases and classification of impactites:

Impactites of the crater interior. Textural and chemical evidence presented by Osinski and Spray [8] and supplemented by additional data from this study, reveals that groundmass-forming calcite is a primary impact melt phase. Evidence for this is provided by: (1) textural evidence for liquid immiscibility between calcite and silicate glass; (2) individual spheres of calcite within the groundmass; (3) rounded calcite grains in silicate glass; (4) evidence for the assimilation of dolomite clasts in the calcite–silicate glass groundmass; (5) flow textures and injections of calcite and silicate glass into clasts; (6) overgrowths (often euhedral) of calcite on dolomite clasts; (7) zoned, euhedral calcite crystals in SiO_2-rich glass clasts; (8) high MgO, FeO, SiO_2, and Al_2O_3 contents of groundmass-forming calcite, which contrasts with those of sedimentary and hydrothermal origin at Haughton. Evidence for the impact origin of the groundmass-forming anhydrite has been presented and discussed elsewhere [9].

Thus, the pale grey-weathering allochthonous crater-fill impactites at Haughton are not clastic matrix or fragmental breccias as previously thought [e.g., 6]. Instead, they can be classified as clast-rich impact melt rocks or impact melt breccias, according to the terminology of Stöffler and Grieve [7]. This work has extended the previous studies of Osinski and Spray [8,9] and indicates that the groundmass for the entire crater-fill unit (i.e., not just isolated samples) has a primary impact melt origin. This should not be as surprising as it might appear, as the crater-fill deposits at Haughton are stratigraphically equivalent to coherent impact melt sheets developed at craters in crystalline targets. Furthermore, the present and probable original volume (~7 km^3 and ~22.5 km^3, respectively), the stratigraphic succession upwards from target rocks into melt breccias, and the relatively homogeneous distribution of clasts, are all analogous to characteristics of coherent impact melt sheets developed in comparably sized structures formed in crystalline targets.

Impactites of the near-surface crater rim region. Pale grey-weathering impactites in the crater rim region comprise a calcite–silicate glass groundmass like similar lithologies in the crater interior. Textural evidence for silicate–liquid immiscibility between calcite and silicate glass and the SiO_2–Al_2O_3–FeO–MgO-rich nature of the calcite indicates that these are impact melt phases.

The pale yellow impactites comprise a microscopic groundmass of microcrystalline calcite and SiO_2 glass that is often devitrified. The SiO_2 glass is unequivocally shock-melted. There is abundant evidence for liquid immiscibility between SiO_2 glasses and calcite. The formation of liquid immiscible textures requires that both phases were in the liquid state at the same time at high temperatures (>1713 ^{o}C, the melting point of pure quartz). Both of these impactites can, therefore, be classified as clast-rich impact melt rocks, or impact melt breccias, according to the terminology of Stöffler and Grieve [7].

References: [1] Dence M. R. (1971) *J. Geophys. Res., 76*, 5552-5565. [2] Grieve R. A. F. and Cintala M. J. (1992) *Meteor. Planet. Sci., 27*, 526-538. [3] Dressler B. O. and Reimold W. U. (2001) *Earth Sci. Rev., 56*, 205-284. [4] Masaitis V. L. (1994) *Geol. Soc. Am. Sp. Pap., 293*, 153-162. [5] Kieffer S. W. and Simonds C. H. (1980) *Rev. Geophys. Space Phys., 18*, 143-181. [6] Redeker H. J. and Stöffler D. (1988) *Meteoritics, 23*, 185-196. [7] Stöffler D. and Grieve R. A. F. (1996) International Symposium on the Role of Impact Processes in the Geological and Biological Evolution of Planet Earth (abstract). [8] Osinski G. R. and Spray J. G. (2001) *Earth Planet. Sci. Letts, 194*, 17-29. [9] Osinski G. R. and Spray J. G. (2003) *Earth Planet. Sci. Letts, 215*, 357-370. [10] Scott D. and Hajnal Z. (1988) *Meteoritics, 23*, 239-247.