A new study published in the journal Science addresses long-standing questions on the formation of large impact craters

Drilling into the Chicxulub crater (Yucatan, Mexico) reveals how peak-rings form and the complex dynamics of large asteroid impacts

Main results presented in the Science paper are on the nature of the peak-ring, which is a distinctive characteristic of large complex craters. The new findings from the Chicxulub drilling show that the peak-ring underground structure is formed by basement rocks, providing important constraints on the formation mechanisms. The basement rocks in the Chicx-03A borehole are crosscut by pre-impact and impact-generated melt dikes and show variable degrees of fracturing. This provides an explanation for the geophysical observations that indicate low seismic velocities and low densities beneath the peak-ring. The results from the drilling, geophysical logs, core analyses and numerical modeling support a dynamic collapse origin for the formation of the peak-ring.

The offshore drilling project forms part of the ongoing geophysical and drilling projects being carried out in Chicxulub for several years. Previous drilling projects carried out by scientists from the National University of Mexico (UNAM) have provided continuous sections for the post-impact, impactites and pre-impact sequences. Ligia Pérez-Cruz and Jaime Urrutia-Fucugauchi, co-authors of the Science paper, comment: In our drilling projects we have cored fragments of the basement - in the Santa Elena borehole outside the crater rim in the southern sector and in the Yaxcopoil-1 borehole in the terrace zone we have centimeter-sized granitic fragments. This contrasts with the hundreds-meter basement sections we now drilled in the Chicx-03A borehole. The study of the basement sections constraints the formation of the peak-ring and the central uplift. The comparative studies give us clues about the excavation depth, transient cavity dimensions, collapse mechanisms, breccias formation lower crust heterogeneities, etc. Additionally, we are analyzing the impact breccias and melt beneath the peak-ring and the effects of hydrothermal alteration.

A particularly intriguing aspect of the peak-ring formation is the behavior of rocks, how they deform and flow during the collapse stage. There are several competing models proposed, including acoustic fluidization, thermal and strain rate weakening. The high energy release and short-time scales make the collapse of large craters an interesting phenomenon. The UNAM researchers emphasize and add on how the different fragile and ductile deformation mechanisms co-exist and interact. In the borehole, the breccias on top of the basement section forming the topographic peak-ring are composed of fragmented material from different crustal levels in the target zone.

Marine drilling projects present major challenges with high budgets, difficult logistics and time-consuming data acquisition and laboratory studies. This has been the case with the Chicxulub project. In this context, Pérez-Cruz and Urrutia-Fucugauchi add: “it is gratifying that interesting results worth publishing came in such a short time. We expect that even more interesting results will come out in the coming months as drilling data and laboratory analyses are being completed. Looking at the objectives of the Chicxulub drilling expedition, we have plenty to do and to expect. Major objectives address a wide range of intriguing questions, including:

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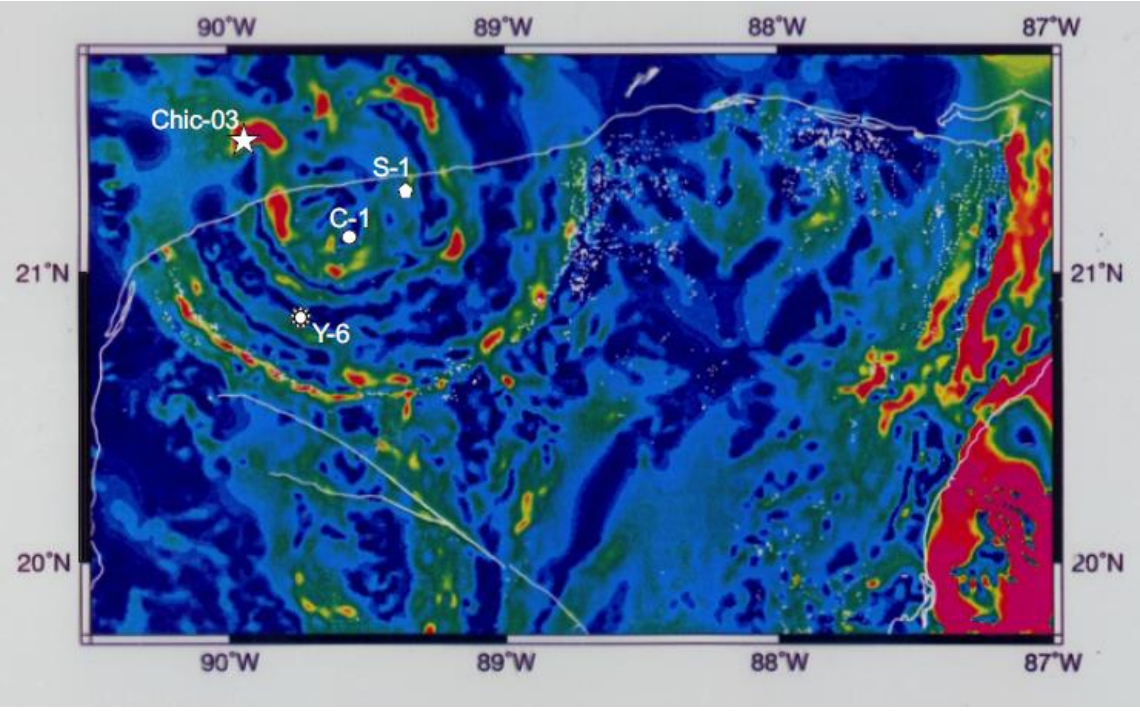
- Nature and underground structure of the peak-ring
- Stratigraphy of post-impact sediments
- Impactites and peak-ring sequences
- Rheological properties and dynamical collapse process, with formation of peak-ring and basement uplift
- Post-impact hydrothermal system
- Life recovery in target zone
- Deep biosphere in the Chicxulub crater
- Impact effects on the climate and environment
- Paleoclimate record during the Paleogene, including the Paleocene-Eocene thermal maximum and other major climatic events
- Impact-generated lithologies
- Geophysical modeling of crater structure



The Chicx-03A borehole is located within the gravity low in the marine central sector of the Chicxulub crater. Drilling sites for the Chicxulub-1, Sacapuc-1, Yucatan-6 and Yaxcopoil-1 boreholes plotted in the horizontal gradient gravity anomaly map (Connors et al., 1996).

The drilling project has implications for the planetary missions and understanding the evolution of planetary surfaces in other bodies of the Solar System. Chicxulub is the best preserved large crater with peak-ring morphology in the terrestrial record and the new study provides important data for understanding the dynamical processes involved in the formation of craters. It constraints the excavation depths and rheological properties of the lower crust, collapse processes, etc. In the paper, we discuss the implications for craters on the Moon concerning the excavation depths, crustal volume affected and nature of lower crust.

The new drilling project sampled the sedimentary section on top of the peak ring and we are now examining the sediments, reconstructing the stratigraphy, and looking into

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the paleoclimate record. The sediments preserve the record of the post impact processes in the basin, for instance how life recovered in the target zone following the impact. In our case, we take advantage of having the cores from the other boreholes, which allows us to correlate the observations and develop a high resolution stratigraphy for the post impact sediments. In the expedition UNAM researcher Ligia Pérez-Cruz participated in the offshore and onshore parties, coordinating the geochemistry group, which opened new opportunities for our studies and collaborations with other groups.

In the coming months, the science party will continue to analyze the results and the samples in the laboratories. We plan to meet, perhaps in Yucatan, to discuss the results and plan for the next steps. In the mean time we will continue refining the model for formation of the peak-ring, constraining this structural element and its relation to the collapse and central uplift.

The drilling project is part of an international collaboration, with the science team formed by scientists from different institutions. The offshore team was formed by a smaller group of 12 researchers who were responsible for the drilling operations on the platform and the initial studies. Team spent several weeks working offshore in the Yucatan carbonate platform.

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View of transfer operations for the drilling platform of the IODP Chicxulub Expedition 364

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