U–Th–Pb SYSTEMATICS IN ZIRCON AND APATITE FROM THE CHICXULUB CRATER, MEXICO

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Introduction: The Chicxulub crater, a buried ~180 km-diameter and ~66.04 million year-old peak-ring basin, is the largest Phanerozoic impact structure on Earth and has been convincingly linked to the K/T boundary mass extinction [1–3]. Impactites have been recovered from several boreholes, among which are a petroleum exploration well Yucatán-6 (Y-6, ~50 km radial distance from the crater center, depth 1,645m) and a scientific well Yaxcopoil-1 (Yax-1, ~65 km radial distance, depth 1,511 m). IODP–ICDP drilling into the peak ring is currently underway in hole Chicx-03B (~45 km radial distance, targeted depth 1,500 m). Affected by a long-lived (up to ~2 Myr) impact-induced hydrothermal system [4], rocks inside the Chicxulub crater are to variable degrees altered [5–8]. Previous U–Pb dating of zircon extracted from crater-hosted impactites [9,10], distal ejecta [11–13], and nearby sedimentary basins [14] yielded the approximate ages of the Early Paleozoic metamorphic–crystalline crater basement of the Maya Block and the impact. We conducted new LA-ICP–MS analyses of zircon and apatite from the Yax-1 and Y-6 cores to test for U–Th–Pb signatures potentially related to the hydrothermal system inside the Chicxulub crater.

Samples and Analysis: LA-ICP–MS analyses used a Varian 810 quadrupole system coupled to a Photon Machines Analyte 193 nm laser (25/50 µm spot size, 30 sec on sample after 14 sec of blank) using the Plešovice and FC5Z zircon standards, Madagascar and Bear Lake apatite standards, and NIST-612 glass [15]. We characterized and analyzed (1) shocked zircon [16,17] (n=10 spots on 7 grains ~20–70 µm in size) in a thin section of Yax-1_832.83 from the central unit 3, a brown impact melt breccia, at a depth of 833 m; (2) F-Cl-apatite (n=16 spots in 3 larger crystals ~400–1,000 µm in size) within a mafic clast in a sample of Yax-1_872.32 from unit 5, a green impact melt, at a depth of 872 m [7,18]; and (3) F-apatite (n=7 spots in 7 grains ~44–86 µm in size) in a thin section of Y6-N14-4 from the middle suevite unit at a depth of 1,208–1,211 m in core Y-6 [19].

Results: LA-ICP–MS analysis of the Yax-1_832.83 zircon (73–5,189 ppm U; 31–8,521 ppm Th; U/Th=1.71±0.63) yielded a weakly robust array of ages (MSWD=3.0; P=0.003), with an upper intercept age of 478±110 Ma, in line with ages for the Maya Block [9–13], and a poorly defined lower intercept age of -11±460 Ma. Noticeable common Pb and/or low concentrations of radiogenic Pb are indicated by a rather low ^{206}Pb/^{204}Pb ratio of ~44–1,200 (although one zircon yielded ≤63,000). No meaningful ages were obtained for either apatite sample. Yax-1_872.32 apatite has ^{206}Pb/^{204}Pb of ~9.7–44 and exhibits some Th zoning, with 4.2–34 ppm Th, 4.2–5.6 ppm U, and U/Th=0.9±0.5 in cores, and 15.5–103 ppm Th, 2.2–5.7 ppm U, and U/Th ≤0.2 in rims. Y6-N14-4 apatite has a ^{206}Pb/^{204}Pb of ~15.3–19.8, similar to impactite whole-rock values [10].

Discussion: ^{206}Pb/^{204}Pb is low from crystal rims to cores, indicating common Pb is not a sample surface contamination. Low ^{206}Pb/^{204}Pb might be attributed to Pb-rich fluids in a rather long-lived, impact-triggered hydrothermal system inside the Chicxulub crater. The presence of secondary galena [5], as well as chalkopyrite and barite [7] (both potential Pb carriers), in the Chicxulub impactites suggests Pb-laden fluids may have impregnated the initially permeable impact breccia [20]. However, ^{206}Pb/^{204}Pb in shocked zircon in Colorado (72–3,586) [11]; Saskatchewan (400–5,896) [12]; Haiti (37–4,640) [9]; Italy (1,557); and Spain (124–3,858) [13], i.e., far outside the crater, show a ^{206}Pb/^{204}Pb range that overlaps with that of the Yax-1 zircon. Although fluid-grown low-temperature zircon can incorporate larger amounts of Pb [21], Pb diffusion in non-metamict, inherited zircon crystals ≥20 µm in size over ~1 Myr requires temperatures >700°C [22], exceeding those of the hydrothermal system, although granular zircon aggregates may support diffusion at lower temperatures [17]. Closure temperatures for Pb diffusion in apatite ~20–1,000 µm in size are ≥400°C for variable cooling rates [23]. A hydrothermal (or diagenetic), low-temperature U–Th–Pb fingerprint in the Yax-1 and Y-6 zircon and apatite, therefore, remains unclear.

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