DATING THE MISTASTIN LAKE IMPACT STRUCTURE, LABRADOR, CANADA, USING ZIRCON (U-TH)/HE THERMOCHRONOLOGY. K. E. Young[1], K. V. Hodges[1], M. C. van Soest[1], and G. R. Osinski[2], [1]School of Earth and Space Exploration, Arizona State University, ISTB4, Bldg 75, 781 E Terrace Rd, Tempe, Arizona, 85287-6004. Contact email: Kelsey.E.Young@asu.edu, [2]Centre for Planetary and Space Exploration/Dept. Earth Sciences, Western University, 1151 Richmond St., London, ON, N6A 5B7, Canada.

Geologic Background: The Mistastin Lake impact structure (55°53'N; 63°18'W) was first identified in 1969 as having an impact origin by Taylor and Dence [1] through the identification of shock features and the prevalence of melt rock, both in veins within brecciated country rock as well as in discrete outcrops (i.e., Discovery Hill, the ~80 m tall outcrop of impact melt that contains boulders of target rock material that were entrained in the melt as it was emplaced; [2]). Mistastin Lake lies in the center of the ~28 km basin formed during the impact event. This lake contains two islands that represent the remnants of the structure's central uplift.

The crater was formed into the Mistastin batholith in the Canadian Shield. Marchand and Crockett (1977, [3]) dated the host rock at 1346 ± 15 Ma using the Rb-Sr technique. The target rocks consist of granodiorite, mangerite (hypersthene monzonite), and anorthosite. The abundance of anorthosite makes Mistastin perhaps the best lunar analogue crater in terms of similar target lithologies. Much work has been done to examine the mineralogy and geochemistry of the impact deposits (i.e., [3, 4]), but the age is still poorly constrained.

Previous Age Estimates: Wanless et al. (1966, 1972; [5, 6]) dated three impact melt samples using the K-Ar method and measured ages of 36 ± 4, 38 ± 6, and 202 ± 25 Ma. Currie (1971; [7]) reexamined these data and, after concluding that the two younger estimates were due to loss of argon post-impact, reported the age of Mistastin at 202 ± 25 Ma. However, Mak et al. (1976; [8]) analyzed eight impact melt samples and one anorthosite sample (using the shocked maskelynite phase) and obtained an age using the $^{40}Ar/^{39}Ar$ method that is more consistent with the younger ages reported in Wanless et al. [5, 6]. Six of the impact melt samples yielded ages ranging from 34 to 41 Ma. The remaining two impact melt rocks yielded complicated release spectra that suggested the inclusion of only partially reset clasts into the impact melt. Data collected from the maskelynite sample yielded an age of ~700 Ma, also indicating partial resetting. Mak et al. [8] therefore reported an age of 36 ± 4 Ma (using the updated decay constants of Steiger and Jager, 1978; [9]), which is now the commonly reported age for the Mistastin impact structure [10].

This Study: The data published in Mak et al. [8] are complex and, at times, hard to interpret. This is most likely due to the contamination of several samples from small clasts that were not completely reset in the impact event (meaning they had excess ^{40}Ar when analyzed). Several samples, however, yield an age of approximately 36 ± 4, which is within error of tektites collected from North America that have been dated at 35.3 ± 0.2 Ma [11]. If the data published in Mak et al. [8] show the correct impact age, then Mistastin could be one possible source of these tektites. There is also a potential multiple impact event that took place around this time. The reported ages of the Chesapeake and Popigai impact structures are within error of each other. The Chesapeake event took place at ~35 Ma [11] and the Popigai event happened at 35.7 ± 0.2 Ma [12]. The age of Mistastin quoted by Mak et al. [8] also lies within this range.

Widespread melting occurred during the Mistastin impact event that resulted in a wide variety of impact related deposits including brecciated target rocks (which have been subjected to varying degrees of shock), impact melt-bearing breccia, and impact melt that now scatter the area. Depending on the rock type, different techniques can be employed to date the structure. We seek to further refine the age of the Mistastin Lake impact structure (and thereby examine whether Mistastin was involved in either the tektite deposits or the multiple impact event) using two techniques: *in situ* $^{40}Ar/^{39}Ar$ thermochronology and (U-Th)/He thermochronology. By using *in situ* $^{40}Ar/^{39}Ar$ technology, we can select spots in impact melt phases that do not have xenocryst contamination and avoid partially reset clasts. This present report, however, focuses on (U-Th)/He thermochronology, which avoids impact melt rocks and instead examines pre-existing mineral grains that have been reset by the impact event.

(U-Th)/He Thermochronology: While traditional dating methods (i.e., K-Ar and $^{40}Ar/^{39}Ar$) have been historically successful in dating impact events, this study seeks to further develop the utility of (U-Th)/He thermochronology in dating terrestrial impact events [13, 14, 15, 16, 17]. (U-Th)/He thermochronology, based on ^{4}He alpha particle production resulting from the decay of ^{238}U, ^{235}U, and ^{232}Th to Pb, has traditionally been used to examine low-temperature processes due to its low closure temperature. The system's resetting temperature (the temperature at which the He daughter product is able to evacuate the system and restart the thermochronologic clock at zero) is also low, which is important in dating impact events [18]. Due to the heterogeneous distribution of temperature and pressure in impact events, this low resetting temperature is crucial. As ^{4}He is very mobile and evacuates its host mineral quickly once the resetting temperature is reached, the (U-Th)/He system is reset relatively easily in impact events and can be used as a chronometer. Because the technique dates whole mineral grains that existed prior to impact and have since been reset, we do not need the presence of impact melt rock to use the (U-Th)/He technique. While this is not a problem at Mistastin, this has proved advantageous in dating smaller impact events that have low amounts of silicate impact melt (i.e., the Haughton impact structure; [16]). The Noble Gas Geochronology and Geochemistry (NG^{3}L) group at Arizona State University (ASU) has already employed (U-Th)/He thermochronology in dating several impact structures including Bosumtwi, Ries, Manicouagan, Lake Saint Martin, and Haughton [13, 14, 15, 16, 17, 18].

New Mistastin Data: Fieldwork was conducted at the Mistastin Lake impact structure in August and September of 2011. All three target lithologies as well as impact melt units were sampled in multiple locations throughout the crater. We have so far collected (U-Th)/He data on zircons from two of the target lithologies (granodiorite and mangerite) as well as an impact melt sample present at the Mistastin Lake structure. No zircons have been found in the collected anorthosite samples. Four zircons from a single granodiorite sample were quite large (up to 291.0 μm in length) and also collected from near the rim of the crater, meaning that the temperatures experienced by these zircons during the impact event were less than those near the crater's center. Data collected from this sample ranged from 936 $\pm$ 35 to 1149 $\pm$ 43 Ma (all errors quoted at 2σ), indicating that the sample was not completely reset from the host rock that was dated at 1346 $\pm$ 15 [3]. Four zircons from two additional samples (one mangerite and one impact melt rock), however, yielded a preliminary weighted mean age of 32.7 $\pm$ 1.2 Ma. It should be noted that the zircons collected from the impact melt sample were most likely zircons entrained into the melt from the adjacent host rock units rather than neoblastic zircons. The fact that the zircons were entrained in impact melt makes it more likely that they were reset by the higher temperatures involved in fluid melt.

While our preliminary age of 32.7 $\pm$ 1.2 Ma is within error of the previously reported 36 $\pm$ 4 Ma [8], it relies on a technique based on grain resetting rather than impact melt production. This preliminary younger age also confirms that the Mistastin impact was not part of the larger impact event that produced the Popigai and Chesapeake impact structures, nor could it have produced the tektites that formed around 35.3 Ma.

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