IMPACT-GENERATED HYDROTHERMAL ALTERATION AT THE MISTASTIN LAKE IMPACT STRUCTURE, CANADA. J. P. Jaimes Bermudez[1], G. R. Osinski[1], G. D. Tolometti[1], and N. S. Chinchalkar[1]. [1]Department of Earth Sciences and Institute for Earth and Space Exploration, University of Western Ontario, London, ON, Canada, N6A 3K7 (jjaimesb@uwo.ca).

Introduction: The Mistastin Lake (Kamestastin) impact structure is a ~28-km diameter, 37.83 Ma complex impact crater located in Labrador, Canada (55°53′N; 63°18′W) [1, 2]. This impact structure has captured the attention of many researchers because it contains some of the best exposures of impact melt rocks in our planet [3], contains the hottest documented crustal rocks of Earth [4], and is an analogue for the Moon as it formed in an anorthosite-rich target [1]. Despite being studied in the past [3, 5], little focus has been given to the hydrothermal alteration of its impactites. This is particularly important because clay-bearing regions on Mars are prime exploration targets [6, 7].

Previous workers have described alteration of impact glass in impact melt-bearing breccias comprising fractures and vesicles filled mainly with Na-, Ca-zeolites, clays, and to a lesser extent, carbonates, as well as partial to complete replacement of glass clasts by clays and zeolites [3, 5]. In addition, levyne-Ca zeolites have been observed to replace diaplectic feldspar glass [8]. Based on alteration indexes, Hill et al. (2020) [5] showed that the glass clasts follow three main trends of alteration: sodic and potassic alteration, and chloritization. The alteration in the impact melt-free rocks consists of sericite, calcite, clays and Ca-zeolites, replacing minerals from the target rocks [3]. These authors have shown the nature of the alteration at Mistastin, however, further studies are needed to fully understand the alteration and its geological context (how and where clays formed). Therefore, this study investigates and summarizes the extent of alteration within the impact structure, the setting in which these minerals occur, and the variations between lithologies and localities (Discovery Hill, Coté, South and Steep Creeks, central uplift, and the eastern rim).

Methodology: Polished thin sections from samples collected in 2009, 2010 and 2021 were characterized using a Nikon Eclipse LV100POL microscope. Backscattered electron (BSE) images were obtained to further investigate microtextures using a JEOL JXA-8530F microprobe.

Discovery Hill: This is a > 80 m thick ejecta unit that shows a two-layer stratigraphy (impact melt rocks and melt-bearing breccias overlying a ballistic ejecta layer of melt-free to -poor impact breccias) [3]. The alteration is mainly focused at the contact between these lithologies, in which heavily altered glass clasts (Mg/Fe clays [5]) within the breccias occur. They contain spherulites and abundant amygdules generally < 200 µm, but up to 1 mm, with the smallest being circular and the biggest being elongated and irregular (Fig. 1A and 1C). BSE imaging qualitatively shows different distributions of elements in the amygdules (Fig. 1A and 1B), with some containing more than one phase and others being zoned (inferred to be Na-, Ca-zeolites [5]). Plagioclase mineral clasts in the breccias are irregularly altered to sericite. Samples from a vertical transect along the southern face of the hill are mainly clast-poor, fine-grained to aphanitic impact melt rocks with unaltered plagioclase. However, zoned minerals infilling openings that optically look different from those at the contact were observed towards the top and middle of the hill.

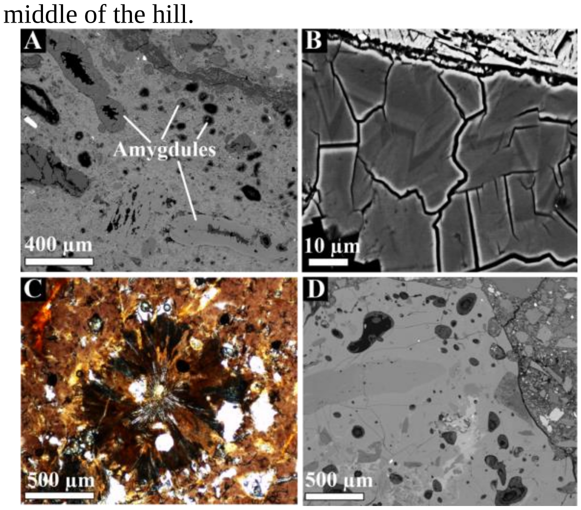

Fig. 1. BSE images showing the morphology of the amygdules (A) and zoning (B), and a PPL optical image of a spherulite in a glass-bearing impact breccia (C) from Discovery Hill, and an unaltered glass clast from South Creek (D).

Coté Creek: These ejecta outcrops also show the two-layer stratigraphy [3]. The alteration is mainly in the form of replacement of glass clasts (Mg/Fe clays [5]) and amygdules < 200 µm, up to 400 µm. The degree of alteration within samples varies considerably, with some glass clasts being completely replaced and others being relatively fresh. Hydrous phases have been identified in the groundmass of melt-poor polymict breccias, but are yet to be studied in detail [3]. Anorthosite clasts in the breccias are heterogeneously altered and clearly display different generations of alteration minerals (Fig. 2A).

South Creek: Glasses from this area appear to be fresh, or only slightly altered, based on optical observations (c.f., geochemical data [5]) of these melt-poor impact breccias. We observed filled, elongated vesicles less than 100 µm diameter, but up to 200 µm in the glasses (Fig. 1D), and hydrous phases have been identified in the groundmass [3]. In contrast to the previous regions, the alteration within the plagioclase mineral clasts is less intense. Calcite filling openings up to 1 mm long (generally < 400 µm) were observed within anorthosite clasts.

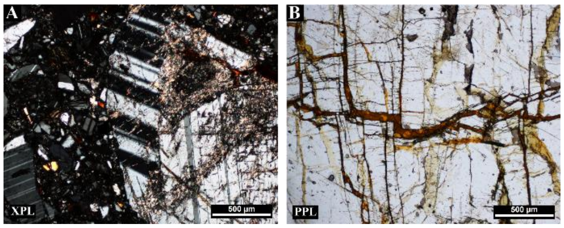

Fig. 2. (A) Different degrees of alteration in plagioclase clasts from Coté Creek and (B) Heavily fractured quartz-monzonite from the central uplift.

Steep Creek: Alteration in this area is less intense. The glass clasts appear to be fresh based on optical observations (c.f., geochemical data [5]). Amygdules up to 350 µm, but more commonly < 80 µm, and calcite infilling openings were observed within melt-poor impact breccias. Plagioclase is slightly altered.

Horseshoe Island (Central uplift): The samples are highly fractured and all correspond to brecciated target rocks (Fig. 2B). These fractures (< 20 µm thick, but up to 80 µm) are filled with clayey material. Plagioclase and orthopyroxenes, the main minerals in these rocks, appear to be fresh. However, localized patches of alteration can be observed in certain areas. Hydrated minerals have been reported in a glass clast from a dyke of melt-bearing breccia [9], however, the glasses appear to be largely preserved.

Eastern outer rim terrace: Samples from this area are all quartz-monzonite and granodiorite target rocks. Slight alteration along the twinning of plagioclase was observed and overall, the rocks appear to be unaltered.

Discussion: Ejecta deposits are the most affected, with the glass-rich rocks showing the highest degree of alteration (Table 1). It is important to note that both unaltered and altered glass clasts can be found in all of the samples. Those from South and Steep Creeks are the least altered [5], in contrast to those from Coté and more importantly, Discovery Hill, where more glasses appear to have been affected, and where devitrification features such as spherulites have been observed. Open-space filling textures suggest the circulation of hydrothermal fluids (e.g. central uplift). However, the differences in glass preservation in the ejecta indicate that rather than a sustained hydrothermal system that would produce a pervasive alteration as seen in the crater-fill impactites at the ~24 km diameter Ries impact structure [10], a combination of alteration processes including devitrification and/or autometamorphism may have come into play at Mistastin, similar to the surficial suevite ejecta at the Ries crater [10, 11]. This is consistent with textural observations indicating that no substantial interaction of impact melt with water occurred at Mistastin [5], and optical observations (zoning within amygdules, different infill material), BSE imaging and alteration indexes [5] showing that the alteration mineralogy and clay chemistry is variable.

It is therefore important to characterize in detail the type of zeolites and clays that replace the glass, infill the vesicles, and compose the groundmass of some melt-free/poor breccias to understand which alteration process may have been more relevant in each of the regions.

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Alteration	*Lithic impact breccias / Target rocks*	*Impact melt-poor breccias*	*Impact melt-bearing breccias*	*Impact melt rocks*
Ejecta				
Discovery Hill	Irregular - Ser	Amg, V, partial to complete glass replacement, Cl, Zeo		Amg, V, Cl
Coté Creek	Irregular – Ser, Cl?	Amg, V, minor to complete glass replacement, Cl, Zeo?		?
South Creek	Mild – Ser, Cl?	Amg, V, minor to partial glass replacement, Cl, Cc, Zeo?		?
Steep Creek	Mild - Ser	Amg, V, minor to partial glass replacement, Cl, Cc		?
Central uplift	Mild – Ser, Cl, V	Amg? Cl?		?
Eastern rim	-	-	-	-
Crater-fill	?	?	?	?

Table 1. Summary of the alteration phases and their occurrence. Abbreviations: Cl = Clay, Cc = Carbonate, Ser = Sericite, Zeo = Zeolite, Amygdule = Amg, Veins = V.