DRILLING THE K-PG CHICXULUB CRATER PEAK RING: INSIGHTS AND MORE QUESTIONS.

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Introduction: In 2016, the International Ocean Discovery Program-International Continental Scientific Drilling Program Site M0077 drilled into the peak ring of Chicxulub during Expedition 364 [1]. Key goals of this project were to answer the following questions: 1) What rocks comprise and how are peak rings formed? 2) How are rocks weakened during large impacts to collapse and form relatively wide, flat craters? 3) What caused the environmental changes that led to a mass extinction and what insights arise from biologic recovery in the Paleogene?, and 4) Can impacts generate habitats for chemosynthetic life? Exp. 364 Site M0077 drilled into a depression in the top of the peak ring in the northwestern portion of the impact structure where it was observed to have the highest relief (hence shallowest drilling target) and clearly imaged early Cenozoic sequence including the Cretaceous-Paleogene (K-Pg) boundary on seismic reflection data. Coring started at 506 meters below seafloor (mbsf) and completed at 1335 mbsf exhibiting a stratigraphy that included 100 m of Eocene and 10 m of Paleocene carbonates overlying ~225 m of K-Pg boundary impactites and ~600 m of granitic basement rocks intercalated with impact melt and pre-impact dikes [1]. These cores, associated downhole geophysical logs, laboratory analyses, and related modeling efforts have resulted in >50 peer-reviewed publications of which we highlight key examples that provided insights into the expedition questions.

Key Findings: The Chicxulub peak ring proved to be Carboniferous volcanic arc granitoids [2] uplifted from ~10 km depth [1] and emplaced along an ~80 m thick melt-rich shear zone [3]. Modeling and structural analyses together support the process of acoustic fluidization as critical in the impact crater modification stage implying, in the case of Chicxulub, 10s of km rebound in the transient cavity, followed by gravitational collapse of the central uplift wherein target materials regain coherency through a process of increasing effective block size culminating in macroscale fault-transported blocks 100s of m in scale forming the peak ring [1,3,4]. Physical properties of the peak ring emphasize generation of porosity through shock, lowering velocity and density by ~25% [5,6]. Comparison of pre-impact to K-Pg boundary stratigraphy and geochemical analyses imply the ejecta curtain and impact plume contained carbonate dust, sulfur/sulfate aerosols, and soot which generated global cooling as a key driver of the mass extinction [7,8,9, 10]. The K-Pg boundary sequence within Chicxulub includes melt rock, unsorted suevite generated by melt-water interactions and ground-hugging flows, sorted suevite consisting of proximal ejecta returned to the impact via ocean resurge and settling throughout the basin, seiche deposits, a returning rim-wave tsunami deposit, and a transition layer the deposited over 10-20 years post impact capped by an Iridium-rich layer that corresponds to the global K-Pg boundary clay layer [7,11,12]. Yet, life was present within the water column overlying the marine Chicxulub impact crater and within the sediments within years of the impact with algae playing a key role in productivity [13,14,15]. Hydrothermal minerals, geothermochronometry, and seismic evidence of upflow zones in the central impact basin give evidence for an impact hydrothermal system that persisted for millions of years [16,17]. Modern elevated active cell counts and DNA extraction demonstrate that thermophilic bacteria continue to reside within the crater lending credence for impact generated chemosynthetic ecosystems [18].

New Questions: While each of these results yield insights into impact cratering processes and effects on the biosphere, these findings suggest additional lines of inquiry. What are the timing and controls on regaining strength of the acoustically fluidized target materials under different impact and planetary conditions? What controls the transition from peak ring to multi-ring impact basins? Is sulfur, dust, or sort the dominant driver of extinction and what is the duration of global cooling? What is the role of the ocean in colonization of impact basins? Where are the different habitats within an impact basins and what processes affect temperature and fluid flow through time? What is the evolution of an impact melt sheet and how is it different in a marine versus terrestrial impact? What changes occur in a chemosynthetic ecosystem as impact craters cool?

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