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Uncovering the physiochemical conditions in the Chicxulub impact plume

COURTNEY J RUNDHAUG[1], MARTIN SCHILLER[2], KIRSTEN LARSEN[1], ZHENGBIN DENG[2], HERMANN BERMUDEZ[3], MARTIN BIZZARRO[2] AND YING CUI[3]

[1]Centre for Star and Planet Formation

[2]Centre for Star and Planet Formation, Globe Institute, University of Copenhagen

[3]Montclair State University

Presenting Author: courtneyrundhaug@sund.ku.dk

The formation of glassy spherules during asteroid impacts involves poorly understood condensation and cooling processes. The most accepted models indicate that glass spherules result from the cooling and recondensation of the materials once they reach the liquid-vapor coexistence curve. However, this notion is still lacking physical and chemical support. We revisit this hypothesis by analyzing the mass-dependent isotopic compositions of K and Rb in mm-sized pristine glass spherules from the K–Pg boundary layer in Gorgonilla Island, Colombia. We combine the new K and Rb isotope data with the previously acquired Mg and Fe isotope data to bring constraints on evaporation and recondensation processes and chemical evolution of the Chicxulub impact plume.

The spherules display a large range of K and Rb isotopic variations, including unfractionated, lighter, and heavier compositions relative to that of the upper continental crust, i.e., the presumably dominant precursor material of the spherules. While Mg and Fe isotopes indicate variable degrees of incomplete recondensation, the Rb and K isotopes reveal more complex recondensation and evaporation processes within the plume. Potassium tends to initially condense with Mg and Fe in the spherules at a slower rate, but subsequently experiences partial evaporation as the molten spherule remains suspended in the expanding impact plume. Conversely, the more volatile Rb shows two populations, where the spherules record (1) light Rb isotopes signatures in spherules with nearly unfractionated Mg and Fe perhaps due to Rb recondensation from a supersaturated and undercooled vapor, and (2) light Mg isotopes, signifying incomplete recondensation with partially evaporated Rb requiring these spherules to have remained molten for a sufficiently long period.

We conclude that Chicxulub impact spherules show both recondensation and evaporation signatures, providing isotopic evidence of their initial formation as recondensation products from the vapor in the impact plume. Additionally, the K and Rb data reveals later stages of physical and chemical evolution of the impact plume. Combined, the isotopic systems show that Chicxulub spherules underwent variable and complex fractionation events, and a complete explanation of their formation requires more than initial recondensation.