ACCURATE AND PRECISE DATING OF IMPACT EVENTS BY U-Pb ANALYSIS OF SHOCKED ZIRCON – A CASE STUDY FROM THE LAPPAJÄRVI IMPACT STRUCTURE

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Introduction: Of Earth's *ca.* 190 confirmed impact structures, only *ca.* 26 have robust ages considered to be reasonably accurate and precise [1,2,3]. The remaining void of geochronological data represents a major and fundamental gap in our knowledge of terrestrial impact cratering and inhibits detailed understanding of the role played by impacts in events such as biotic crises.

Of the terrestrial impact craters that have been assigned absolute ages with less than 2% uncertainty, most have been dated with the $^{40}Ar/^{39}Ar$ method, five have been dated with the U-Pb system in zircon ($ZrSiO_4$) and other minerals that crystallised from coherent bodies of impact melt, and four have tight stratigraphic constraints. Here we build on recent advances in our understanding of how zircon responds to extreme temperatures and pressures associated with an impact event [e.g., 4,5,6,7], and report the first high-precision U-Pb age for shocked zircon from a Phanerozoic impact crater. Furthermore, we compare our new results from the 23 km-in-diameter Lappajärvi impact structure, Finland, with the pre-existing $^{40}Ar/^{39}Ar$ framework for the site [8], thereby allowing comparision of the two isotopic techniques.

Results: We report a U-Pb concordia age for shocked zircon from the Lappajärvi impact structure of 77.8 ± 1.1 Ma (MSWD = 0.47; probability = 0.86; n = 4; 2σ; full external uncertainty). This age, obtained by *in situ* ion microprobe analysis, is resolvable from the previously published 'best estimate' $^{40}Ar/^{39}Ar$ age for the impact event (76.20 ± 0.29 Ma) and $^{40}Ar/^{39}Ar$ K-feldspar ages as young as 75.11 ± 0.36 Ma (Fig. 1).

Discussion: The U-Pb concordia age reported here is interpreted to most accurately reflect the time of the impact, sampling a higher isotopic closure temperature, as compared to the younger $^{40}Ar/^{39}Ar$ ages, which are interpreted to record the progressive cooling of different domains of the structure. The disparity between the zircon U-Pb age and the $^{40}Ar/^{39}Ar$ ages indicates that even the oldest $^{40}Ar/^{39}Ar$ ages obtained at medium- and large-sized craters may not always accurately record the timing of an impact event at a kyr level. Combining the U-Pb and $^{40}Ar/^{39}Ar$ chronometers provides a detailed record of the crater's post-impact history and increases the estimated extent of prolonged crater cooling to 2.7 ± 1.5 Myr, i.e., temperatures >200ºC locally lasted for at least *ca.* 1.2 Myr. This equates to a likely average cooling rate of *ca.* 260–580ºC/Myr for the Lappajärvi structure. Our results demonstrate that well characterised shocked zircon is likely to have wide utility as a tool in the accurate and precise dating of terrestrial impact events.

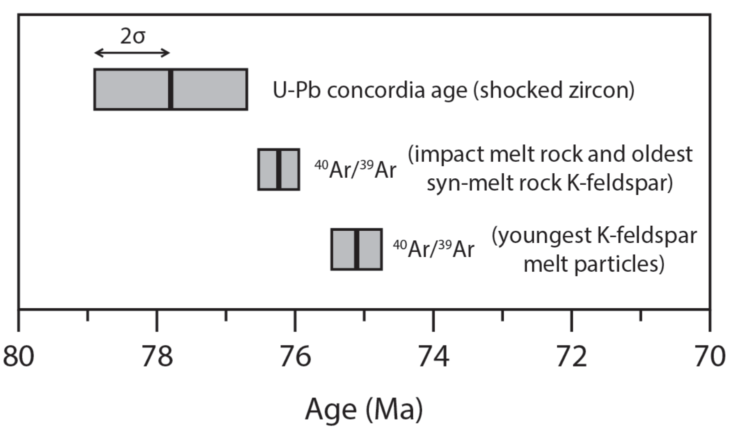

Fig. 1. *Ages for the Lappajärvi impact structure. A comparison of the new U-Pb concordia age here reported with $^{40}Ar/^{39}Ar$ ages, including analyses from the same sample [8]. All uncertainties are included.*

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