Geophysical Research Abstracts,
Vol. 10, EGU2008-A-04577, 2008
SRef-ID: 1607-7962/gra/EGU2008-A-04577
EGU General Assembly 2008

Future integrated ICDP-IODP drilling of the Chicxulub impact crater: scientific targets

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Background

Chicxulub is the most pristine large impact crater on Earth and is the only terrestrial impact crater with a demonstrable peak ring, which displays the morphological characteristics of peak rings on other planetary bodies, such as our moon. Chicxulub is also the only terrestrial crater with a known global ejecta layer and a clear link to a mass extinction event. Hence, Chicxulub is a unique natural laboratory and has a critical role in providing ground-truth information on large-scale cratering processes, including the formation of peak rings, and the global effect of a large-scale impact event.

Chicxulub was formed in a shallow shelf environment and almost immediately buried by post-impact Tertiary sediments, which now form an $\sim$1 km thick package. This accounts for its pristine nature but unfortunately masks the detailed characteristics of this unique and critical structure. Thus, mapping Chicxulub is limited to geophysical investigations and drilling. Seismic reflection, refraction, gravity, magnetic, and MT data are available across the crater. Geophysical data, when combined with the results of previous drilling data from PEMEX, UNAM and the results of ICDP drilling in 2002 (Urrutia-Fucugauchi et al., 2004) have led to a reasonably well-constrained three-dimensional structural model of the crater. Due to the location restrictions of the offshore seismic lines, however, interpretations of the central portion of the crater are reliant on potential field data, refraction data and shallow drill holes. Thus, models of the central crater remain less constrained, partly due to the inherent ambiguity of interpretations of geophysical data, and partly because there are no deep drill holes that can ground-truth the models in this critical area of the structure.

Results from workshop on joint IODP-ICDP drilling

An international workshop to discuss joint IODP/ICDP drilling of Chicxulub was held in September 2006. The consensus of the 50 attendees from 11 nations was that, in order to produce an accurate structural and lithological model of Chicxulub, and large-scale craters, in general, new deep drill holes are required at Chicxulub (Morgan et al., 2007). Two holes were identified as critical: 1) A drill hole to document the lithological and structural character of the peak ring and test competing models for its formation, and 2) A drill hole to penetrate through the impact breccias and melt sheet within the central basin, and into the underlying stratigraphic uplift.

Understanding peak-ring formation is fundamental to understanding the mechanics of large-scale cratering processes and demonstrable peak ring materials have never previously been sampled. Based on current geophysical models, the proposed drill hole will penetrate $\sim$700 m of post-impact sediments, the materials of the peak ring itself (determining its lithologies and their physical state) and pass through an enigmatic set of inwardly dipping seismic reflectors, which may have significance for cratering kinematics, at $\sim$2.35 km depth. The peak ring materials have low seismic velocity and are predicted to have a relatively high porosity, which combined with their proximity to the hot impact melt sheet may have led to intense hydrothermal circulation, mineralization and possibly a niche for exotic post-impact fauna.

The proposed hole through the impact melt sheet and into the underlying stratigraphic uplift. The top of the impact melt sheet has been identified in previous nearby PEMEX drill holes (S-1, C-1) and the impact melt sheet is identified in the seismic data as a zone of increased seismic velocity (5.8-6.0 km/s). The principal objective of this hole is to characterize the suevitic breccias and impact melt rocks and their variation with depth within the central basin. These data, along with the geophysical data, will be used to calculate the total volume of melt produced and to constrain the energy of impact, which is fundamental to modeling the global climatic/environmental effects of the Chicxulub impact. Other objectives include determining variations in lithic and mineral clast content, composition and degree of shock, in an attempt to reconstruct the original (crystalline) target. For the impact melt itself, the focus will be on a search for the projectile component and its variation, evidence of differentiation, mineralization and hydrothermal alteration. Given the similarities in size and target composition, it is likely that there will be direct comparisons with the Sudbury impact structure and its impact melt lithologies, manifest largely as the 2.5 km thick Sudbury Igneous Complex (Therriault et al., 2002).

Update on drilling

An IODP proposal to drill a 3-km hole through the peak ring was reviewed by SPC and considered to be of high scientific merit. However, the recent dramatic rise in drilling costs has made a deep hole prohibitively expensive. An ICDP hole to drill the melt sheet was also considered to be of high scientific merit, and ICDP encouraged us to develop the proposal further. We are now looking at descope options for drilling the peak ring, and are considering the possibility of a joint IODP-ICDP program to drill three 1500 m deep holes offshore in the central sector of the crater, that transect across the peak ring to sample the earliest Tertiary to examine resurgence of life, study the post impact hydrothermal system, determine origin of the peak ring lithologies to understand their formation, and to drill the melt sheet to examine the energy released during the K/T impact. The transect area has been recently surveyed by 3-D seismics (Morgan et al., 2005) and borehole locations appear reasonably well constrained from seismics and potential field data. An update on progress will be presented at the meeting.

Morgan, J. et al. (2005) EOS 86(36), 325-332. Morgan J. et al. (2007) *Scientific drilling 4*, 42-44. Therriault et al. (2002) *Economic Geology 97*, 1521-1540. Urrutia-Fucugauchi J. et al. (2004) *MAPS 39*, 787-790.