Constraining Impact Cratering Pressure and Temperature Conditions Using Zircon and Zirconia Polymorph Crystals

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The pressure and temperature conditions of impact cratering events provide insight for how episodes of high impact flux built and modified the primordial crust of the Earth and the Moon, affected Earth's early atmosphere through devolatization of crustal material, and played a role in the emergence of microbial life. To constrain the pressure and temperature conditions encountered during terrestrial and lunar impact events, we analyzed the microstructures and crystallographic relationships of zircon grains and zirconia crystals found within impact melt deposits at the Mistastin Lake impact structure, located in central Labrador Canada. Mistastin is a 28-km diameter complex impact structure with some of the world's best-preserved impact melt deposits. It is situated in a target rock suite comprising granodiorite, quartz-bearing pyroxene monzonite, and sodic-anorthosite, which are compositionally analogous to the lunar crust. Shock metamorphic features, and crystallographic orientations of zircon grains and zirconia crystals in impactite samples from Mistastin were analyzed using electron micro-probe analysis (EMPA) and electron backscatter diffraction (EBSD).

We report systematic orientation relationships of high-temperature zirconia and high-pressure zircon polymorphs preserved in two impactite samples from the Mistastin Lake impact structure. We identified three granular zircon grains containing domains of high-P polymorph reidite — the first occurrence of reidite to be discovered at Mistastin — and one fully granular zircon confirmed to be a Former Reidite in Granular Neoblastic (FRIGN) grain[1] in a glass-bearing breccia sample. In addition, we discovered four zircon grains with vermicular coronas of baddeleyite (monoclinic zirconia) in an impact glass sample, with orientation relations indicative of cubic → monoclinic transformation sequence. This implies the impact melt had a superheated temperature >2370 °C[2]. From our results, we demonstrate how the preservation of both high pressure and high temperature mineral indicators in a single impact structure can help for refining our understanding of hypervelocity impact events in the Solar System.

[1] Cavosie, A.J., Timms, N.E., Ferrière, L., and Rochette, P., 2018, FRIGN zircon-The only terrestrial mineral diagnostic of high pressure and high-temperature shock deformation: Geology, v. 46, p. 891–894, doi:10.1130/G45079.1.
[2] Timms, N.E., Erickson, T.M., Zanetti, M.R., Pearce, M.A., Cayron, C., Cavosie, A.J., Reddy, S.M., Wittmann, A., and Carpenter, P.K., 2017b, Cubic zirconia in >2370◦C impact melt records Earth's hottest crust: Earth and Planetary Science Letters, v. 477, p. 52–58, doi:10.1016/j.epsl.2017.08.012.