Helium Diffusion Kinetics of Shocked Zircons from the Chicxulub Impact Crater

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While meteorite impacts are thought to have profoundly influenced the habitability of the early Earth, the timing and magnitude of such events remain challenging to constrain. (U-Th)/He dating of impactites is an intriguing application of low-temperature thermochronometry and has been employed to directly date the timing of shock heating and post-impact hydrothermal circulation. However, in order to evaluate the reliability and accuracy of (U-Th)/He impact dates and the possible effects of post-impact hydrothermal fluid flow require a better mechanistic and quantitative understanding He diffusion kinetics in shock-damaged minerals. While the effects of radiation damage of He diffusion kinetics and He retentivity in apatite and zircon have recently been investigated, no systematic studies exist for the effect of shock microstructures and damage. In zircon, high doses of radiation damage, leading to metamictization, appear to substantially lower He retentivity in zircon as damage seems to become interconnected at percolation thresholds. In contrast, low levels of damage, such as in apatite, appear to lead to an increased He retentivity due to He trapping, leading to an increased activation energy for volume diffusion. This study investigates the effects of increasing levels of shock microstructures—ranging from brittle cracking, planar deformation features, granular (polycrystalline) textures, amorphization, to reidite transformation—on the He diffusion kinetics. The He kinetics analysis was done by in-vacuo single zircon fractional loss step-heating experiments of zircons that were previously imaged by scanning electron microscopy and classified for by shock microstructures and textures. While moderate shock-induced damage could lead to microstructural He trapping, enhancing He retentivity, pervasive impact microstructures and amorphization appears to lower He retentivity and closure temperatures through the introduction fast diffusion pathways. Granular textures lead to a dramatic reduction in effective domain size, decreasing the closure temperature. Quantification of the He diffusion kinetics as a function of impact microstructure allows for an evaluation of impact chronology, chronology robustness, and hydrothermal processes.