CONSTRAINING THE TEMPERATURE OF IMPACT MELT FROM THE MISTASTIN LAKE IMPACT STRUCTURE USING ZIRCON CRYSTAL STRUCTURES. G. D. Tolometti[1], G. R. Osinski[1], C. D. Neish[1], R. A. F. Grieve[1], and T. M. Erickson[2]. [1]Dept. of Earth Sciences/Institute for Earth and Space Exploration, University of Western Ontario, 1151 Richmond St, London, Canada, N6A 5B7 (gtolomet@uwo.ca) [2]Jacobs – JETS, Astromaterials Research and Exploration Science Division, NASA Johnson Space Center, Houston, TX 77058, USA

Introduction: Impact melt is a product of hyper-velocity impact events formed by the instantaneous melting of near-surface target rocks. Constraining the temperature of impact melt is vital to understanding its prograde heating and cooling history [1], which can have implications for inferring the environment of early Earth ~4.0 billion years ago when microbial life potentially arose. To date, only one datum on the initial impact melt temperature has been derived by Timms et al. [2]. These authors studied zirconia microstructures and crystallographic orientations that revealed the former presence of cubic zirconia, found in a black impact glass at the Mistastin Lake impact structure, Canada. The presence of cubic zirconia indicates a minimum temperature for the impact melt of >2370°C from the dissociation temperature of zircon to cubic zirconia and liquid SiO_2 [2]. With only one temperature datum, it is still difficult to constrain the entire temperature range experienced during the impact melting process; from its instantaneous formation to thermal equilibrium with the "cold" clasts collected along the crater floor and walls. In addition, obtaining a temperature value from only one type of impactite limits the inferred temperature range, because each impactite experiences a different cooling history.

In this study, we present a preliminary investigation of 61 zircon crystals, 14 of which are similar to those studied by Timms et al. [2], from the Mistastin Lake impact structure. To acquire a more accurate temperature profile representative of impact melt, zircon crystals were collected from different types of impactites containing impact melt, including additional samples of the black impact glass studied by Timms et al. [2].

Mistastin Lake Impact Structure: Mistastin Lake is a 28 km diameter complex impact structure with an approximate age of 37.83 ± 0.05 Ma [3]. The impact structure is one of few on Earth that hosts a relatively well preserved impactite stratigraphy, with impact melt rocks containing various amounts of clasts. They also show a transition in crystalline grain size and petrographic textures, from glassy-aphanitic to micropoikilitic at the top [3,4,5]. Mistastin is also an analogue for studying the formation and morphology of lunar craters because the composition and mineralogy of the surrounding country rocks are primarily anorthositic [3,4,5].

Mistastin Impactite Samples: Four impactite samples were studied for this work. These samples were selected because of their difference in petrographic textures and clast abundance.

Clast-Poor Melt Rock. The clast-poor melt rocks have fine to medium grained micro-poikilitic crystalline textures with clast abundances <5%. Clasts primarily comprise plagioclase and quartz. The quartz clasts have vesicular textures with inclusions of opaque minerals.

Clast-Rich Melt Rock. The clast-rich melt rocks have fine grained crystalline textures with clast abundances ranging from <15% – 33%. Clast mineralogy includes shocked quartz (toasting, undulose extinction and fracturing), plagioclase, pyroxene and opaques. Some of the quartz clasts exhibit coronas of very fine-grained brown/opaque minerals, presumed to be iron oxides and/or glass.

Impact Melt-Bearing Breccias. These breccia samples exhibit deep brown impact glass intermingling with a clastic matrix comprising plagioclase, quartz and pyroxene. Fragments of plagioclase and quartz crystals in the deep brown glass show little evidence of thermal digestion or recrystallization.

Black Impact Glass. The quenched black impact glass, which was studied by Timms et al. [2], was sampled from the 85 m thick Discovery Hill melt deposit at Mistastin. Textures are not visible under optical light and can only be observed using electron probe microanalysis techniques. Very few plagioclase and quartz clasts are encased in the black glass matrix.

Methodology: Zircon crystals were characterized in situ from polished thin sections using backscattered electron (BSE) images, scanning electron images and cathodoluminescence (CL) (Figure 1), taken using the JEOL JXA-8530F electron probe at the University of Western Ontario. The beam was set to 25 kV and ~25 nA. The resolution of the images is 720×540 pixels and a dwell time per pixel of 0.5 ms for CL was set. The BSE and secondary electron images were used to identify and describe the different zircon crystal morphologies, and CL images were used to reveal potential zonation within the cores of the zircon crystals [5].

Zircon Crystal Morphology: Three main types of zircon crystal morphologies were identified in the samples, plus one unusual morphology: (1) Zircon cores with a surrounding vermicular corona of ZrO_2–SiO_2 crystals. Some of the zircon cores were fractured or locally vesicular, while others maintained their solidity.

(2) Anhedral and fractured zircon crystals with no coronas. These crystals exhibit less extensive recrystallization and/or thermal digestion. (3) Subhedral to anhedral zircon crystals with no fractures, coronas or evidence of recrystallization and thermal digestion. One zircon crystal found in a black impact glass sample exhibits a brecciated core surrounded by a vermicular corona. The corona post-dates the brecciation of the zircon core because no ZrO_2–SiO_2 crystals grew in between the zircon core fragments. The zircon core was either brecciated due to the release of the shock wave during the impact or originated from a pre-impact event. Further work is required to understand development of the textures within this zircon grain.

The CL images show no evidence of zonation within the zircon cores. This is unusual because we would expect to see evidence of diffusion of constituents between the minerals and the impact melt if exposed to high temperatures for a sufficient time. Other than the coronas and partially consumed margins, it appears the zircons experienced little thermal digestion in the impact melt.

Next Stages: The next stages include calculating and inferring the temperature of impact melt from the zircon crystals are discovered in the following sections.

Microstructures and Crystallographic Orientations. To derive temperature values from the impactite samples we will analyze the microstructures and crystallographic orientations of the characterized zircon crystals. The procedure will follow the same methods implemented by [2] when they identified zircon dissociation textures using electron backscatter diffraction (EBSD).

Thermal-Mass Balance Equations. In addition to deriving temperature from the zircon crystals, we will be using the clast abundance to calculate the equilibrium temperature of impact melt at Mistastin. Using equations by [1], the clast abundance can be used to calculate the equilibrium temperature of impact melt rocks by assuming the initial clast abundance before thermal digestion and implementing the 2370°C datum derived by [2]. The results will be compared to the temperature data derived from the zircon crystals. By comparing the results, we will be able to confirm the accuracy of the zircon derived temperatures and reconstruct the prograde heating and cooling history of the Mistastin impact melt rocks.

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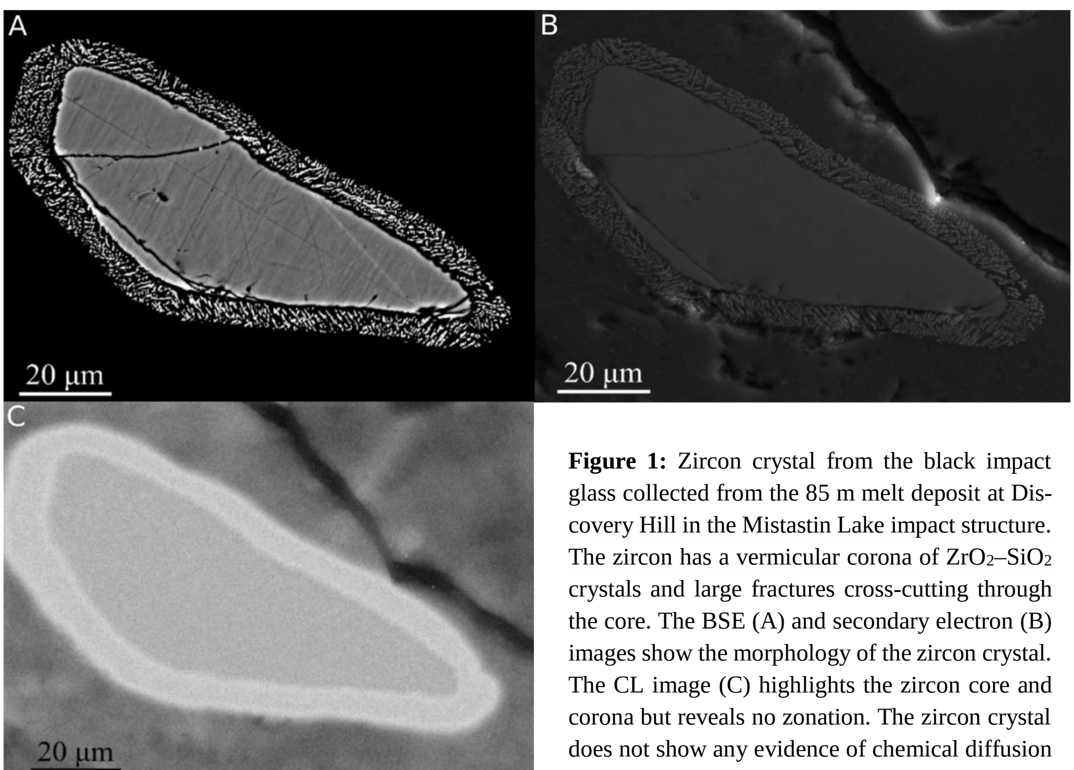

Figure 1: Zircon crystal from the black impact glass collected from the 85 m melt deposit at Discovery Hill in the Mistastin Lake impact structure. The zircon has a vermicular corona of ZrO_2–SiO_2 crystals and large fractures cross-cutting through the core. The BSE (A) and secondary electron (B) images show the morphology of the zircon crystal. The CL image (C) highlights the zircon core and corona but reveals no zonation. The zircon crystal does not show any evidence of chemical diffusion reactions with the impact melt matrix.