U–Pb ANALYSES OF NEOBLASTIC AND POROUS MONAZITE REVEAL TARGET ROCK AND IMPACT AGES AT THE HIAWATHA IMPACT STRUCTURE, GREENLAND

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Introduction: U–Pb dating of shocked zircon from impact melt rocks is a robust and proven method for determining the age of terrestrial impact structures. More recently, monazite alongside zircon has been used to date impact craters, such as the Araguainha impact structure, Brazil [1-2]. A critical methological advance has been documenting shock microstructures in monazite, for example microtwins and neoblasts, by electron backscatter diffraction (EBSD) analysis [3] and integrating this with U–Pb analysis by secondary ion mass spectrometry (SIMS) [2, 4-5]. Here we further explore the utility of monazite in dating impacts by analyzing shocked monazite from two impact melt rock samples from the Hiawatha impact crater, NW Greenland [6], that were both previously dated using in situ zircon U–Pb dating, revealing a Late Paleocene age for the crater at 57.99 ± 0.54 Ma [7].

Methods: Monazite grains were separated from two hemicrystalline clast-rich melt rocks collected proximal to the Hiawatha impact structure. Backscattered electron (BSE) imaging and microstructural characterization by EBSD were performed on an FEI Quanta FEG 650 scanning electron microscope (SEM) at the Swedish Museum of Natural History, Stockholm. The grains were then analyzed for U–Pb isotopic composition and age by SIMS on the CAMECA IMS1280 ion microprobe at the NordSIMS Laboratory, also at the Swedish Museum of Natural History. We applied a ~6 µm spot diameter, the smallest U–Pb analytical spot yet applied to shocked monazite, almost half the size of previous analyses performed on shocked monazite (~10 µm; [2, 4-5]), enabled by the recent installation of a Hyperion H201 RF plasma high-brightness oxygen source.

Results: Microstructural mapping of shocked monazite by EBSD revealed various shock deformation features, including shock microtwins and neoblasts. We also report monazite grains rich in densely packed sub-micrometer pores. To the best of our knowledge, similar porous grains have only been reported at one other impact structure [5] and never in the absence of other features of shock deformation, i.e., neoblasts or microtwins. In situ U–Pb analyses of porous and neoblastic domains define an impact-related discordant array, consistent with a Late Paleocene impact into Paleoproterozoic bedrock. The upper intercept age is within error of known ages of local bedrock in Inglefield Land, immediately adjacent to the structure (~1915 Ma) [8], despite no unshocked grains having been analyzed. The full discordant array, including granular and porous monazite grains, gives a lower intercept age of 63 ± 25 Ma, within uncertainty of the 57.99 ± 0.54 Ma age of the structure [7]. Targeted analyses on neoblasts plot closer to the lower intercept, giving a more precise lower intercept age of 73 ± 15 Ma, whereas analyses on porous monazite grains give a less precise, but still accurate, lower intercept age of 59 ± 36 Ma.

Discussion: In-situ U–Pb dating of shocked monazite grains here provides valuable insights into dating impact structures. Recrystallized domains of monazite grains show the greatest Pb loss, giving ages closest to concordant ages of previously dated shocked zircon [7]. However, while porous monazite shows less complete Pb loss, when analyzed alone they still give accurate impact ages. Therefore, we suggest that future studies should also consider porous monazite a promising target in dating impacts, especially when neoblastic monazite has not been found.

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