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The Chicxulub Scientific Drilling Project (CSDP)

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In the June and July issues of *Meteoritics & Planetary Science*, we present the initial results of the Chicxulub Scientific Drilling Project (CSDP).

The Chicxulub crater is a unique impact structure associated with one of the most dramatic geological events in the Phanerozoic. It is buried beneath carbonate sediments in the northern Yucatán Peninsula, southeastern Mexico. It has a diameter of 180–200 km and a complex multi-ring structure (Fig. 1). It represents the youngest and the best preserved of only three large multi-ring impact basins documented in terrestrial geological record. The impact that excavated the Chicxulub crater has been dated at 65 Ma and, therefore, is related to the event that marks the Cretaceous/Tertiary (K/T) boundary and the extinction of about 75% of species (50% of genera, including the dinosaurs) (Alvarez et al. 1980; Hildebrand et al. 1991). This crater presents a unique opportunity to discover new important information on the formation and characteristics of such large multi-ring impact craters, their environmental and climatic effects, and their implications for geological and biological evolution.

The Chicxulub crater has been the focus of numerous studies, particularly in the last decade. Studies include offshore and onshore geophysical surveys, drilling/coring, laboratory analyses of impact breccias and melt, and computer modeling (e.g., Sharpton et al. 1992; Morgan et al. 1997, 2000; Collins et al. 2002; Ebbing et al. 2001). Drilling inside the structure and in its immediate vicinity has been carried out within the oil exploratory program by PEMEX with intermittent core recovery and, more recently, by the National University of Mexico (UNAM) Chicxulub drilling program resulting in continuous core recovery.

The need for drilling/coring within the deeper part of the impact basin, where the crater floor is buried under several hundred meters of Tertiary carbonate sediments, was recognized already during the early studies of the crater because only the uppermost crater-related deposits were drilled (Urrutia-Fucugauchi et al. 1996; Rebolledo-Vieyra et al. 2000). With the initiation of the International Continental Scientific Drilling Program (ICDP), interest in drilling the crater increased and CSDP was developed as part of an international collaboration within the framework of ICDP.

The drilling project was financed by ICDP and the National University of Mexico (UNAM) and was coordinated by UNAM. The CSDP borehole Yaxcopoil-1 was drilled from December 2001 through March 2002 in the southern sector of the crater at ~62 km radial distance from the approximate crater center at Chicxulub Puerto (Fig. 1). The Yaxcopoil-1 (Yax-1) borehole was planned to core continuously into the lower part of the post-impact carbonate sequence, the impact breccias, and the displaced Cretaceous rocks. The drill site at Hacienda Yaxcopoil (Figs. 2a and 2b) was selected based on integration of gravity, magnetics, magnetotelluric and offshore seismic surveys, pre-existing boreholes of PEMEX and UNAM programs, site conditions and access, land ownership, water availability, and an environmental impact assessment (Urrutia-Fucugauchi et al. 2001).

An INDECO rotary drill rig from Perforaciones Industriales Termicas, S. A. (PITSA) and the coring device from the Drilling, Observation, and Sampling of the Earth's Continental Crust (DOSECC) were used for the drilling/coring operations. Rotary mode was used to drill from the surface to the depth of 404 m. After running wireline logs and casing the borehole, drilling was continued with wireline coring of the carbonate sequence and impact lithologies. Cores 63.5 mm in diameter were obtained to the depth of 993 m. At this depth, the HQ coring string became stuck and eventually was left in the hole as casing. Coring resumed with an NQ string (core diameter of 47.6 mm) to the final depth of 1511 m.

Geophysical logging was conducted after completion of drilling through the first 400 m and reaching the final depth of 1511 m. Observations included hole deviation and azimuth (caliper, SP), magnetic susceptibility, radioactive element contents, gamma ray, electrical resisitivity, temperature, and conventional and waveform sonic. The Yax-1 borehole is open and available for experiments under a ten-year agreement between the Yaxcopoil Hacienda and UNAM. Several geophysical logging campaigns have been conducted after completion of the drilling project.

A core laboratory and temporary repository was established at the University of Yucatán in Mérida. Facilities for digital photography of core boxes and core segments and

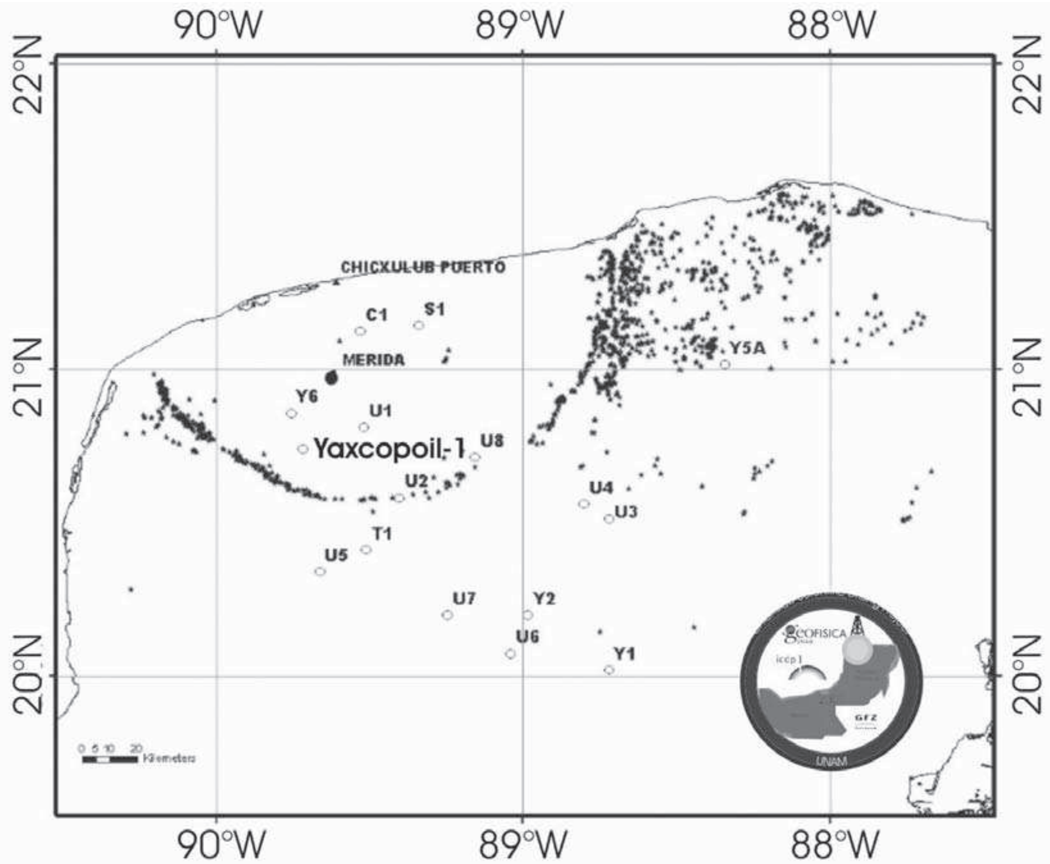

Fig. 1. Location of the CSDP borehole Yax-1.

Fig. 2a. Drilling operations at Hacienda Yaxcopoil.

an automated digital core scanner were available for documentation. Cores were transported from the drill site daily, and information was made available on the CSDP web site through the ICDP information system. After completion of drilling operations, cores were packed and shipped to the UNAM Core Repository in Mexico City. Cores were further examined and then cut longitudinally in halves (one half is the project archive, while the other one is available for sampling by CSDP science team). Full cores and halves were digitally scanned for high resolution images, some of which are presented in the papers included in these two volumes of *MAPS*.

The CSDP recovered core from the lower Tertiary carbonate sequence, impact breccias, and overlying Cretaceous carbonates, down to the depth of 1511 m. Core recovery was 98.5%. The Tertiary carbonates were cored between 404 m and 795 m. Impact breccias were cored between 795 m and 895 m, presenting an unexpectedly thin sequence of impactites, given the greater thickness of such breccias in wells located toward and outward the crater center relative to Yax-1. Beneath the impact breccias, a sequence of carbonate rocks (limestones, dolomites, and anhydrite) were recovered. The dip of the carbonates varies from being sub-horizontal to up to 60 degrees, and these rocks contain thin dikes of breccia and melt. Impact breccias have been divided into six units which, from top to bottom, are (prelimary log names): redeposited suevites (794.63–808.02 m), suevites (808.02–822.86 m), chocolate-brown melt breccias (822.86–845.80 m), glass-rich variegated suevites (845.80–861.06 m), green monomicitic-autogene melt breccias (861.06–884.92 m), variegated polymicitic, allogenic clast melt breccias (884.92–894.94 m) (Dressler et al. 2003). A similar subdivision with a different classification of the lithologies

Fig. 2b. The CSDP rig at Hacienda Yaxcopoil.

has been proposed in Dressler et al. (2003) and in other papers included in these volumes (e.g., Tuchscherer et al. 2004; Stöffler et al. 2004). The Cretaceous sedimentary rocks below about 895 m are cut with dikes of polymict breccias and display zones of monomict brecciation. They appear to represent "megablocks" displaced by the impact event. Anhydrite layers, the thickness of which varies from a few centimeters to up to 15 m, and make some 27% of the megablocks. Organic-rich layers and oil-bearing units are present at depths between 1410 and 1455 m (according to Kenkmann et al. [2004], this layer starts at 1263 m.).

Scientific study of Yax-1 core samples and complementary studies are allowing researchers to: 1) evaluate the link between the Chicxulub crater and global K/T boundary layer and mass extinction; 2) study large-scale cratering processes; 3) investigate post-impact crater modifications, environmental evolution, and faunal recovery; and 4) provide additional constraints on target compositions and deformation styles characteristic of the zone flanking the collapsed transient cavity.

Initial studies have already provided important progress on these issues and, at the same time, left questions unanswered and opened new lines of inquiry. For instance:

1. The proportion of basement material within the impact breccias is higher than observed at other craters, opening exciting possibilities for investigations of excavation models and the nature of the Yucatán crust.
2. The impact breccia layers are thinner than predicted, with implications for crater structure, breccia emplacement, and crater formation.
3. Although there are layers of anhydrite in the target rocks, there is a surprising lack of evidence for anhydrite in the impact breccias.
4. Several different analyses document the importance of post-impact hydrothermal alteration within the core samples.
5. Recovered blocks of Cretaceous and impactites provide valuable material for laboratory analyses, despite the effects of subsequent alteration.
6. The origin of the thick carbonate sequence beneath the breccias (>600 m) has provoked an interesting debate and requires further study.
7. Initial studies of the impactite and early Paleocene stratigraphy have provided interesting age constraints and information on sequence completeness (for example the identification of the 29r/29n chron boundary just above the appearance of the first Danian fossils), provoking a debate about the age of the Chicxulub impact.

In two consecutive volumes of *MAPS*, we present the initial results of the CSDP Science Team. These volumes include papers on the petrology, mineralogy, geochemistry, hydrothermal alteration, and degree of shock of the impactites, as well as interpretations of their deposition, including numerical modeling. Papers on the late Cretaceous section include studies of their stratigraphy, sedimentology, structure and deformation, and cross-cutting dikes, as well as interpretations of their origin. Other contributions include physical property measurements on the core, seismic-, bio- and magneto-stratigraphic studies, and evidence for the existence of a hydrothermal plume in the early Tertiary ocean.

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