UPDATED (U-Th)/He ZIRCON AGES FOR THE LAKE SAINT MARTIN IMPACT STRUCTURE (MANITOBA, CANADA) AND IMPLICATIONS FOR THE LATE TRIASSIC MULTIPLE IMPACT THEORY.

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Introduction and background: In 1998, Spray et al. [1] proposed that multiple impacts on Earth of fragments from a disrupted asteroid or comet could have occurred ~214 Ma ago and may have formed the following impact structures: Manicouagan (100 km diameter) and Lake Saint Martin (40 km) in Canada, Rochechouart (23 km) in France, Obolon (20 km) in Ukraine, and Red Wing Creek (9 km) in North Dakota, USA. From the similar ages of these five impact structures and the good fit to a small-circle impact trajectory of the three largest structures (Rochechouart, Manicouagan, and Lake Saint Martin), [1] suggested a Late Triassic impact event on Earth, similar to the impact of the tidally disrupted Comet Shoemaker-Levy 9 with Jupiter in July 1994 [2]. Therefore, determining the precise age of these five impact structures is important for validating/disproving this Late Triassic multiple impact event hypothesis.

The Lake Saint Martin impact structure has been previously dated yielding a whole rock and mineral isochron Rb-Sr age of 219 ± 32 Ma (2σ) [3], K-Ar ages of whole rock impact melt samples of 200 ± 25 Ma and 250 ± 25 Ma [4], an apatite fission track age of 208 ± 14 Ma [5-6], and (U-Th)/He zircon and apatite ages of 235.2 ± 5.6 Ma and 231.5 ± 7.2 Ma (2σ), respectively [7].

Here we report new (U-Th)/He zircon single crystal ages from an additional melt rock sample from Lake Saint Martin, obtained with the aim of better constraining the age of this structure, by the application of the relatively new (U-Th)/He low temperature geochronological technique.

Geological setting of the Lake Saint Martin impact structure: The ~40 km Lake Saint Martin impact structure (at 51°47' N and 98°32' W), is located in the Interlake Region of southern Manitoba. It is hosted by Ordovician to Devonian sedimentary rocks on the NE flank of the Williston Basin, which overlie a Precambrian granite of the Superior Province of the Canadian Shield. Impact lithologies comprise carbonate, granitic, and suevitic breccias, as well as impact melt rocks, which are partially covered by post-impact Jurassic red beds and evaporites, and Pleistocene glacial till [4]. Outcrops of coherent impact melt rocks occur in the eastern central part of the impact structure [4-5].

The Lake Saint Martin region has also been affected by an Eocene 60-70°C heating event that has been recorded by apatite fission track analysis, and which resulted in partial resetting of some apatite fission track ages to 166-180 Ma [6].

Samples and analytical techniques: We have used the low-temperature (U-Th)/He geochronological technique on individual zircon crystals to date the first of five additional impact melt samples obtained from Lake Saint Martin. The dated sample was collected ~10 km E of the centre of the Lake Saint Martin impact structure. The impact melt sample used in our previous study [7] was of very similar in appearance, but was collected ~7 km NE of the centre. The new sample (LSM-2-78) is of reddish colour, microcrystalline and vesicular, and contains some late impact-associated hydrothermal phases (calcite, quartz and pumpellyite), which indicates low temperature (~200°C) metamorphism. Some plagioclase clasts show incipient maskelynitization (25-30 GPa) and quartz clasts contain multiple sets of planar deformation features.

We analysed five zircon grains selected on the basis of their euhedral habit. All these zircon grains were cloudy in appearance, possibly indicating shock metamorphism, and were very similar in appearance to the five previously analysed zircon grains [7]. ^{4}He was extracted by infra-red diode laser heating and measured by an ASI Alphachron at the Noble Gas Geochemistry and Geochronology Laboratories (NG^{3}L) at ASU. The grains were then dissolved and U and Th was measured on a Thermo X-Series quadrupole ICP-MS in the ASU Keck Laboratory [8].

(U-Th)/He dating results: Of the five zircon grains analysed, one gave an anomalously young (U-Th)/He age of 192.1 ± 6.8 Ma (2σ). This grain was the smallest one analysed from both samples and also contains the lowest U and Th concentrations, hence it may have been more susceptible to partial He loss during the low-temperature Eocene event. The remaining four new zircon ranged in age from 212.5 -

215.8 Ma. Combining the five new zircon (U-Th)/He ages with the five zircon ages from our previous study [7] yields an age range from 192.1 - 244.5 Ma (Fig. 1).

Excluding the youngest 192.1 Ma age, a mean (U-Th)/He zircon age of 213.8 ± 3.0 Ma (2σ) was calculated from a cluster of five young zircon grains (Fig. 1). The four oldest zircon grains yielded a mean (U-Th)/He age of 234.4 ± 3.9 Ma (2σ) (Fig. 1).

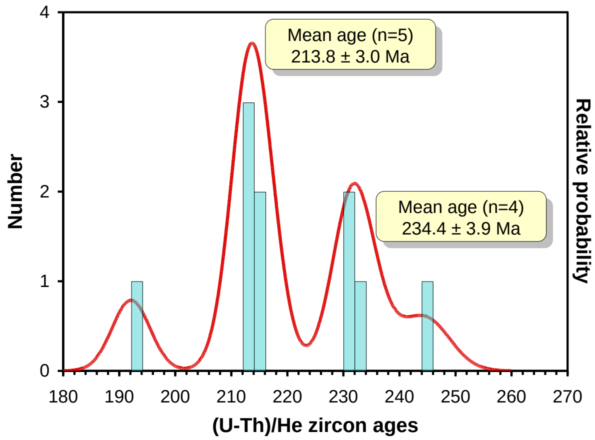

Figure 1. Cumulative probability (red line) and histogram (blue boxes) plot of the Lake Saint Martin (U-Th)/He zircon ages (n=10) from two impact melt samples.

Interpretation and discussion: Against the background of the largely undeformed Paleozoic sedimentary sequence that conformably overlies the Precambrian basement in southern Manitoba, the low-temperature (U-Th)/He geochronological technique (with a He closure temperature of 230°C for zircon, assuming grain diameters of 100 µm, a cooling rate of 1000°C/Ma, and using the He diffusion parameters of [9]) may provide important insights into the timing of Phanerozoic thermal events. Impact-triggered shock melting during the Lake Saint Martin impact locally caused post-shock temperatures of up to 1500°C, as indicated by the high-degree shock metamorphism of clasts in melt rock and whole-rock melting [10].

Dating of the Lake Saint Martin impact structure may be complicated by a later 60-70°C Eocene event, which has partially reset apatite fission track ages to 166-180 Ma [6]. In addition, this study [6] also yielded an older apatite age of ca. 352 Ma, which indicates that the ~214 Ma Lake Saint Martin impact event did not completely reset the apatite fission track ages. Therefore, partial resetting of the (U-Th)/He systematics in zircons in heterogeneously shocked samples may explain the older cluster of zircons that yielded a mean age of 234.4 ± 3.9 Ma.

Considering that: (1) there is evidence of partial resetting of low temperature geochronometers (i.e., apatite fission track) from the Lake Saint Martin region, and (2) the previous most precise geochronological ages obtained from Lake Saint Martin suggested an impact age of 208-219 Ma [3, 6], we interpret the younger cluster of (U-Th)/He zircon ages, with a mean age of 213.8 ± 3.0 Ma (2σ, n=5) to be the best estimate for the age of the formation of the Lake Saint Martin impact structure. This Late Triassic age refutes our previous older mean 231-235 (U-Th)/He apatite and zircon ages [9].

Conclusions: The 213.8 ± 3.0 Ma (2σ) (U-Th)/He zircon age for Lake Saint Martin is within error of the U-Pb single crystal zircon Manicouagan age of 215.56 ± 0.05 Ma (2σ) [11]. Therefore, with regards to the hypothesized Late Triassic multiple impact theory [1], the new (U-Th)/He zircon Norian age of 213.8 ± 3.0 Ma (2σ) for the Lake Saint Martin impact structure suggests that this impact structure could be a potential candidate for the proposed impact crater chain.

However, K-Ar and palaeogeographic studies have shown that the Obolon impact structure in Ukraine is younger (i.e., 169 ± 7 Ma [12] and <185 Ma [13]) than suggested earlier and can no longer be included in the hypothesized ~214 Ma multiple impact event. In addition, K-feldspars from Rochechouart have recently been ^{40}Ar-^{39}Ar dated and yielded plateau ages of 201.4 ± 2.2 and 200.5 ± 2.2 Ma (2σ) [14].

Whilst U-Pb and (U-Th)/He dating of single grains offers some advantages over many bulk whole rock or multi-grain mineral separate geochronological techniques, care obviously needs to be exercised in interpreting impact formation ages from grains that may have been heterogenically affected by the impact event.

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