THE LAKE SAINT MARTIN IMPACT AND THE PROBLEM OF ISOTOPIC DATING ON ALTERED IMPACT MELT ROCKS. F. Jourdan[1], M. Schmieder[2], E. Buchner[2,3]. [1]Western Australian Argon Isotope Facility, Applied Geology & JdL-CMS, Curtin University of Technology, GPO Box U1987, Perth WA 6845, Australia (f.Jourdan@curtin.edu.au). [2]Institut für Planetologie, Universität Stuttgart, Herdweg 51, D-70174 Stuttgart, Germany. [3]HNU Neu-Ulm University, Wileystrasse 1, D-89231 Neu-Ulm, Germany.

Introduction: Lake Saint Martin (LSM) is a ~40 km diameter impact structure located in southern Manitoba, Canada. Its age is stratigraphically constrained by Devonian sediments that constitute part of the target rocks and Jurassic post-impact sediments (e.g., [1]). The LSM impact is an important feature in the hypothesis of multiple impacts at ~214 Ma proposed by Spray et al. [2] and thus, relevant to the debate of the role of multi-impacts in mass extinctions. Testing this hypothesis relies heavily on obtaining an accurate date for the LSM impact, which in turn, relies on careful isotopic dating.

Fig. 1: Fine-grained impact melt rock from the Lake St. Martin impact structure, Manitoba, Canada (sample courtesy: R. K. Bezys).

Some altered melt rocks (Fig. 1) were recovered ~7 km from the center of the impact and, in addition to drill core material [3], provides surface outcrop material for isotopic dating. Previous geochronological investigations yielded a Rb/Sr apparent age of 219 ± 32 Ma [3], and K/Ar apparent ages of 200 ± 25 and 250 ± 25 Ma [4]. These methods are however not in use anymore for impact dating due to now well-recognized difficulty of the task (e.g. [5;6]). Dating impact craters requires a very careful statistical test of the data and the sensitivity of these chronometers to geological perturbations without the possibility to assess the extent of the disturbance, prevent the use of these techniques.

Another approach has been to use low-temperature thermochronometers on apatite and zircon separates. This approach yielded a fission track age of 208 ± 14 Ma [7] for LSM and, more recently, a series of apparent zircon (n = 5) and apatite (n = 5) U-Th/He ages ranging over more than 15 and 20 Ma, respectively, with a preferred mean at 235 ± 6 Ma (n = 3 zircon grains [8]). However, the large range of apparent ages covered by a low number of data indicates some perturbation of the system as well. In order to qualitatively estimate the severity of the perturbation of the system, we undertook $^{40}Ar/^{39}Ar$ high-resolution step-heating (n=35) measurements on LSM melt rock separates.

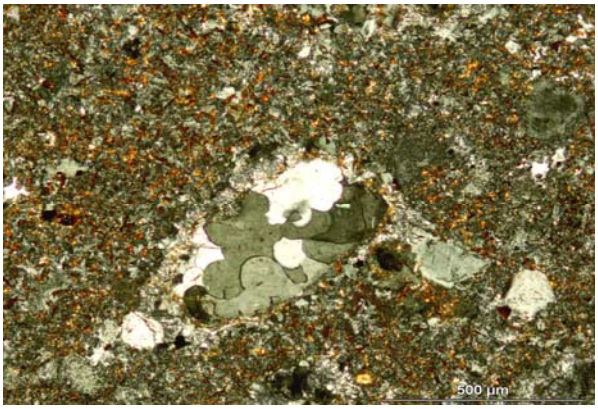

Fig. 2: Thin section picture of the Lake St. Martin impact melt rock with 'ballen quartz' in fine-grained altered melt matrix (cross-polarized light).

Samples: Hand specimens of the LSM melt rock investigated in this study show a characteristic red-orange colour (Fig. 1), typical of melt rocks that are severely altered and, therefore, are likely to be isotopically partially reset by hydrothermal fluids (e.g. [8]). The rock is composed of lithic and mineral debris of the target rock within a fine-grained, oxidized melt matrix of K-feldspar, plagioclase, pyroxene, quartz, and Fe-Ti oxides (Fig. 2); accessories include calcite, zircon, apatite, and titanite, some of which seem to be melt-grown.

$^{40}Ar/^{39}Ar$ Systematics: 5 mg of the LSM melt rock crushed in 200 µm size grains have been analyzed at the Western Australian Argon Isotope Facility. The samples were wrapped in a 0-blank Nb foil and step-heated using a 110 W Spectron Laser Systems, with a continuous Nd-YAG (IR; 1064 nm) laser rastered over the Nb package during 1mn. This approach is crucial to obtain a detailed structure of the $^{40}Ar/^{39}Ar$ distribution within the melt rock as conventional CO_2 laser directly used on "naked" multi-grain aliquots tend to yield temperature distribution not completely homogenous.

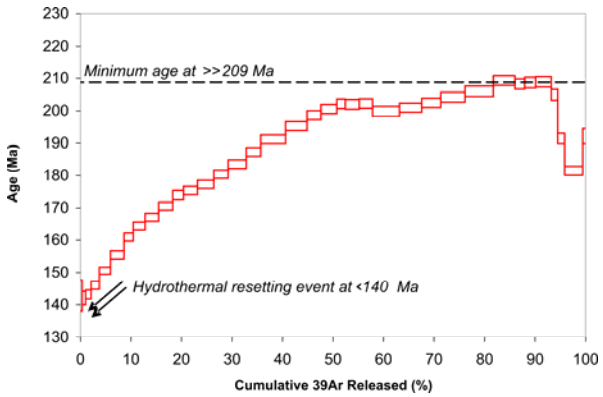

Fig. 3: $^{40}Ar/^{39}Ar$ high-resolution age spectrum illustrating the severity of the alteration undergone by the Lake St. Martin melt rock.

The melt rock sample yielded a increasing staircase age pattern throughout most of the step-heating experiment (Fig. 3). The low temperature ages start at ~140 Ma and the ages gradually increase toward ~ 209 Ma. The last steps (last 8% of the ^{39}Ar release) show a drop in the apparent age, back to ~ 180 Ma and, according to the high Ca/K ratio (not shown), correspond to contribution from Ca-rich domains of the melt rock.

Discussion: the main information carried by this analysis is the severity of the alteration and its effect on the isotopic ratios. The large amount of ^{40}Ar loss and/or recrystallization of new K-bearing phases during the hydrothermal alteration event is illustrated by the diffusion-like profile of the age spectrum. The apparent age is continuously rising over 80% of the experiment and reach a maximum at ~209 Ma, between 80 and 90% of the ^{39}Ar released. We can draw three conclusions. (1) The maximum age of the hydrothermal alteration event is given by the youngest steps at ~ 140 Ma. (2) The minimum age of the impact is given by the maximum age recorded by the $^{40}Ar/^{39}Ar$ chronometer at >> 209 Ma, i.e., the age of the LSM impact can be much older than that. (3) the severity of the alteration is such that not only the exact age of the impact cannot be constrained by the $^{40}Ar/^{39}Ar$ technique on the melt rock but will be also difficult to constrain by low-temperature thermochronological techniques (e.g., He closure temperatures are ~230°C for zircon and ~105°C for apatite, respectively) as all the minerals in the melt rock have been in contact with the hot hydrothermal fluids and might have lost part of their He and gained or lost U.

As such, obtaining the age of the LSM impact with low-temperature isotopic chronometers will be a difficult task (albeit worth trying). A reliable age result would consist in a large number of U-Th/He zircon analyses clustering near a single age as a single population (i.e., with reasonable MSWD and statistical numbers) and without a range of ages. Whether this is feasible remains to be seen for LSM, as well as to be tested on well-dated structures (this is currently in progress at the Arizona State University [8;9] and Curtin University).

One of the most alteration-resistant geochronometers is the high temperature U/Pb system, particularly when applied to minerals such as zircon and titanite. In fact, it is so resistant that the problem in dating impacts is that zircon or titanite grains from the target rock will not be reset during the impact and will tend to conserve part of their radiogenic lead and produce spurious old ages (e.g. [10]). However, when the minerals are authigenic, i.e., precipitated directly from the melt, U/Pb is the tool of choice to obtain a reliable and precise age (e.g., Manicouagan [11]). Authigenic titanite grains have been identified within the LSM impact melt rocks (Fig. 4) and will be run with the SHRIMP at Curtin University in the near future. If this approach is successful, it will be a good test for the U-Th/He ages currently available.

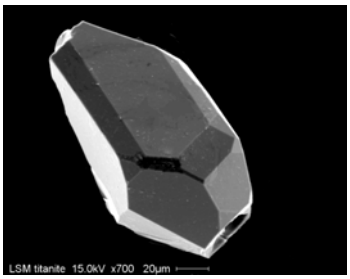

Fig. 4: Scanning electron microscope image image of a melt-grown idiomorphic titanite grain from the Lake St. Martin impact melt rock to be analysed with the SHRIMP.

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