HIGH-RESOLUTION IMAGING OF THE CHICXULUB IMPACT BASIN

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Introduction: Joint IODP-ICDP Expedition 364 drilled an offshore hole, M0077A (Figure 1), 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 these three lines was performed to obtain high-resolution models of seismic velocity across the peak ring [6], to help distinguish between models of peak-ring formation. The FWI results confirmed that the peak ring was formed from low-velocity rocks (3.9-4.5 km/s), and also identified the presense of a 100- to 150-m thick low-velocity zone (3-3.2 km/s) (LVZ, light blue in Figure 1) in the uppermost peak ring, 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 1). Wireline logging and VSP data confirmed that the suevite in the upperost 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 (3.5-4.8 km/s) [1].

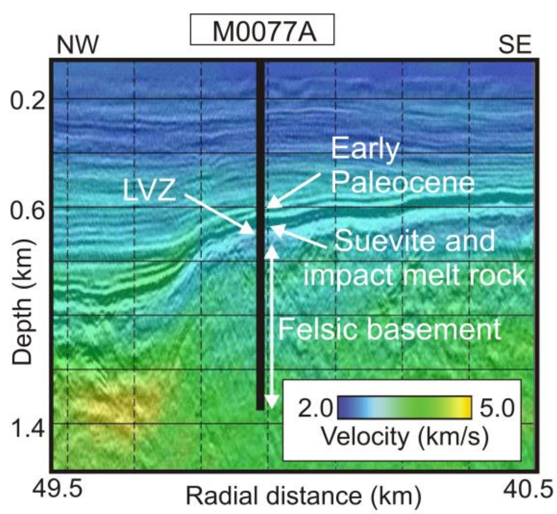

Figure 1. Drill Site M0077A located on a depth-converted seismic reflection profile ChicxR3 [3]. Color is seismic velocity obtained using full-waveform inversion [6]. LVZ is a low-velocity zone (light blue) where rocks that form the uppermost peak ring have a lower velocity than the Paleocene rocks above. Redrawn from [1].

We are currently using FWI to obtain a new suite of high-resolution velocity models across the impact basin. The acquisition of borehole VSP and sonic data allows us to ground truth our velocity models, and thus better constrain the depth and thickness of subsurface layers. One of the objectives of this research is to map the thickness of the suevite layer and top of felsic basement across the peak ring, and track the suevite away from the borehole into the surrounding annular trough and central basin.

Method: We are using a newly-developed time-domain FWI code that has additional capabilities, including being able to account for anisotropy (the difference in seismic velocity in different directions) [7]. Reflection and borehole data are more sensitive to vertical velocity, while refraction data are more sensitive to horizontal velocity – which can be 5-20% higher that vertical velocity in horizontally-layered sediments. Borehole data will be used to construct a subsurface model for anisotropy, which will lead to an improved velocity model of the subsurface away from the borehole. This velocity model will then be used to perform pre-stack depth migrations on the seismic reflection data, which is expected to lead to improved images of the internal structure of the Chicxulub peak ring.

Results: A preliminary inversion of the seismic data along profile ChicxR3 is shown in Figure 2. 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 2, 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. Inversions of seismic data across the peak ring are currently in progress.

References: [1] Morgan J. V. et al. (2016) *Science*, 354, 878-882. [2] Morgan J. V. et al. (1997), *Nature*, 390, 472–476. [3] Gulick S. P. S. et al. (2008) *Nat. Geosci.*, 1, 131-135. [4] Morgan et al. (2000) *EPSL*, 183, 347-354 [5] Barton et al. (2010) *Spec. Pap. Geol. Soc. Am.*, 465, 103-113. [6] Morgan J. V. et al. (2011) *JGR*, 116, doi: 10.1029 2011JB008210. [7] Warner M. R. et al. (2013) *Geophys*. 78, R59-R80. [8] Rebolledo-Vieyra M. and Urrutia-Fucugauchi J. (2004), *MAPS*, 39, 821-830.

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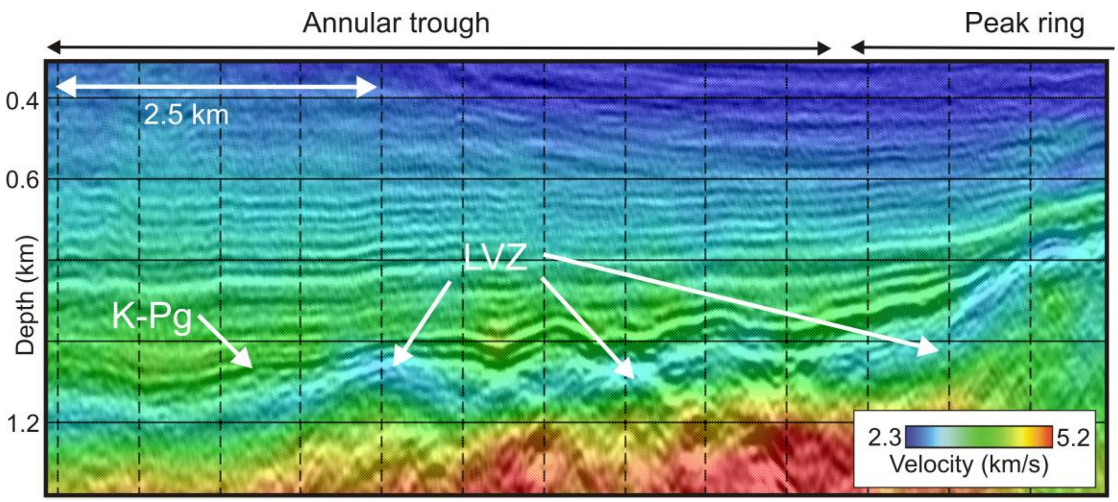

Figure 2. Depth-converted seismic reflection profile ChicxR3. Color is seismic velocity obtained using full-waveform inversion, and LVZ is a low-velocity zone that is interpreted to reperesent impact breccia.