WHAT HAS CHICXULUB TAUGHT US ABOUT LARGE IMPACT PROCESSES AND MASS EXTINCTION? S. Gulick1, J. V. Morgan2, and IODP-ICDP Expedition 364 scientists*, 1University of Texas at Austin, Institute for Geophysics & Department of Geological Sciences, Austin, Texas 78758, USA (sean@ig.utexas.edu). 2Department of Earth Science and Engineering, Imperial College London, SW7 2AZ, UK.

Introduction: Three terrestrial impact structures, Vredefort, Sudbury and Chicxulub impact structures, are large enough to be comparable to multi-ring impact basins observed on other planets [1]. Study of these craters is critical to understanding large impact basin formation as 3-D characterization is currently only possible on Earth where seismic, potential fields, petrophysics, and direct sampling from scientific drilling can be applied. Of these three craters only the ~200 km diameter Chicxulub impact structure contains a fully preserved ring structure, terrace zone, peak ring, melt sheet, and impactite sequence. In particular the integration of core-log-seismic data within the peak ring of Chicxulub at IODP-ICDP Site M0077 has been a critical path for the testing models of formation and architecture [2].

Figure 1. Gravity image of Chicxulub with the coastline of the Yucatán in white, cenotes as black dots, and Site M0077A as a red square. Exterior, Outer and Inner Rings are clusters of faults where the area of these ring faults shown in gray. A terrace zone is present from the inner ring to beneath the peak ring and shown here as a zone of slump blocks. The discontinuous topography of the peak ring is outlined in white and observed as a gravity low. Modified from [3].

The ~66 Ma Chicxulub impact event is also the only asteroid impact conclusively linked to a mass extinction event. A global impact-generated sedimentary layer that is unique in the geologic record marks this Cretaceous-Paleogene boundary (K-Pg). Study of Chicxulub is important for examining the environmental effects of the impact event to understand the so-called kill mechanisms, and how life recovered globally and within the crater. Here we summarize recent geophysical and borehole studies of Chicxulub and emphasize key discoveries applicable for studies of impacts generally.

Testing Geophysical Insights: Potential fields data over Chicxulub highlight two key features: 1) the low densities (Fig. 1) associated with both the crater fill and the peak ring, and 2) high magnetic anomalies in some way associated with the impactites [3]. Two key constraints were added by Expedition 364 and previous drilling data. First, all peak ring lithologies from suevite to uplifted granite are low velocity, high porosity, and low density [4]. Detailed analyses of the Chicxulub cores demonstrate much of this porosity is from micro-fracturing by shock effects [5]. Second, while the melt rocks drilled exhibit reversed polarity magnetization consistent with the time of impact, numerous zones within the suevite that caps the peak ring or are within the central basin exhibit normal polarity [6]. This result may reflect hydrothermal overprinting of magnetization acquired at the time of the impact.

Seismic imaging offshore has allowed mapping of faults from the central basin outwards. We observe a zone of slump blocks present beneath the peak ring outwards to the inner rim or outer ring of the impact basin (Fig. 1) [3]. The inner ring consists of one or more large offset (>500 m) faults at radial distances from crater center of 70-85 km. The outer ring also consists of a group of large faults 95-105 km radial distance (thus crater diameter is 190-210 km). Exterior ring faults are also present in most imaged azimuths at distances < 125 km. Assessment of the topography these ring faults would have generated is needed for better comparison with multi-ring basins elsewhere. These observations show that exposed portions of terrace zones are a small part of the structural collapse features related to crater modification and that the structural deformation that generates crater rings and basin rims is complex and appears to be influenced by target heterogeneities [3].

Integration of seismic imaging and Expedition 364 drill cores demonstrate that peak rings form in a manner consistent with the dynamic collapse model [7]. Implications are that significant vertical transport occurs during large impacts as in the case of Chicxulub where the peak ring granitoids originated at ~10 km depth. Seismic images show the peak ring is underlain by Cretaceous sediments transported as slump blocks but also
100s of meters of seismically indistinct material that extends to beneath the crater floor and in places reaching 2 km thick. We interpret this seismic facies as a breccia derived from transient cavity wall collapse. Full waveform images in concert with the Expedition 364 drill cores further allows definition of distinct units of suevite present inside, above, and outside of the peak ring which form the crater floor.

ICDP Yaxcopoil-1 demonstrated the dynamic sedimentological setting of Chicxulub, not just immediately after impact but well into the Paleocene, due to newly created topography and slopes [9]. With 100% core recovery, IODP-ICDP Expedition 364 with its 100% recovery provides a very high temporal resolution record of the impact aftermath. Site M0077 includes 130-m of impact melt rock and suevite, covered by < 1m of micrite-rich carbonate deposited over the subsequent weeks to years. The presence of terrestrial soil derived biomarkers and a reflected rim-wave tsunami deposit at the top of the 130-m sequence implies that the poorly sorted suevite may have been deposited through a combination of density flows and melt-water interactions, and the well sorted suevite deposited in a flooded crater within the first day of the Cenozoic (Fig. 2) [6].

Environmental Effects of Impacts and Resiliency of Life: The K-Pg mass extinction demonstrates that impact events can have global consequences. Impacts cause mass extinction by inducing rapid physical and chemical changes to the atmosphere and/or oceans that cannot be accommodated by adaptation or motility. In the case of Chicxulub and the K-Pg extinction it appears that the presence of sulfur-rich evaporites, and other volatiles, was a key, but not unique, ingredient driving the extinction [6,10]. Site M0077 however also provided evidence for rapid return of life to the crater environment [11] and generation of a subsurface habitat.


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