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THE FINAL SETTLING OF METEORITIC MATTER ON THE PEAK-RING OF THE CHICXULUB IMPACT STRUCTURE AT SITE M0077A OF IODP-ICDP EXPEDITION 364.

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Introduction: The ~66.0 Myr old, ~200 km diameter Chicxulub impact structure marks the K/Pg boundary and is the only terrestrial crater with an unequivocal peak-ring. In 2016, the International Ocean Discovery Program (IODP) and the International Continental Scientific Drilling Program (ICDP) jointly drilled the 1335 m deep Site M0077A into the Chicxulub peak ring offshore of the Yucatán Peninsula and successfully recovered a continuous core from 505.7 to 1334.7 mbsf (meters below sea floor). The core is mainly composed of three lithological units: ~110 m of Paleogene sedimentary rocks (post-impact interval), ~130 m of suevite and impact melt rock (upper peak-ring interval), and ~610 m of granitoid basement, intruded by pre-impact dikes and intercalated with suevites and impact melt rocks [1].

This abstract focuses on Core 40R-Section 1 (616.24–617.68 mbsf), which samples the ~75 cm "transitional unit" between the upper impactites and early Paleogene sediment. This unique interval of the core, marked by siderophile element enrichments and pyrite-rich intervals, is studied here in detail to better constrain the final phases of impact crater formation and determine the fate of the Chicxulub impactor.

Samples and methods: Core 40R-1 has previously been subdivided into three main lithological units [1], (1) the upper part of the core is composed of marlstone (Unit 1F), from 616.24 to 616.58 mbsf; (2) an intermediate section composed dominantly of micrite (Unit 1G), from 616.58 to 617.33 mbsf; (3) a size-sorted suevite (Unit 2A), from 617.33 mbsf downward.

Bulk samples were selected throughout the core and analyzed for major and (siderophile) trace element concentrations, using (isotope dilution) ICP-MS and INAA (and ICS). Osmium isotope ratios (^{187}Os/^{188}Os) were determined for a smaller subset of samples using N-TIMS. Particular attention was paid to the highly siderophile elements (HSE: Os, Ir, Ru, Pt, Pd, and Re) that can potentially trace contributions from the inferred carbonaceous chondritic impactor [2,3]. In total, 41 samples were measured for iridium by four independent laboratories, resulting in a unique profile. In addition, four discrete core sections at 616.54–616.60, 616.62–616.68, 617.30–617.34 and 617.35–617.37 mbsf, sampling the three units and their transitions, were subjected to μXRF analysis (2D maps) and LA-ICP-MS.

Results: At its base, Core 40R-1 transitions from a fine-grained, sorted suevite (Unit 2A) into laminated carbonate-rich claystone to micrite, interbedded with silt-sized laminae at 617.32 mbsf (Unit 1G; Fig. 1). The upper part of the sorted suevite (617.34–617.50 mbsf) appears finer grained than that at the base of the core (below 617.50 mbsf). The suevite is silicate-rich and contains carbonates, both as fine clasts (mm) and in the matrix. Just above a relatively sharp contact, the lowermost part of the laminated micrite unit (617.30–617.33 mbsf) contains several mm-thick layers, enriched in Ni over a few cm (Fig. 1). Overlying the Ni-rich layers, the sediment is composed of alternating dark brown/gray fine carbonate layers. Another sharp contact separates the micrite-rich interval of Unit 1G from the overlying Unit 1F, which at its base is composed of gray/green claystone that may represent stylolites and contains pyrite (up to a few cm in size).

Siderophile element concentrations, including those for the HSE, show systematic variations across the transitional unit, with strong Ni and Co enrichments at the top and bottom of the unit relative to the rest of the M0077A core (this work and [4]). While Ni, Re, and Os show the highest enrichment at the bottom of the transitional unit, the upper part of the unit (616.55–616.60 mbsf) is characterized by approximately one order of magnitude higher Ir, and Ru contents than the average continental crust. The highest anomaly reaches 0.8-1.0 ppb Ir in a ~5 cm interval, concurrent with the lowest initial ^{187}Os/^{188}Os ratios of ~0.218. Relatively flat CI chondrite-normalized HSE patterns are observed in the upper part of the unit, while HSE concentrations elsewhere in the core display HSE signatures equivalent to those of the upper continental crust, with relatively low Ir and Ru and high Pt and Pd concentrations.

Discussion: The upper part of the transitional unit displays an Ir enrichment comparable to K/Pg boundary sites, proximal to Chicxulub (e.g., 0.8 ppb Ir at Guayal, Tabasco and 1.0-1.5 ppb at Bochil, Chiapas). These values are lower than those measured for many distal K/Pg boundary sites (e.g., 4.9-8.0 ppb at Gubbio, Italy or 16.6-56 ppb at Caravaca, Spain; [3,5]). Initial Os isotope ratios (^{187}Os/^{188}Os$_i$) and Re/Os in the transitional layer gradually decrease from 0.367 to 0.218 and 35.45 to 0.85, respectively, from bottom to top. The former are within range of those found for global K/Pg boundary deposits (^{187}Os/^{188}Os$_i$ of 0.139-0.230; [6]). These results suggest that the projectile component, consistent with a carbonaceous chondritic composition, is enriched in the uppermost part of the transitional layer just below the post-impact pelagic carbonates that are early Danian in age. The HSE enrichments appear distributed over a thicker interval (~5 cm) than typically observed for most distal Ir-enriched sites [3,5], which may reflect the faster sedimentation rates recorded in the crater core.

While the siderophile element enrichment at the bottom of the unit remains enigmatic, it likely indicates the presence of meteoritic or mafic components that were hydrothermally redistributed, based on bulk Pt/Ir and pyrite compositions. The observed bulk Ir enrichment at the top of the unit denotes the presence of a uniquely preserved meteoritic component within the Chicxulub impact structure. The observed impactor signature, likely the result of atmospheric fallout, places important time constraints on the deposition of the transitional unit. Given the absence of obvious carrier phases for the Ir anomaly and it position across a lithological boundary and pyrite interval, the observed enrichment was likely transported as fine, microscopic dust. Hydrocode modeling infers such particles were deposited within a few years (at most) after the impact [7]. This suggests a fast return to low-energy environments in the crater and strikingly rapid reappearance of life to the site [8].

Conclusions: The very top of the transitional unit of IODP-ICDP Expedition 364 Site M0077A represents the top of a well-preserved, continuous K/Pg boundary sequence with a well-defined elevated HSE anomaly that uniquely documents the final deposition of remnants of the Chicxulub asteroid.

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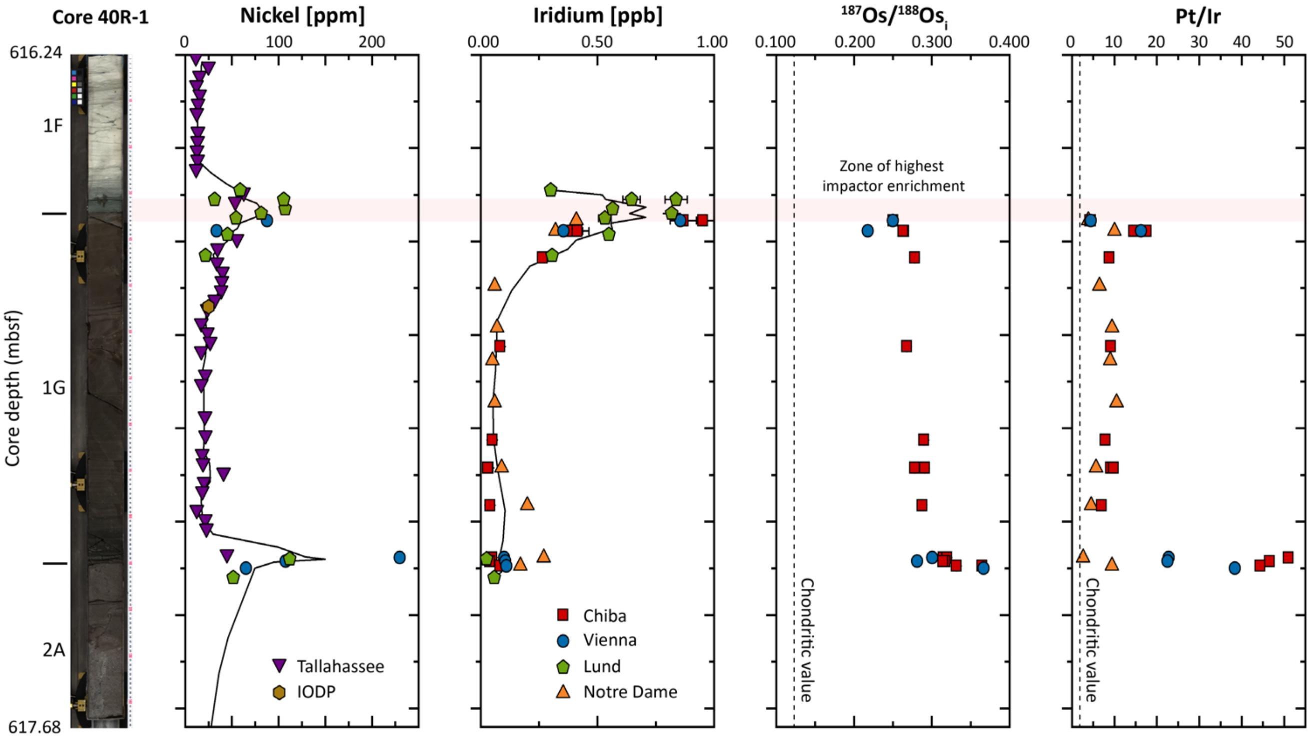

Figure 1: Siderophile element profile across the transitional unit in Core 40R-1 at Site M0077A of IODP-ICDP expedition 364. Black lines represent three-point moving averages.