**HETEROGENEITY OF LARGE IMPACT STRUCTURES AS ILLUMINATED BY CHICXULUB: A TERRESTRIAL ANALOG WHILE PLACING IODP-ICDP EXPEDITION 364 IN CONTEXT.**

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**Introduction:** Remote sensing techniques reveal heterogeneities in large impact structures, both in terms of their crater morphology and associated gravitational anomalies. However, assigning explanations for these heterogenieties remains challenging due to inherent non-uniqueness when interpreting geologic process from topography and/or gravity alone. Insights can be provided by detailed studies of heterogeneity in terrestrial craters where the range of possible geologic processes that produce a particular observation can be greatly reduced, due to the use of higher-resolution geophysical imaging techniques and direct sampling through scientific drilling.

The terrestrial Chicxulub impact crater (Fig. 1) which occurred at the Cretaceous-Paleogene (K-Pg, 66 Ma) boundary provides the unique opportunity to study crater formation processes related to a large impact at a full range of distances from the impact site [1]. It is well preserved due to its relative youth and burial of the impact structure itself beneath 100s of meters of Cenozoic carbonates [2].

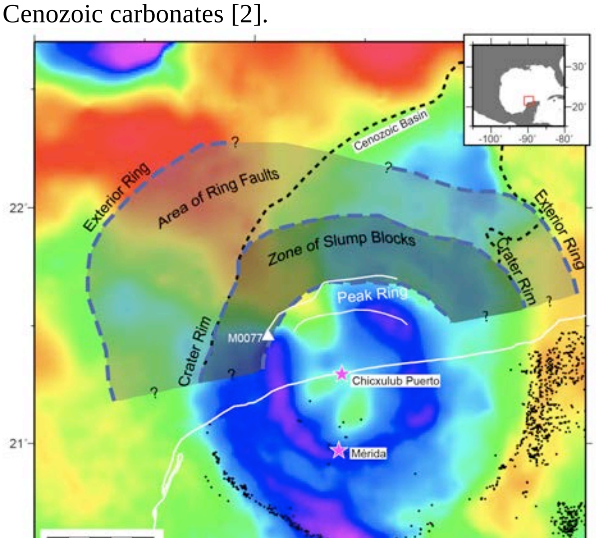


**Figure 1.** Gravity anomaly map of Chicxulub impact structure showing mapped area of ring faults and slump blocks. Black dots are cenotes. Modified from [3] such that peak ring bounds are mapped using new FWI images and IODP Site M0077 is shown.

Chicxulub is also a great case study for the attribution of asymmetries in the crater, which has led to discussions of which effects are associated with the pre-impact structure versus those related to impact angle and direction. Based on hydrocode modeling and seismic reflection and refraction data interpretation, current understanding attributes shallow crater features such as absence of a crater rim to the north-northeast to the pre-impact dipping target (a carbonate ramp) beneath water depths up to 2 km [4,5]. However, deeper asymmetries, such as a southwestward offset in the buried central uplift relative to the upwarped Moho, have been attributed to a southwest directed impact angle [6].

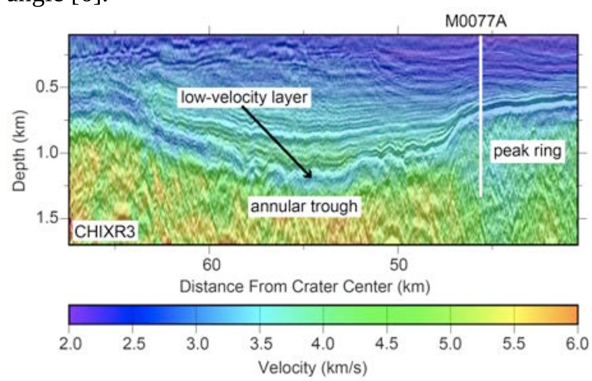


**Figure 2.** Seismic reflection image overlain by full waveform inversion generated velocity model. The peak ring of the Chicxulub impact crater is shown overlain by a low-velocity zone that can be mapped into the adjacent annular trough. Expedition 364 Site M0077 is shown with the length of the white line representing depth reach during drilling (1335 meters below seafloor) Figure modified from [8].

**Insights from Scientific Drilling and New Geophysical Analyses:** The International Ocean Discovery Program with co-funding from the International Continental Scientific Drilling Project drilled into the offshore portion of the Chicxulub impact crater in April-May, 2016 [7]. Hole M0077A recovered core from 505.7-1334.73 meters below seafloor (mbsf) (Fig. 2). The cores and downhole logs from this expedition have provided a first order calibration of the physical properties of the impact crater and a lithologic understanding as to key features of the crater. At Site M0077, the peak-ring rocks average <4000 m/s velocity and 2.1 g/cc density and are dominantly granitic. This observation is consistent with the dynamic collapse model of peak-ring formation [7]. Overlying the uplifted crystalline rocks of the peak ring is a layered deposit consisting of impact melt rock overlain by melt rock breccia, suevite, and finally sorted suevite of decreasing clast size upsection. The melt rock breccia through sorted suevite all have a low velocity (~3000 m/s or less) and high porosity (20-40%). Interpretation of this sequence is that the lower portion was rapidly deposited onto the impact melt rocks that capped the peak ring while the upper sorted suevite is a resurge deposit formed within the first day of the Cenozoic [8].

To map these crater lithologies beyond Site M0077, here we use new two-dimensional, full-waveform tomographic velocity images from the grid of seismic data recorded on a 6-km streamer across the Chicxulub impact crater (Fig. 2). These full-waveform inversion (FWI) velocity models are obtained from refracted arrivals that penetrate down to 1.5-2 km depth. These images show both the lower and upper portions of the low-velocity layer present at Site M0077 thus allowing us to potentially map the thickness of both the resurge deposit and the lower more rapidly deposited layer of suevite and melt rock breccia. Additionally, prominent high-velocity zones are visible that are interpreted to represent intact melt rock consistent with previous interpretation (Fig. 2, 3) [3].

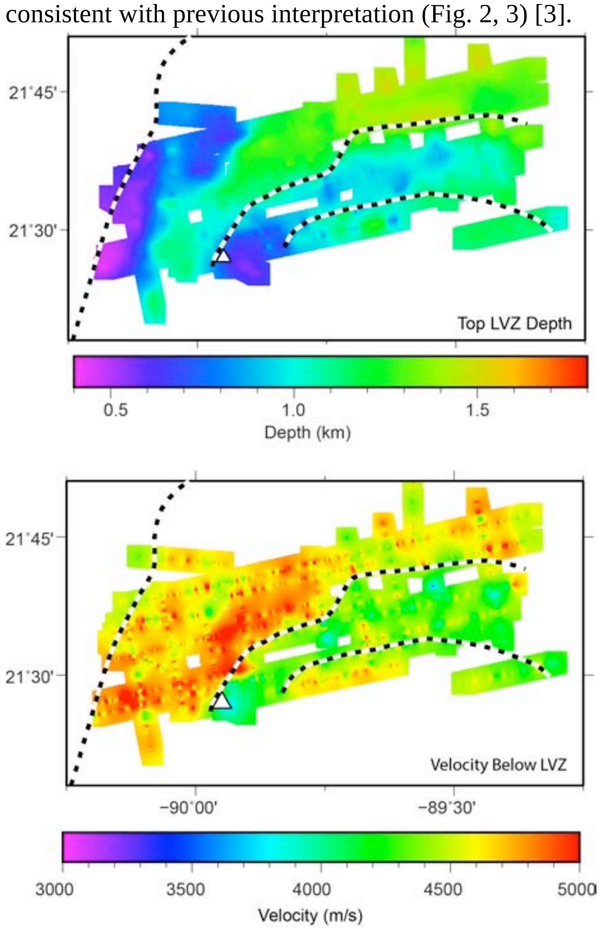


**Figure 3.** Top panel shows depth to top of the LVZ as mapped using FWI data shown over portion of Chicxulub impact structure. The white triangle represents the locations of IODP-ICDP Site M0077 that drilled into the peak ring. The western single dashed line is the inner rim of the crater and the inner two dashed lines are the inner and outer bounds of the peak ring in this area mapped on FWI images. These same bounds are shown in Fig. 1. Bottom panel are interval velocities just below the LVZ with dashed lines representing the same features.. LVZ is low-velocity zone , FWI is full waveform inversion, and IODP-ICDP are Internationl Ocean Discovery Program and International Continental Scientific Drilling Program.

Mapping of the lower and upper low-velocity layers on the FWI images yields some basic observations (Fig. 3). The upper low velocity layer, which we interpret to be the resurge deposit, is relatively uniform in thickness around the mapped portion of the crater with only localized thickening. The lower more rapidly deposited layer however varies more greatly with the greatest thicknesses in the central basin. High velocities potentially associated with impact melt rock are notable adjacent to the peak ring and particularly to the west where peak ring is narrowest, has the highest relief, and depth to top of slump blocks are deepest beneath the crater floor (Fig. 3).

**Discussion:** Patterns and thicknesses of rapidly deposited impactites and resurge deposits may reflect role of annular trough and peak-ring morphology affecting the resurge process into Chicxulub. In turn the peak-ring geometry (width and relief) may reflect some aspect of the dynamic collapse of the central uplift interacting with the inward faulting of the transient crater rim during the crater modification stage. Lastly prevalence of melt rocks outside and inside the highest relief peak ring intriguingly suggests control on impact melt distribution by initial crater morphology present just prior to resurge of ocean waters into Chicxulub. Seeking to apply these insights to other large impact craters as well as attributing thes geometric relationships to known causes of heterogeneities (target asymmetries and impact direction/angle) is a future goal.

**Acknowledgements:** The European Consortium for Ocean Drilling (ECORD) implemented Expedition 364, with contributions and logistical support from the Yucatán state government and Universidad Autónoma de México (UNAM). We thank the IODP-ICDP Expedition 364 Science Party including S. Gulick (US), J. V. Morgan (UK), E. Chenot (France), G. Christeson (US), Ph. Claeys (Belgium), C. Cockell (UK), M. J. L. Coolen (Australia), L Ferrière (Austria), C. Gebhardt (Germany), K. Goto (Japan), H. Jones (US), D. A. Kring (US), J. Lofi (France), X. Long (China), C. Lowery (US), C. Mellett (UK), R. Ocampo-Torres (France), L. Perez-Cruz (Mexico), A. Pickersgill (UK), M. Poelchau (Germany), A. Rae (UK), C. Rasmussen (US), M. Rebolledo-Vieyra (Mexico), U. Riller (Germany), H. Sato (Japan), J. Smit (Netherlands), S. Tikoo-Schantz (US), N. Tomioka (Japan), M. Whalen (US), A. Wittmann (US), J. Urrutia-Fucugauchi (Mexico), K. E. Yamaguchi (Japan), and W. Zylberman (France).

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