

THROUGH THE IMPACT GLASS: UNDERSTANDING THE ORIGIN AND EVOLUTION OF IMPACT MELT FROM THE MISTASTIN LAKE IMPACT STRUCTURE. P. J. A. Hill¹; G. R. Osinski¹; N. R. Banerjee¹; ¹Department of Earth Science and Centre for Planetary Science and Exploration (CPSX), University of Western Ontario, London, ON, Canada.

Introduction: The Mistastin Lake impact structure (55°53'N; 63°18'W) is a complex impact crater within the Mesoproterozoic (~1.4 Ga [1]) Mistastin batholith. Initially mapped by the Geological Survey of Canada, Taylor and Dence [2] determined the structure's origin by hypervelocity impact based on field observations of shatter cones and microscopic observations of planar deformation features (PDFs) in quartz and diaplectic glass. Marion and Sylvester [3] built off work done by others [4,5] to investigate the impact melt rock at Mistastin Lake. Geochemical analysis of the melt rock showed compositional heterogeneities on both the macro-scale (outcrop and hand sample) and micro-scale (thin section), particularly within the matrices of the impact melt rock, suggesting that the entrainment of clasts into the melt was the main cause of the variation in composition [3]. This study aims to better understand the evolution of the melt at Mistastin by examining the impact glass found in samples outside of the central uplift [6].

Methodology: The clasts were first characterized using a Nikon Eclipse LV100POL compound petrographic microscope. The thin sections were then analyzed using the JEOL JXA-8530F Field Emission Electron Probe Micro-Analyzer. Backscattered electron (BSE) imaging and energy dispersive spectroscopy (EDS) was used to investigate the microtextures and qualitatively map the elemental distributions. The chemical composition of the glass was quantitatively determined using wavelength dispersive spectroscopy (WDS).

Petrography: Impact glass clasts were found around Mistastin Lake in a range of lithologies, including polymict breccias and clast-rich melt rock. All glasses in this study are isotropic and are either holo-

hyaline or hypocrySTALLINE. Samples were classified into 3 types.

Type A. Type A glass is defined by its flow-textured, colourless nature. Forming elongated glass bodies with several samples exhibiting flow banding that follows quasi-parallel along the glass clast's margins (Fig. 1A). Generally, the clasts are 1–3 mm wide and can exceed 2 cm long. Clasts of plagioclase and pyroxene were observed within the glass; however, type A glass is generally clast-poor compared type B and C. The clasts range in size but can exceed 1 mm wide. Crystallites are rare and only observed in a few instances. Overall, type A glass defined predominately by the absence of crystallites or schlieren. In BSE images the glass appears to be homogenous in composition. Type A glass is observed in polymict breccias and impact melt rock from Coté Creek, Piccadilly Creek, and Steep Creek.

Type B. Type B glass is defined by being schlieren-rich, flow-textured, brown in colour and with distinctive and irregular geometry. Unlike type A, this glass type forms irregular, discreet clasts that do not exhibit preferential elongation. The glass is observed in a range of settings, including: coating lithic clasts; as stretched clasts within crystalline impact melt rock; and as massive “globular” clasts within polymict breccias. This glass was commonly clast-bearing; however, several type B clasts were observed to be clast-free. Within several samples, crystallites of plagioclase and pyroxene were observed. Larger clasts of type B glass (>1 mm wide) contain numerous vesicles, some of which exceed 100 µm in diameter. One sample from Coté Creek was observed to contain spherulites along a boundary with a large vesicle and a clast of plagioclase (Fig. 1B). Type B glass was observed in polymict

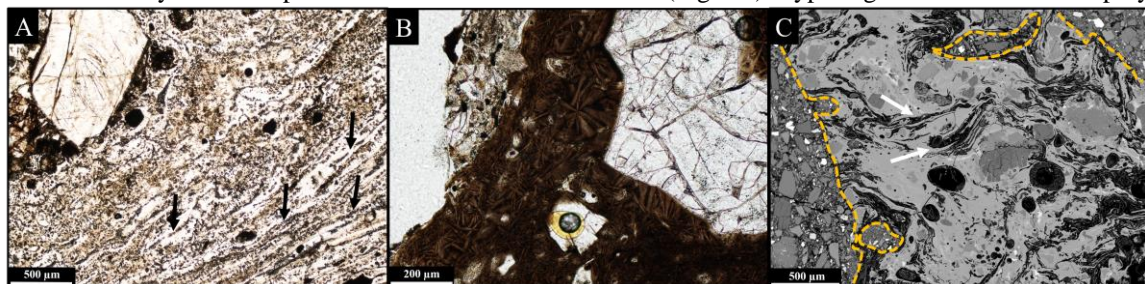


Fig. 1: (A) Plane polarized light (PPL) image of type A impact glass. The clast seen in this image exceed 2 cm in length and is ~0.5 cm wide. The black arrow is highlighting the formation of flow banding. (B) PPL image of type B impact glass. Small spherulites are present along the margins. (C) BSE image of type C glass. The note the sharp contact (yellow) and incorporation of the matrix material into the clast. The arrow demonstrate two vesicles that have been elongated in a common direction.

breccias and impact melt rock from Coté Creek, Discovery Hill, and South Creek

Type C. Type C glass is defined by its light brown to colourless, vesicular nature. Unlike type A and B, type C glass is generally more regular in shape and occurs exclusively within polymict breccias that have a clastic matrix (Fig. 1C). The glass occurs as large clasts (300 μm to 2 mm wide) that are generally equant with rounded edges. Clasts that exceed 2 mm in size become more irregular in shape, with some large clasts showing pinched out edges. The type C glass range from clast-rich to clast-free, but only glass clasts less than 500 μm in diameter were completely free of clasts. The glass is also highly vesicular, with several clasts showing clusters of vesicles that are elongated in a common orientation; however, on the whole, the vesicles are chaotic and random in direction with no relationship between clasts observed. Crystallites of plagioclase and pyroxene are observed but are rare. Schlieren were observed in many of the clasts of impact glass. Type C glass was observed in polymict breccias with a clastic matrix from Piccadilly Creek, South Creek, and Steep Creek.

Alteration of the Glass. Several of the glass clasts show alteration phases replacing glass and infilling vesicles. EDS analysis of the various phases revealed the occurrence of carbonate, zeolites, and clay phases within the samples. Zeolites are the most abundant alteration phase, infilling vesicles within type A and B glass.

Chemical Analysis: After characterizing the petrography of glass clasts within each of the samples, 1295 WDS spots were used to quantify the major oxide chemistry. As these spots include both glass and altered phases, large variation was observed within the major oxide chemistry of the entire dataset ($\text{SiO}_2 = 55.84 \pm 14.06 \text{ wt\%}$, $2\sigma_{\text{SD}}$; $\text{Al}_2\text{O}_3 = 19.92 \pm 9.89 \text{ wt\%}$, $2\sigma_{\text{SD}}$; $\text{MgO} = 1.33 \pm 1.71 \text{ wt\%}$, $2\sigma_{\text{SD}}$; $\text{CaO} = 7.43 \pm 9.96 \text{ wt\%}$, $2\sigma_{\text{SD}}$; $\text{FeO} = 5.23 \pm 7.62 \text{ wt\%}$, $2\sigma_{\text{SD}}$; $n=1295$). To examine the cause of the variation in the dataset, the mean composition for each glass clasts was grouped based on the petrographic types described above. As seen in Fig. 2, much of the variation in major oxide chemistry is a product of alteration phases replacing the glass. There is considerable overlap in the composition between types A, B, and C with a combined mean of $\text{SiO}_2 = 55.28 \pm 4.65 \text{ wt\%}$, $2\sigma_{\text{SD}}$; $\text{Al}_2\text{O}_3 = 21.91 \pm 5.36 \text{ wt\%}$, $2\sigma_{\text{SD}}$; $\text{MgO} = 1.22 \pm 0.94 \text{ wt\%}$, $2\sigma_{\text{SD}}$; $\text{CaO} = 8.05 \pm 3.05 \text{ wt\%}$, $2\sigma_{\text{SD}}$; and $\text{FeO} = 5.11 \pm 4.45 \text{ wt\%}$, $2\sigma_{\text{SD}}$ ($n=114$).

Discussion: Impact glass clasts from Mistastin Lake have been petrographically and geochemically categorized. Despite showing differences in their petrography, the various types of glasses have significant

overlap in their major oxide composition suggesting a large degree of homogeneity. Type C glass however, shows the highest variation of the three glasses. This is the result of two factors. Firstly, of the three types, schlieren is most prevalent in type C. These areas of more mafic glass (Mg-Fe-Mn rich) cause a heterogeneity in the WDS points. Secondly, the highly vesicular nature of this subtype results in the glass being prone to alteration and replacement. Given the fact that the impact glass is a product of rapidly quenched impact melt, it is a useful tool for modelling the original composition of the crater's impact melt. However, the presence of alteration phases indicates that the impact glass composition is susceptible to change and must be accounted for in any modelled composition. To better understand the evolution of the melt produced at Mistastin Lake, the following work will be done:

- Pristine glass clasts will be used with the known target rock chemistry in a least-squares mixing model [7,8] to determine the initial melt composition.
- A petrographical, geochemical, and textural analysis will be conducted to compare the glass at Mistastin Lake with other terrestrial impact craters (e.g. Ries) and the Moon.

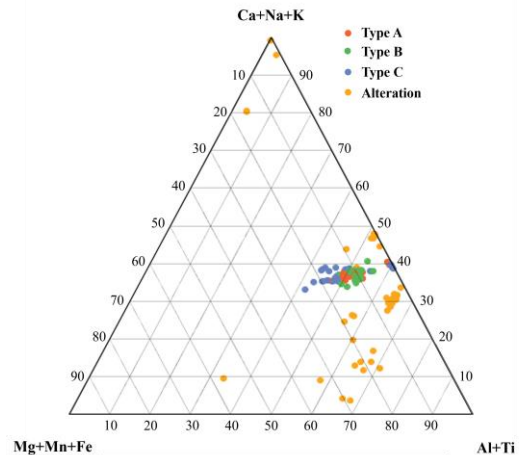


Fig. 2: The distribution impact glass clasts plotted on a Ca+Na+K (mol%) – Al+Ti (mol %) – Mg+Mn+Fe (mol%) ternary diagram.

References: [1] Emslie R. F. et al. (1971) *Curr. Res. Part A: GSC, Paper 80-1A*, 95–100. [2] Taylor F. C. and Dence M. R. (1969) *Can. J. Earth Sci.*, 6, 39–45. [3] Marion C. L. and Sylvester P. J. (2010) *Planet Space Sci.*, 58, 552–573. [4] Grieve R. A. F. (1975) *Geol. Soc. Am. Bull.*, 86, 1617–1629. [5] Marchand M. and Crocket J. H. (1977) *Geochim. Cosmochim. Acta*, 41, 1487–1495. [6] Mader M. and Osinski (2018) *Meteoritics & Planet. Sci.*, 53, 2492–2518. [7] Byran W.B. et al. (1969) *Science*, 163, 926–927. [8] Wright T. L. and Doherty P. C. (1970) *Geol. Soc. Am. Bull.*, 81, 1995–2008.