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Proximal ejecta deposits of the K-Pg Chixulub impact: The case for carbonate impact melt spherules

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When 65.5 million yrs. ago an about ∼10 km-sized asteroid hit Earth (Chicxulub impact event), ejecta was distributed world-wide to form the Cretaceous-Paleogene (K-Pg) event bed. Continuous sections across this K-Pg boundary document unambiguously that the "K-T" mass extinction was triggered by the Chicxulub event, not only because of the projectile's size but particularly by the specific composition of the target, namely a 3-km- (in the West) to about 4.5-km-thick (in the Gulf area) layer of volatile-rich carbonate and sulfate platform sediments on top of the crystalline basement (Schulte et al., 2010). Modeling, petrographic and geochemical studies on natural samples as well as experimental results show that shock pressure and high post-shock temperatures yield irreversible deformations and transformations on carbonate and sulfate target lithologies which are also expected to occur in the context of the Chicxulub event. Twofold devastating effects on life are predicted (i) dissociation of carbonates and sulfates with nearly instantaneous release of vast quantities of CO_2, and of about 100 to 500 Gt sulfur triggering severe climate effects, and (ii) deposition of carbonate and sulfate melts together with silicate melts, causing short-term disruption of the thermal conditions proximal to the crater. Silicate impact glasses with high CaO contents occur, for example, as spherules in the K-Pg event bed at Haiti and in melt lithologies from drill cores (e.g., Yucatan-6, Chicxulub-1, Yaxcopoil-1). Carbonate melt glasses have not been reported so far in K-Pg event beds. Hence, the following question was answered so far: Where are the huge amounts of carbonates that suffered impact metamorphism and were ejected in the Chicxulub event?

The Chicxulub ejecta deposits in the Gulf of Mexico area contain up to 80 wt% carbonates which, however, have been interpreted as precipitation product during diagenesis. In consequence, the abundant mm-sized ejecta spherules consisting of a sparry calcite core and a μm-thick silicate rim have been described as altered silicate glass spherules, with a diagenetic wall of smectite that formed after an early palagonite shell. The calcite in the inner part was interpreted as secondary phase after total dissolution of the original silicate glass. This proposed process is ad odds with observations in volcanoclastic deposits and theoretical considerations. There a complete pseudomorphic replacement of silicic glass by carbonates is extremely rare and has been observed to occur only by specific depositional conditions (e.g., at methane seeps). A physical constraint for such a glass replacement scenario without disruption of the delicate internal textures of the spherules is the significant change in density (ρ) from fresh glass (ρ $\leq$2.75 g cm^{-3}, depending on the Si content), over palagonite (ρ of 1.90 to 2.10 g cm^{-3}), to Cc (ρ = 2.71 g cm^{-3}). Other arguments in favor for a primary origin of calcite in the impact spherules are: (i) calcite spherules contain smaller Cc spherules, separated by a few tens of μm-thin smectite; (ii) silicate glass spheroids contain bubbles filled with radially grown calcite; (iii) considerable compositional differences co-occur with sharp contacts within one spherule – dissolution of these different types of "glass" would require very different pH/eH conditions; (iv) the K-Pg event bed in NE Mexico, Texas, and Alabama contain spherules with evidence for silicate-carbonate liquid immiscibility, spherules consisting of sparry calcite or accreted μm-sized clacite crystals as well as silicic spherules rimmed by sparry calcite; (v) the cathodoluminescence of Cc spherules differs drastically from that of diagenetic calcite; (vi) foraminifera shells that occur together with the carbonate spherules lack alteration or diagenetic effects; and finally, (vii) preservation of silicic glass in certain K-Pg event beds implies that replacement of glass by smectite happened in a short time, indicating that weathering and not diagenesis was the major reason for alteration of the spherules. In conclusion, our petrographic data indicate that the Chicxulub impact event yielded considerable amounts of carbonate melt that was deposited in the Gulf of Mexico region.

Schulte, P. et al. (2010) Science, in press.