RECONSTRUCTION OF THE CHICXULUB EJECTA PLUME'S DEPOSITIONAL HISTORY AT DRILL CORE YAXCOPOIL-1

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Introduction: A 100 m thick continuous section of suevite-like impactites was recovered by the ICDP-Yaxcopoil-1 (YAX-1) drilling in the K/T Chicxulub crater. This section was subdivided based on petrographic characteristics [1]: Upper Sorted Suevite (USS) (794–808 m), Lower Sorted Suevite (LSS) (808-823 m), Upper Suevite (US) (823–846 m), Middle Suevite (MS) (846–861 m), Brecciated Impact Melt Rock (BMR) (861–885 m) and Lower Suevite (LS) (885–895 m). Furthermore, two 8 and 80 cm thick suevitic dike breccias (SD) occur in underlying megablocks at 909 and 916 m [2]. This study aims to reconstruct formation conditions of these impactites, which includes a) an estimate of the temperature regime during deposition that is inferred from preserved shock metamorphic features and the degrees of crystallization of impact melt rock particles with liquidus phase phenocrysts [3], b) identification of depositional processes from petrographic and sedimentological characteristics, and c) a time-frame for the deposition of the impactites.

Samples and Methods: 63 samples and photographic documentation of the ~100 m sequence were available. Petrographic analyses by optical microscopy and scanning electron microscopy were used to identify component types. The bulk chemical composition of impact melt particle types was determined by defocused-beam electron microprobe analyses. Image analysis was applied to provide shape-parameter data on impact melt particles, grain-size distribution and modal composition of the suevite-like rocks.

Results: The lowermost suevitic units LS and SD are characterized by a relative large content of lithic clasts derived from the sedimentary cover rocks along with silicate impact melt rock particles. These melt particles are unsorted and indicate flattening and shape-preferred orientations that suggest deposition of low-viscosity silicate impact melt particles at high turbulence. A cooling gradient towards the BMR is indicated by the dominance of crystallized impact melt particles in the LS compared to the dominance of melt particles that were rapidly quenched to glass in the SD. This is also supported by the higher ratio of preserved shock features in zircon in the SD compared to the LS [4]. The BMR is characterized by the exclusive presence of unsorted, fully crystallized silicate impact melt particles and a matrix that was locally melted. These impact melt particles exhibit a grossly similar composition alike the coherent impact melt sheet at Chicxulub [5]. All lithic clasts incorporated indicate incipient resorption, moreover, carbonate clasts are thermally metamorphosed to marble. Shock metamorphic features suffered strong thermal annealing, e.g., zircons exhibit coarse recrystallization of diaplectic glass, suggesting prolonged annealing at T ~ 700 °C [3]. Melt particles with features suggesting airborne transport first appear in the overlying MS. A thermal gradient is indicated in the "airfall suevites" from the MS to the USS by the dominance of rapidly quenched impact melt rock particles towards the top (LSS-USS) and more strongly crystallized impact melt rock particles in the MS-US. This is confirmed by the ratio of preserved shock metamorphic features in zircon that overall indicate that all zircon bearing components deposited in the suevite-like units of Yax-1 suffered temperatures over ~ 1200°C because no high-pressure polymorphs were retained [4]. The general scarcity of anhydrite clasts in the suevite-like section, with some exemptions in the LSS-USS, may indicate the decomposition of anhydrite under ejecta plume conditions [6,7]. Furthermore, carbonate clasts indicate progressive recrystallization to marble-like textures with depth towards the BMR. Shape parameter data on impact melt particles of the airfall suevites indicate weak thermal annealing, possibly due to incipient welding in the MS, which requires temperatures >700°C [3], and no indication for thermal softening in the US-USS. Melt particles in the MS-US exhibit no shape-preferred orientation, possibly due to deposition under high turbulence. Distinct shape-preferred orientations of very rapidly quenched melt particles in the USS suggests deposition under low turbulency. The LSS and USS appear matrix deficient compared to the MS-US. Grain-size distribution indicates clear sorting in the USS and some less well developed sorting in the LSS, where the coarsest grain-size fraction is missing. Aquatic reworking is indicated in the uppermost meter of the USS with laminations and cross-bedding structures. Some melt bodies in the LSS discount previous inferences that the USS and LSS represent resurge-tsunami-reworked ejecta [8]. Atmospheric interactions with the collapsing ejecta plume are also indicated by the presence of melt particles in the US that are reminiscent of "droplet chondrules" [9,10] that are possible vapor condensates. Moreover, melt particles and lithic clasts in the uppermost US exhibit accretionary rims and melt particle types that crystallized under elevated oxygen fugacities are relatively enriched in that section [7].

Conclusions: The temporal evolution of the cratering process from the initial stage of excavation to the collapse of the ejecta plume at Chicxulub was recorded in the 100 m thick sequence of melt-rich impactites of Yax-1 [11]: The LS and SD were likely emplaced in the first minute after the impact by the passing ejecta curtain that interacted with the expanding ejecta plume [12]. These ejecta deposits were capped by a tongue of coherent impact melt that was likely transported outward from the crater's center during the collapse of the central uplift. According to latest numerical models, the central uplift at Chicxulub likely collapsed about 5 minutes after impact [13]. On top of the BMR, the collapsing ejecta plume deposited airfall suevites. The basal airfall unit MS may have been deposited due to a density current-like clumping of hot debris [9]. With progressive cooling, atmospheric interactions with the collapsing ejecta plume occurred and led to a winnowing out of matrix fines, formation of melt particles that crystallized under elevated oxygen fugacities, and accretionary rims. Particles larger than ~ 10 cm were only deposited from the ejecta plume until ~820 m in the LSS. According to [12], particles of that size fall back within 10 minutes after the initial collapse of an ejecta plume. A late stage of ejecta plume collapse is characterized by the reestablishment of atmospheric conditions and decreasing turbulence that led to distinct sorting in the USS. The largest grain size near the top of the USS suggests recording of the fall back at Yax-1 until ~ 1 hour after the cessation of turbulent conditions through a reestablished atmosphere [1,11].

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