LA-ICP-MS U-Pb Dating of Shocked Zircons of Siljan Impact Structure, Sweden – Impact-related Ages or Post-impact Hydrothermal Pb loss?

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Introduction: Impact structures are traditionally dated through $^{40}Ar/^{39}Ar$ on impact melt glass [1], which "freezes" instantaneously relative to the analytical precision of the isotopic $^{40}Ar/^{39}Ar$ system and thus the resulting whole rock ages are directly related to the impact event. However, $^{40}Ar/^{39}Ar$ dating is sometimes not viable when impact glasses are contaminated by the target rock or absent due to erosion of the impact crater. U-Pb dating of shocked zircons from the Vredefort crater, South Africa [2], and the Chixulub crater, Mexico [3] have yielded reliable impact ages. Here we present zircon U-Pb spot data on rocks from the Siljan impact structure, south-central Sweden, that were affected by shock pressures ranging from 0 to 20 GPa [4]. The age of the impact event is well constrained to 377±2 Ma [5] and is therefore suitable for testing the effect of impact shock waves on zircon and to what extent the U-Pb system is affected at different shock pressure levels.

Methods: We analysed U-Pb in zircon from 29 samples (n=1601 spots) using a Bruker Aurora Elite ICP-MS equipped with a 193 nm Cetac Analyte G2 excimer laser and two volume HelEx2 sample cell. A spot size from 18 to 20 µm in diameter was used. GJ-1 and 91500 were used as primary and secondary reference material. The spots were selected on the basis of CL and BSE derived images of internal zircon structures, which were obtained using an FE-SEM with an accelerating voltage of 15 kV at Lund University to identify textures, such as planar shock features. Data was reduced using Iolite (version 3.63) and the age calculations and concordia plots were made using isoplot (version 4.15) [6].

Results: All analyses show concordant to discordant data with upper intercept dates ranging from 1883±100 Ma to 1657±40 Ma whereas the lower intercept dates lie between 540±150 Ma and 129±160 Ma, clustering between 350 Ma and 250 Ma, which fits to the general lower intercept range (500 Ma to 150 Ma [7]) of the Baltic Shield. There is no systematic difference in lower intercept dates between samples that lie within or outside of the central uplift. However, samples that are more distal from the impact centre show a positive correlation between discordance and U concentration.

Discussion: The upper intercept dates are in good agreement with known ages of the basement and interpreted as protolith ages [8]. The lower intercept dates overlap with the 377±2 Ma impact age [5], potentially implying a causal relationship between our lower intercepts and the age of the impact event. However, lower intercept dates do not decrease from outside to inside of the impact structure, i.e., there is no difference between zircon from the high shock pressure zones (15-20 GPa) to no shock pressure zones. Consequently, the lower intercept ages do not reflect the impact event. The presence of planar shock features, which are formed at p<20 GPa and T<900 ºC [9], indicates that the pT conditions were not high enough to reset the U-Pb system by shock waves. It is notable, however, that zircon from the no- to moderate pressure zones (10-15 GPa) are more discordant compared to those from the centre of the crater, and where discordance is positively correlated with U concentration. Furthermore, SEM images reveal metamict zircon domains in the more discordant grains. These zircons are more likely to be affected by Pb-loss that was induced by hydrothermal leaching [10], where perhaps the fluid migration was triggered by the impact [11]. In contrast, the less discordant data within the high shock pressure zone likely represent crust that was uplifted several kilometres (<10 km [12]) during crater modification, bringing rocks that were previously more deeply buried to near surface conditions at the time of the impact. Prior to uplift, zircons within rocks from the central uplift was likely continuously annealed and did not lose Pb at all or to the same extent as the surrounding crust, which was already near the surface. Pb-loss therefore mostly occurred after the impact event, leading to a more coherent and less discordant zircon population. Our results corroborates the model of [10], which stipulates that deeply buried zircon will continuously anneal whilst near surface zircon are more prone to lose Pb.

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