A FORMATIONAL MODEL FOR AN IMPACT MELT-BEARING BRECCIA DYKE AT THE MISTASTIN LAKE IMPACT STRUCTURE, LABRADOR, CANADA. A.E. Pickersgill[1], G. R. Osinski[1], and M.M. Mader[1], Centre for Planetary Science and Exploration, Dept. of Earth Sciences, University of Western Ontario, 1151 Richmond Street, London, ON, Canada, N6A 5B7 (apickers@uwo.ca).

Introduction: The extreme temperatures and pressures generated by hypervelocity impact events generate a unique suite of rock types characteristic of impact structures. These impact metamorphosed rocks (impactites) are characterized by the presence of microscopic shock metamorphic effects in minerals such as planar fractures, planar deformation features (PDFs), and diaplectic glass [1]. At the highest end of the pressure scale material is completely melted during impact and, when quenched, results in impact glass. These effects are all indicators of shock metamorphism. Because shock pressure decays with radial distance from the impact point, the peak pressures to which the material was exposed can be used to reconsturct where in the pre-impact stratigraphy the material originated.

Impact melt-bearing breccia (sometimes called "suevite") is a particularly poorly understood type of impactite. It can be defined as a "polymict impact breccia with a clastic matrix containing lithic and mineral clasts in various stages of shock metamorphism, including cogenetic impact melt clasts, which are in a glassy or crystallized state." [2] The type locality for suevite is the Ries impact structure in Germany, but it has since been identified at various other impact sites, including the Mistastin Lake impact structure, which is the focus of this study.

Mistastin Lake Impact Structure: The ~36 Ma Mistastin Lake impact structure [3], known locally as Kamestastin, is located in central Labrador, Canada (55°53'N; 63°18'W). The ~28 km diameter complex structure, though now eroded, has retained some of the original ejecta deposits including impact melt-bearing breccias [4]. As they are both well preserved at various sites around the crater and found in a variety of stratigraphic locations, the Mistastin Lake structure provides an excellent opportunity to understand the genesis of impact melt-bearing breccias.

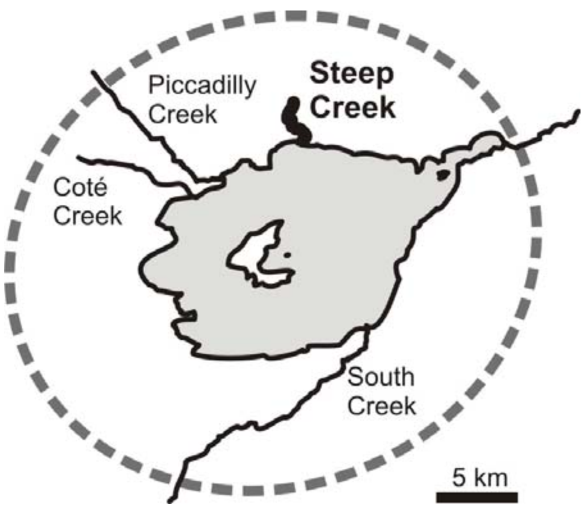

Figure 1: Schematic map of the Mistastin Lake impact structure. Dashed line indicates approximate location of crater rim [5].

At Mistastin, impact melt-bearing breccias occur underlying coherent impact melt rocks and in a dyke-like intrusion into metamorphosed basement rocks. This variation in stratigraphic location suggests an extremely dynamic, and as yet poorly understood, mechanism(s) of emplacement.

Field Work: During September 2010 a field team spent four weeks investigating the stratigraphy and field relationships of different units at the Mistastin Lake impact structure. Samples of impact melt-bearing breccia were collected from Steep Creek, at which it outcrops as a dyke-like intrusion into shock metamorphosed basement rock (fractured mangerite) (Figure 2). The contact between the breccia and basement rocks is sharp, with distinct macroscopic differences in colour and texture. The mangerite is very fractured and non-cohesive, brownish-red in colour, and has a distinct augen texture with large grains of feldspar. The impact melt-bearing breccia has a pale grey groundmass with dark grey glass clasts and lithic clasts concentrated near the middle of the dyke. The location of Steep Creek is interpreted to be part of the crater floor.

Petrography: Eight polished thin sections were made from representative samples of impact melt-bearing breccia. They were studied under a petrographic microscope and scanning electron microscope (SEM) revealing microtextural variation within minerals and various shock metamorphic effects.

Figure 2: The pale grey unit cutting the outcrop from top right to bottom left is the impact melt-bearing breccia at Steep Creek.

Glass Type	*Alteration*	*Inclusions*	*Quench Crystallites*	*Morphology*			
				Flow Textures	*Angular*	*Amoeboid*	*Rounded*
I	Low	< 10%	No	Yes	Yes	Yes	Not seen
II	Medium	~ 20%	Yes	Yes	Yes	Yes	Not seen
III	Unknown	> 50%	No	No	Not seen	Yes	Yes
IV	High	Variable	No	Variable	Yes	Yes	Not seen

Table 1: Classification of glass types in the Steep Creek impact melt-bearing breccia.

The Steep Creek impact melt-bearing breccia is made up of glass clasts (Figure 3) and shocked lithic and mineral clasts that consist of feldspar, quartz, pyroxene, and biotite with a small amount of accessory mineral phases embedded in an optically unresolvable groundmass. Many of these rock and mineral grains are incorporated into glass clasts. Approximately 80% of large feldspar (plagioclase) grains are partially diaplectic glass. Large quartz grains display multiple well developed sets of planar deformation features (PDFs). Planar fractures (PFs) are also present in quartz grains, though less frequently than PDFs.

The glass clasts have been broadly divided into four groups based on the following criteria: 1) level of alteration; 2) number of inclusions; and 3) presence or absence of quench crystallites (Table 1). These four groups do not constitute four discrete types, but rather four stages in a spectrum of possible glass clast compositions and levels of alteration. Glass clasts can be further divided based on morphologic characteristics (i.e., the external shape of the glass clasts – Figure 3, Table 1).

Discussion: The similarities in shock level between mineral and lithic clasts in the breccia groundmass and mineral and lithic inclusions in glass clasts suggest that the groundmass material and the inclusions originated from approximately the same source region within the target rock (i.e., the mineral inclusions are not from a vastly different part of the original stratigraphy than the mineral and lithic clasts).

The ubiquitous presence of whole rock glass, in the form of clasts and as part of the groundmass, indicates that some material now in the breccia experienced peak pressures well over 60 GPa. This glass would have flowed along the floor of the transient crater picking up shocked mineral inclusions, in agreement with the excavation flow model of Melosh [6].

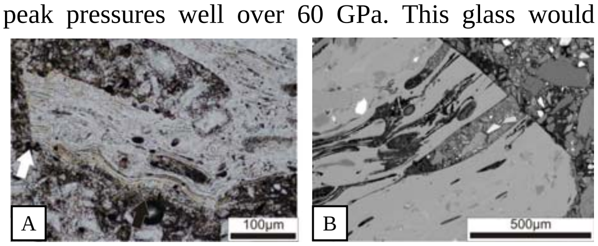

Figure 3: a) PPL photomicrograph showing a glass clast with both amoeboid and angular morphology; stretched and aligned inclusions and different glass colours emphasize flow textures; white arrow shows the angular break sharply cutting off flow textures.
b) BSE image of the angular edge of a glass clast showing stretched vesicles and mineral inclusions which have broken right in line with the glass.

The intrusive nature of the dyke at Steep Creek immediately suggests an extremely dynamic mode of emplacement, as a great deal of energy would be required to inject the impact melt-bearing breccia into a fracture in the basement rock.

Based on the variation in shock level with proximity to the crater centre, along with the evidence of macroscopic flow, a dynamic flow rather than ballistic airborne emplacement model is favoured. Similar rock types at other terrestrial craters are almost invariantly attributed to ballistic emplacement [7] based on the elongate, "aerodynamic" shape morphology of the glass clasts. Here, we have shown that this "aerodynamic" shape need not some from transport through the air but rather from a confining flow (cf. [8]).

Variable glass clast morphology supports a multistage emplacement model consisting of four main stages: 1) formation of Types I and II glasses and collection of shocked lithic and mineral clasts; 2) incorporation into breccia and formation of Type III glasses; 3) emplacement into the dyke; and 4) alteration of glasses and chemical weathering.

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