ACTIVE SEISMIC AND DRILLING STUDIES OF THE CHICXULUB IMPACT CRATER: A STATUS REPORT.

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Introduction: The 65 Ma Chicxulub impact structure (Fig. 1) in Mexico is the largest Phanerozoic impact crater known on the Earth and likely records one of the more significant events in Earth history. Burial beneath ~1 km of Tertiary carbonates has preserved the crater in a uniquely pristine condition, where it is amenable to detailed investigation by drilling and surface geophysics. The Chicxulub crater was the focus of many past international efforts and is the focus of recent and upcoming efforts including continental (ICDP-1) drilling in 2002, future integrated ocean drilling program (IODP) drilling, and a combined 3D onshore-offshore tomographic study and 2-D/2.5-D seismic reflection survey planned for Spring 2004.

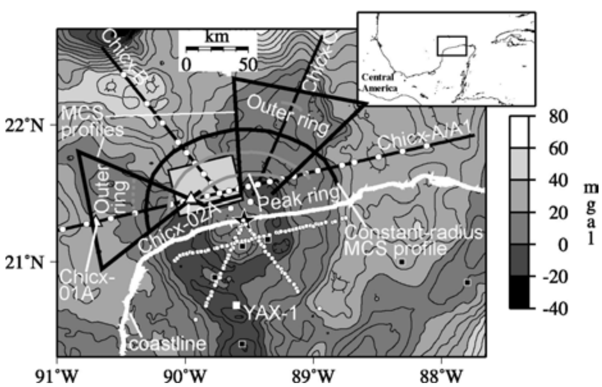

Figure 1. Gravity map of Chicxulub impact crater (courtesy of A. Hildebrand and M. Pilkington) showing location and layout of 1996 seismic program and planned 2004 MCS experiment. Coastline is delineated by the white line, center of crater is shown as a black star, and locations of onshore wells are marked by black squares. The white square shows the ICDP borehole (Yax-1), and white triangles mark the proposed IODP drill sites Chicx-01A and Chicx-02A. Inset shows location relative to the Yucatan Peninsula and Central America. Gray lines are locations of peak ring, crater rim, and outer ring as observed on existing MCS profiles. Shaded box shows location of UK 3D tomographic survey in Fig. 2.

Previous Work: These recent and planned geological and geophysical studies build upon previous studies including gravity surveys, seismic profiling, impact crater modeling, and industry drilling. In 1996 a combined seismic reflection/refraction experiment (Fig. 1) provided new constraints on the size and structure of the crater [1]. Major observations from these profiles are shown in Figure 2 and include the morphology of the peak ring, slumping on normal faults, position of the crater rim, vertical offset across the outer ring, and the destruction of the Cretaceous stratigraphy. An irregular, rugged peak ring was imaged that stands a few hundred meters above the basin floor with an average diameter of 80 km. The profiles also showed 3-5 km of slumping from the crater rim towards the center of the crater that occurred along a single fault or a sequence of faults on all profiles. The crater rim was shown to average 130 km in diameter. Further outward from the crater's center an outer ring with an averaged diameter of 195 km exhibited 400-500 m of total vertical offset of the Cretaceous stratigraphy observed on two profiles. This offset exists either entirely across a monocline or straddling a monocline and a fault-bounded asymmetric graben. The outer ring appears to be related to bands of dipping, linear reflections in the crystalline crust that dip towards the crater center. At one location the reflections appear to offset the Moho by ~1 s (3-4 km). The images suggest that immediately after impact, there were two distinct inward-facing asymmetric scarps (the crater rim and outer ring) demonstrating that Chicxulub is a multi-ring crater. Inward of approximately 85 km diameter, no intact Cretaceous stratigraphy is observed, providing constraints on excavation cavity and transient cavity size. Restoring the slumped blocks to their pre-impact positions and reconstructing the transient rim uplift gives an estimate of 90-105 km for the diameter of the transient and excavation cavity. Scaling laws [2] place the maximum depth of excavation at 12 km and the depth of the transient cavity (with respect to the uplifted crater rim) at 35-40 km.

Recent and Upcoming Studies: Efforts to drill into the crater include the recent ICDP onshore drilling which cored ~100 m of impact breccia and IODP offshore drilling. Offshore IODP drilling at Chicxulub is one of the top four Mission Specific Platform (MSP) proposals and is expected to be scheduled for drilling early in the new program. ODP/IODP proposal 548-Full suggested two drill sites (Fig. 1 and 2). Chicx-01A would drill 4.3-km-deep borehole just outside the crater, in order to penetrate the Tertiary section, the proximal ejecta blanket, the entire Mesozoic section, and the Paleozoic basement rocks. Principal objectives of this borehole are to identify the thickness, composition, and character of the target rocks and proximal ejecta. Chicx-02A is a 3-km-deep borehole, which proposes to penetrate the peak

peak ring within the impact basin. Principal aims of this borehole are to determine the composition of the peak ring, test models of peak-ring formation, constrain the mechanism of transient cavity collapse that forms the final crater, and to use this information to improve estimates of crater size. Drilling at the shallow-water Chicxulub sites would be part of the post-2003 IODP multi-platform operation and is tentatively planned for 2005. The UK seismic program is, in part, a response to the recommendation by the science advisory panels that high-resolution 3D seismic tomography over the peak ring will be important for final drill-site selection and for understanding the sub-surface structure once drilling has occurred at Chicx-02A.

The UK-funded 3D tomographic experiment will collect onshore-offshore wide-angle data covering the northwest quadrant of the crater (Fig. 2). The UK teams will conduct a 3D tomographic survey over the northwest quadrant of the Chicxulub impact crater; embedded within the 3D tomographic survey will be a smaller, high-resolution tomographic survey centered over proposed IODP drill site Chicx-02A. The program will take place on the R/V *Ewing* in 2003, and will use the *Ewing* airgun array to shoot to a grid of OBS and land-based receivers. The planned 3D tomographic survey will consist of 40-60 OBS receivers (2 deployments of 20-30 instruments) in a staggered grid with resulting OBS instrument spacing of ~5 km (Figure 4); 100-150 land stations will record all shots. Shot spacing along the lines will be 50 m and cross-line spacing will be 3.75 km. The planned high-resolution survey will use 20-30 OBS instruments at a spacing of ~3.75 km, with 24 air gun profiles at a shot spacing of 50 m and a cross-line spacing of 1.875 km (Figure 4). The UK seismic program will map features critical to our understanding of large crater formation and the KT impact that were not sufficiently resolved by the larger-scaled reconnaissance study of 1996, and will undoubtedly map out new unknown features of the Chicxulub impact crater.

NSF-ODP recently funded a collaborative seismic reflection imaging (Fig. 1) and modeling program to: 1) acquire four new regional deep reflection profiles crossing through the proposed IODP drill sites Chicx-01A and Chicx-02A, 2) collect a pseudo-3D MCS survey during data acquisition of the UK tomographic survey, and 3) conduct 3D numerical modeling of the impact. Our goals are fourfold. First, we seek to determine the direction of approach and angle of the Chicxulub impact through the collaborative seismic and modeling effort. Experimental and numerical modeling studies show that vaporization depends on impact angle, with oblique impacts resulting in as much as a 15-20 fold increase in vapor production. Thus any constraints we can place on the obliquity of the Chicxulub impact will help quantify the amount of volatiles released into the atmosphere by the K-T event. Second, we will map the deformation recorded in the upper crust near the crater center that has previously been poorly imaged and cannot be properly imaged with tomographic data. Third, by imaging the peak ring and other morphologic features in the northwest quadrant of the crater we can further understand the physical parameters of the Chicxulub impact structure and in doing so complete the site survey requirements for the IODP holes. Fourth, we intend to model the 3D collapse of an asymmetric transient crater. This modeling will not only help us better understand the mechanics of large impact craters, but will also quantify many of the environmental effects of the KT impact. The combined results of this proposed work, together with the UK tomographic experiment and the continental and oceanic drilling should significantly expand our understanding of the KT impact and by extension other large-diameter bolide impacts on Earth and our neighboring rocky planets.

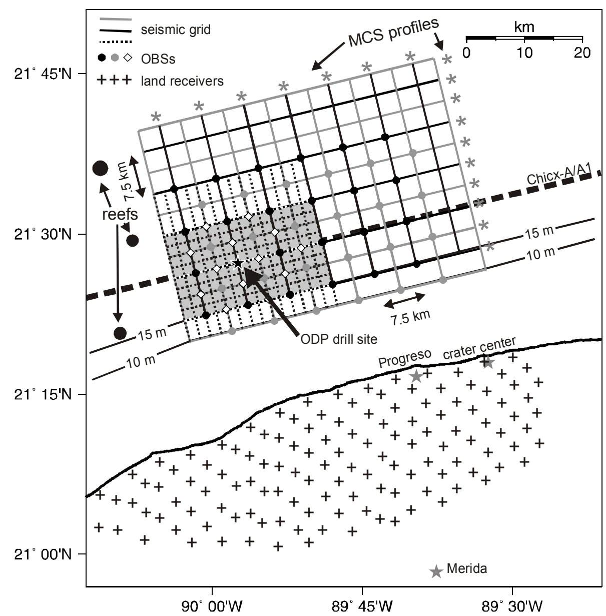

Figure 2. Planned UK-US-MEXC seismic program over the peak ring, consisting of nested MCS-OBS survey centered at IODP drill site Chicx-02A. Current plan is to 1) deploy 40-60 OBSs (circles and diamonds, 2 deployments of 20-30 instruments) within a 52.5x37.5 km grid, with air gun profiles at a cross-line spacing of 3.75 km, and to 2) deploy 20-30 OBS (circles and diamonds in gray shaded region) within a 26.25x15 km grid, with air gun profiles at a cross-line spacing of 1.875 km. Approximately 100-150 land receivers will record all shots (see Fig. 1). Coincident MCS data will be shot along the seismic profiles marked with the gray asterisks.

References:

[1] Morgan, J., Warner, M., and the Chicxulub Working Group (1997) *Nature*, *390*, 472-476, [2] Melosh, H.J. (1989), *Oxford monographs, 11*, Oxford University Press.