NEW (U-Th)/He ZIRCON AND APATITE 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, [1] proposed that a multiple impact event from the fragmentation of a single bolide occurred in the Late Triassic and involved the following impact structures: Manicouagan (100 km diameter; 214 ± 1 Ma [2]) and Lake Saint Martin (40 km; 219 ± 32 Ma [3]) in Canada, Rochechouart (23 km; 214 ± 8 Ma [4]) in France, Obolon (20 km; 215 ± 25 Ma [5]) in Ukraine, and Red Wing Creek (9 km; 200 ± 25 and 210 ± 10 Ma [6-7]) 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 (Rochechouart, Manicouagan, and Lake Saint Martin), [1] suggested an impact event on Earth, similar to the multiple comet fragment impact of Comet Shoemaker-Levy 9 with Jupiter observed in July 1994 [8]. This study presents new (U-Th)/He age data for the Lake Saint Martin impact structure, which is a member of the postulated Late Triassic impact crater chain.

Geological setting of the Lake Saint Martin impact structure and previous age constraints: The ~40 km Lake Saint Martin impact structure (at 51°47' N and 98°32' W), located in the Interlake Region of southern Manitoba, is hosted by Ordovician to Devonian sedimentary rocks (sandstones, shales, and carbonates) on the NE flank of the Williston Basin, which overlie a Precambrian granite of the Superior Province of the Canadian Shield. Impact lithologies (also termed the 'St. Martin Series' [9]) comprise carbonate, granitic, and suevitic breccias together with impact melt rocks partially covered by post-impact Jurassic red beds and evaporites, as well as by Pleistocene glacial till. Outcrops of coherent impact melt rocks occur in the eastern central part of the impact structure. A detailed geologic overview of the Lake Saint Martin impact structure is given by [9-10]. In addition to the currently accepted whole-rock and mineral isochron Rb-Sr age of 219 ± 32 Ma [3], previous age determinations yielded K-Ar whole rock ages for impact melt rocks of 200 ± 25 Ma and 250 ± 25 Ma, respectively [9], as well as an apatite fission track age of 208 ± 14 Ma [10-11].

Samples and analytical techniques: Recently, we have used the low-temperature (U-Th)/He geochronological technique on individual zircon and apatite crystals to date a series of terrestrial impact structures [12]. We analysed optically preselected individual euhedral zircon (n=5) and apatite (n=7) crystals from a heavy mineral separate obtained from massive impact melt rocks that were collected ~7 km NE of the centre of the Lake Saint Martin impact structure.

(U-Th)/He dating results: Excluding one young age of 212.2 ± 5.6 Ma (2σ), a mean (U-Th)/He zircon age of 235.2 ± 6.2 Ma (2 standard error (SE)) was calculated for 4 zircon grains (Fig. 1a). An older cluster of 5 apatite grains yielded a mean (U-Th)/He age of 231.5 ± 7.2 Ma (2 SE), and two younger ages gave a mean (U-Th)/He age of 177.2 ± 1.4 Ma (2 SE) (Fig. 1b).

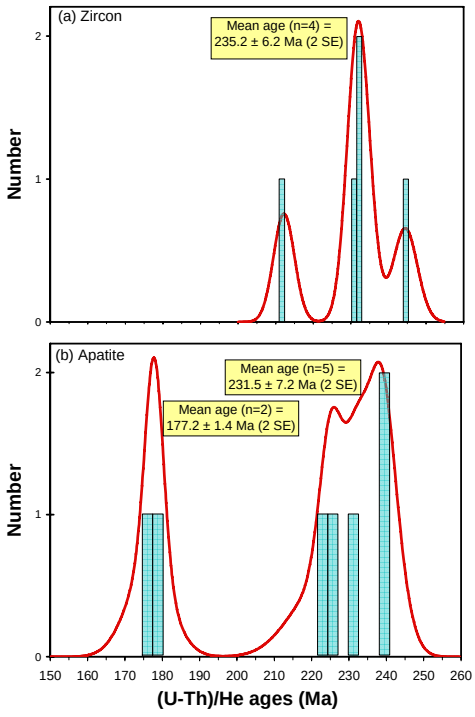

Figure 1. Cumulative probability (red lines) and histogram (blue boxes) plots of the Lake Saint Martin (U-Th)/He (a) zircon and (b) apatite ages.

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 He closure temperatures of 230°C for zircon and 105°C for apatite, assuming grain diameters of 100 µm, cooling rates of 1000°C/Ma, and using the He diffusion parameters of [13-14]) may provide important insights into the timing of Phanerozoic thermal events. The Precambrian-Paleozoic host rocks of the Lake Saint Martin impact structure did not undergo endogenic thermal metamorphism during the whole of the Phanerozoic. On the other hand, impact-triggered shock melting during the Lake Saint Martin impact locally caused post-shock temperatures of >1500°C, as indicated by the high-degree shock metamorphism and whole-rock melting [15].

Therefore, we consider the 235.2 ± 6.2 Ma (2 SE) zircon and 231.5 ± 7.2 Ma (2 SE) apatite mean ages, corresponding to Anisian to Carnian times [16], to reflect the Lake Saint Martin impact age. The new (U-Th)/He ages are similar to (i.e., within the comparatively large errors of) previous dating results [3, 9, 11].

The Earth experienced a series of worldwide extinction events in the Triassic (Smithian/Spathian (Olenekian [16]), Ladinian/Carnian; Carnian/Norian, and Norian/Rhaetian), but the number and causes of these extinction events are disputed [17-19]. Given the original size of the Lake Saint Martin impact structure, i.e., 40 km, this impact might be regarded as too small to be related to a semi- global extinction event (e.g., [20]). The link between the Lake Saint Martin impact and a proposed Ladinian/Carnian extinction event [19] remains speculative.

With regards to the Late Triassic multiple impact theory [1], ^{40}Ar-^{39}Ar and palaeogeographic studies have shown that the Obolon impact structure in Ukraine is far younger (i.e., 169 ± 7 Ma [21] and <185 Ma [22]) than suggested earlier and can no longer be included in the ~214 Ma multiple impact event. The new Anisian to Carnian age of the Lake Saint Martin impact structure also suggests one less candidate structure for the hypothetical Late Triassic terrestrial impact crater chain.

Conclusions: The newly obtained (U-Th)/He zircon (235.2 ± 6.2 Ma (2 SE)) and apatite (231.5 ± 7.2 Ma (2 SE)) ages suggest that the Lake Saint Martin impact structure is Middle to early Late Triassic (Anisian to Carnian) in age and, therefore, too old to be involved in the postulated ~214 Ma (Norian [16]) Late Triassic multiple impact event [1]. Conversely, the Obolon impact structure is too young to be involved [22]. Additional U/Pb-SHRIMP dating of impact melt-grown zircon and titanite crystals is desirable to test the (U-Th)/He Middle to early Late Triassic age for the Lake Saint Martin impact structure.

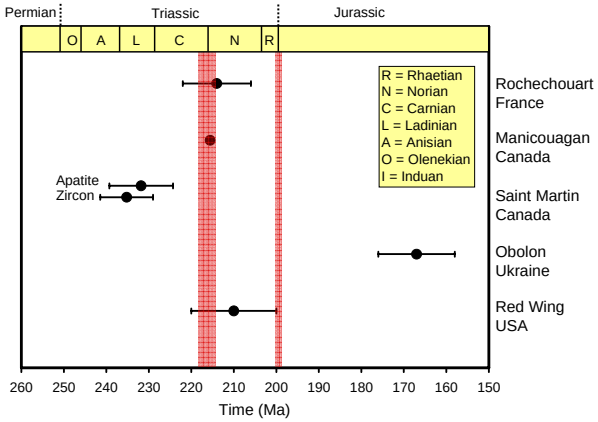

Figure 2. Time (Ma) versus impact age for the five postulated Late Triassic impact structures. The red bars highlight the Norian/Carnian and Rhaetian/Hettingian stages [16].

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