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Hot carbonates deep within the Chicxulub impact structure as revealed by clumped isotope thermometry

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Carbonate clumped isotope thermometry has increasingly been used over the last 15 years to reconstruct absolute temperatures in the geological record. Besides its common use in paleoclimatology, clumped-isotope analyses have recently shown great potential in constraining temperatures of carbonate phases involved in impact ejecta processes. The ~200 km wide Chicxulub impact crater in Yucatán, México, formed by a hypervelocity impact event ~66 Myr ago, constitutes an ideal natural laboratory to also apply this method on lithologies deep within an impact structure. The target stratigraphy at Chicxulub consists of a ~3 km thick Mesozoic carbonate-evaporite platform, and carbonates are present as clasts, fine-grained matrix particles, and secondary precipitates in impact melt-bearing breccias (suevites) and impact melt rock. However, the role of these carbonates in the cratering processes, such as shock-melting, devolatilization, and post-impact carbon cycle perturbations, remain poorly constrained.

Hence, we present the first clumped-isotope (Δ_{47}) analysis on drill cores from a transect throughout the Chicxulub crater that preserve hot signatures of impact-related thermodynamic processes. Together with conventional isotope analysis ($\delta^{18}O$ and $\delta^{13}C$) and high-resolution petrography, we introduce three scenarios to explain the high temperatures. 1) Outside the Chicxulub crater, the proximal ejecta blanket shows traces of thermal processing of carbonate material during ejection (>100°C). 2) Within the crater the influence of a widespread hydrothermal system is determined in all lithologies (>35.5°C) except post-impact sediments. 3) Superimposed on the hydrothermal overprint, highly elevated temperatures (up to 327 ± 33°C) in lower suevites and impact melt rocks are measured in microcrystalline calcite phases. This calcite resembles microcrystalline petrographic features produced by laser-melting experiments on limestones. We interpret that these features likely formed by impact-induced decarbonation and rapid back-reaction, in which highly reactive CaO recombines with impact-released CO_2 to form secondary $CaCO_3$ phases. This dataset provides the first physical and chemical evidence for back-reactions deep within the Chicxulub impact structure. This has important climatic implications for the Cretaceous-Paleogene mass extinction event, as current numerical models likely overestimate CO_2-release from the Chicxulub impact. We therefore propose that the recombination effect to form secondary $CaCO_3$ phases needs to be accounted for in these climate models.