High-Resolution Imaging of the Chicxulub Impact Basin

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1. Introduction

Joint IODP-ICDP Expedition 364 drilled an offshore hole into the peak ring of the Chicxulub impact structure in Mexico [1]. Prior to drilling, a suite of seismic data were acquired in 1996 and 2005 [2, 3] that imaged the peak ring and indicated it was formed from rocks with a low seismic velocity [4, 5]. As part of a site survey, three crossing lines through the proposed drill site were acquired in 2005. Full-waveform inversion (FWI) of seismic data acquired for these three profiles was performed to obtain high-resolution models of seismic velocity across the peak ring [6], to help distinguish between models of peak-ring formation (Figure 1). The FWI results confirmed that the peak ring was formed from low-velocity rocks (3.0-4.5 km/s), and also identified the presence of a 100- to 150-m thick low-velocity zone (3-3.2 km/s) (light blue in the uppermost peak ring in Figure 1), that was interpreted to be impact breccia [6]. Drilling revealed that the Chicxulub peak ring is formed from a ~130-m of suevite and impact melt rock that lies above uplifted, shocked, felsic basement (Figure 2). Wireline logging and VSP data confirmed that the suevite in the uppermost peak ring has a lower velocity (~3 km/s) than the Paleocene sediments (3.5-4.0 km/s) above and basement below, and that the felsic basement itself has an unexpectedly low seismic velocity (3.4-4.8 km/s) (Figure 2) [1].

2. Objectives

- To use FWI to obtain high-resolution velocity models across the Chicxulub impact basin
- To use the FWI velocity models to map the low-velocity impact breccia away from the drill hole
- To use the FWI velocity model to map the low-velocity impact breccia away from the drill hole

3. Method

Full-waveform inversion (FWI) is a technology that is used for generating high-resolution high-fidelity models of physical properties in the subsurface [7]. FWI:
- Seeks a model which can predict the entire recorded wavefield, wiggle-for-wiggle
- Uses low frequencies (3 – 12 Hz)
- Uses predominantly transmitted arrivals
- Is a least-squares iterative inversion from a starting model
- Uses the complete physics to solve the wave equation
- Is computationally intensive
- Has a high-spatial resolution (~ an order of magnitude better than conventional tomography)

FWI has changed practice in the petroleum industry, where it is used: a) to obtain high-resolution models of seismic velocity that lead to improvements in images of the reservoir; and b) for the identification of drilling hazards.

4. Drilling

Drilling indicates that the low-frequency reflector identified in Figure 1 is the interface between impact breccia and basement, and is of low frequency since the velocity change is not sharp – but gradually increases within the uppermost basement (Figure 2C).

5. Preliminary FWI Results

A preliminary inversion of the seismic data along profile ChicxR3 is shown in Figure 3. The low-velocity zone at the top of the peak ring can be tracked from the peak ring into the annular trough, suggesting that the impact breccia that covers the peak ring is also present in the trough, as found onshore in drill holes Y-6 and Yax-1 [8]. In Figure 3, the velocity of the, presumably, Paleocene rocks is ~3.8-3.9 km/s and the impact breccia (LVZ) below ~3.1-3.2 km/s. A decrease in velocity within the Paleocene section and impact breccia is observed in the sonic log in well M0077A (Figure 2C).

6. References


7. Acknowledgments

The Chicxulub drilling expedition was funded by the International Ocean Discovery Program as Expedition 364 with co-funding from the International Continental Scientific Drilling Project. The European Consortium for Ocean Drilling implemented Expedition 364, with contributions and logistical support from the Yucatan state government and Universidad Nacional Autónoma de México (UNAM). We thank the sponsors of the FULLWAVE consortia for support in developing the 3-D FWI software used here. Morgan is funded by NERC Research Grant: NE/P005217/1.

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