SPATIAL U-PB AGE PRESERVATION IN SHOCKED ZIRCON – A BRIEF CASE STUDY FROM THE ROCHECHOUART IMPACT CRATER. C. Rasmussen[1,2] and D. F. Stockli[2], [1]Univeristy of Texas Institute for Geophysics (10601 Exploration Way, Austin, TX 78758; crasmussen@utexas.edu), [2]Jackson School of Geosciences, the University of Texas at Austin (23 San Jacinto Blvd & E 23rd St, Austin, TX 78712).

Introduction: The age determination of impact structures is notoriously difficult, and <10% of craters on Earth are assigned a precise and accurate age [1]. The zircon U-Pb system reliably used to determine the age of geologic events is affected by (partial-) open system behavior and/or re-crystallization in shocked metamorphosed material. Because of this issue, often a wide variety of ages are preserved from pre- to impact- to post-impact [2]. However, zircon is able to preserve partial age information, even of several thermal events, within a single crystal [2]. But extracting this information from those chemically complex altered samples can be challenging.

We use U-Pb LA-ICP-MS depth profiling to identify spatially-variable age domains preserved within shocked zircon material from the Babaudus melt rock of the medium sized (crater diameter ~20-25 km) Rochechouart impact structure in France (45°50'N; 0°56'W). Not only has the impact age been recently revised with the $^{40}Ar/^{39}Ar$ system to 201 ± 2 Ma [3] (recalculated to 203 ± 2 Ma, [4]) and 206.92 ± 0.32 Ma [4] but also the target rock at Rochechouart experienced extensive alteration by regional tectonics [5]. This alteration encompasses pre-Variacan intrusions, ductile deformation, synorogenic extension, and plutonic intrusions due to the Variscan orogeny [5]. Therefore, the crater lithologies are well suited to test if U-Pb depth profiling can be used to disentangle the complex alteration history of the target and the impact melt rock.

We show that U-Pb LA-ICP-MS depth profiling and the investigation of one-second ablation increments from crystal rim-to-center allows the identification of different U-Pb age domains that elucidate the complex alteration history within shocked zircon, that can also be also used to determine the time of impact. In addition, we show how shock metamorphism may influence the mode of age preservation.

Material and methods: We report zircon depth-profile LA-ICP-MS U-Pb age data from zircon extracted from the Babaudus melt rock of the Rochechouart impact crater. First, zircon crystals were imaged using a JEOL 6490LV SEM to identify the crystal morphology, followed by LA-ICP-MS analyses using a Photon Machines 193 nm Analyte G2 excimer laser-ablation system coupled to a Thermo Scientific Element2 HR-ICP-MS. Analyses were conducted against a primary and two secondary standards (GJ1; Plešovice; Pak1), and zircon crystals were continuously analyzed for 40s per spot to create a LA-ICP-MS depth profile. The data were corrected for downhole fractionation and an initial Pb correction after Stacey and Kramer correction was applied [6]. Finally, the data were exported in one-second increments to visualize and identify age trends within individual zircon crystals (using isoplot [7]). Weighted mean ages were calculated from age plateaus that formed for, at least, three continues seconds which overlap with one another in uncertainty. In addition, their robustness was tested by introducing the chi-squared distribution to evaluate their MSWD versus the number of data points [8]. If a chi-squared of 2–sigma was not achieved we recalculated the uncertainty by multiplying the standard error of the mean by the square root of the MSWD (Bab-3B).

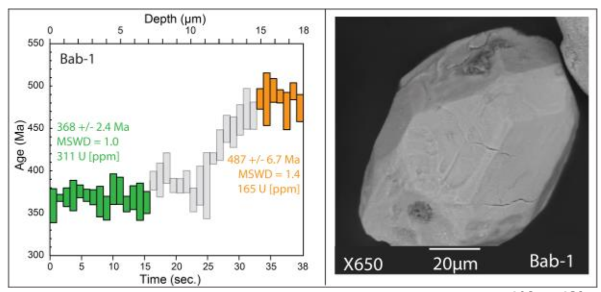


Figure 1: U-Pb depth profile including the calculated $^{206}Pb/^{238}U$ weighted mean ages and the U [ppm] concentration for a virtually undeformed zircon crystal. One-second increments are plotted vs. ablation depth and time. Possible age mixing in greyscale.

Results: The zircon crystals are either virtually undeformed (Bab-1) or display granular textures, in variable distinctness, ranging from well-developed (Bab-3) to medium-well developed (Bab-2) to nascent granular textures (Bab-4).

The U-Pb depth profiling reveals that different age domains are preserved within those crystals, weighted mean ages range from 487 ± 6.7 Ma (MSWD = 1.4) to 204 ± 2.8 Ma (MSWD = 1.3). Moreover, we observe that younger weighted mean ages are not only restricted to the crystal rim, but they can also occur in deeper located zones (Bab-3; Bab-4A).

By comparing the calculated weighted mean ages with the U [ppm] concentration obtained during the LA-ICP-MS analyses we observe a trend between younger ages and increased U concentration. In addition, we observe that especially well-developed granular textures can be linked to a crystal with a relatively high U [ppm] concentration but not to the youngest preserved ages (Fig. 2).

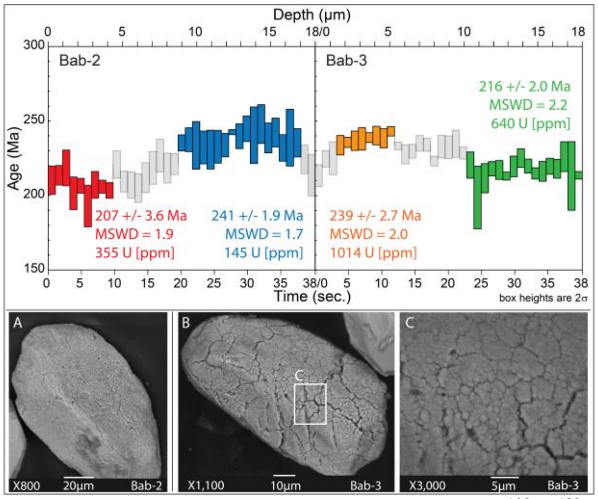
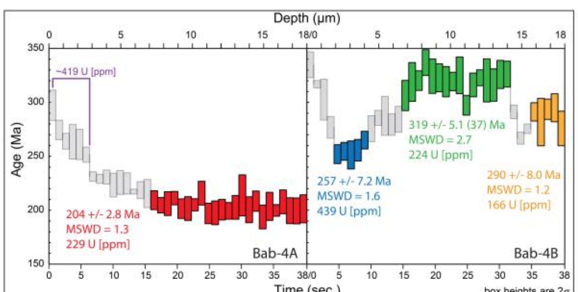


Figure 2: U-Pb depth profile including the calculated $^{206}Pb/^{238}U$ weighted mean ages and the U [ppm] concentration for zircon crystals displaying granular textures. Possible age mixing in greyscale.

In addition, we observe that crystals that were analyzed with two ablation spots, set next to one another on the crystal surface, result in different age profiles and therefore also provide plateau ages that vary significantly (Fig. 3).



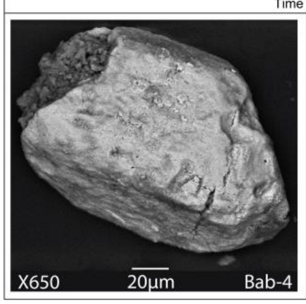


Figure 3: U-Pb depth profiles of two analyses, each conducted next to one another on the same zircon crystal. Within those tests, we observed crystals with divergent age patterns that only partially contained overlapping age information. ($^{206}Pb/^{238}U$ weighted mean ages and the U [ppm] concentration in colcor, Possible age mixing in greyscale).

Discussion and conclusion: Whereas the weighted mean ages obtained from the virtually undeforemd crystal (Bab-1) can be linked to regional tectonics, such as pre-Variscian intrusions (~480 Ma) and ductile deformation (~360 Ma) [5], the crystals displaying granular textures (Bab2-4) are mainly associated (partial) age resetting by the impact event (~207-204 Ma). In zircon with well-developed granule, the highest U [ppm] concentration is measured (Bab-3). Therefore our results verify previous findings, where the formation of granules has been linked to crystals with a high U concentration making them more susceptible to shock and post-impact temperatures leading to increased Pb loss and (partial) age resetting [e.g., 9&10].

Further, we demonstrate that the age preservation is highly inhomogeneous, even within a single crystal. Often several (partial) reset age domains are preserved and younger ages are not restricted to the crystal rim but also occur in interior zircon zones. Whereas younger rim ages are associated with zones with a relatively high U concentration (possible metamictization) that enhances Pb loss [11], younger interior zones are not. This finding suggests that other, petrological, factors influence the impact age preservation such as increased Pb loss due to granular textures [10]. Upcoming work will focus on the petrographic analyses (CL-imaging and EBSD mapping) of the zircon crystals presented here to better understand what drives the (impact) age preservation.

In conclusion, the zircon material from the Babaudus melt rock preserve a complex alteration history, ranging from ~487 Ma to the impact age. With aid of U-Pb depth profiling in combination with the data export in one-second increments we are able to distinguish different age domains within a single crystal and show how inhomogeneous zircon crystals are reset by the impact event. This result shows how important a detailed petrographic understanding of the sample in question is in order to choose ideal analytical spots for impact age determination. Moreover, younger rim ages (incl. the impact age) can remain undetected in crystals that are polished prior to analyses.

Acknowledgements: A special thanks to Dr. Darren Mark for supplying the sample material. We also like to acknowledge Lisa Stockli ((U-Th)/He and U-Pb Geo-Thermochronometry Laboratory) and Dr. James Maner (Austin Electron Microbeam Laboratories) for their exceptional support during the LA-ICP-MS analyses and the SEM imaging.

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