ADJUSTMENTS AND PRELIMINARY ANALYSIS OF CHICXULUB PEAK RING CT SCANS.

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Introduction: IODP-ICDP Expedition 364 drilled the peak ring of the Chicxulub impact crater in April and May 2016 providing opportunities to study impact cratering and peak-ring emplacement processes. Core was recovered from 505.70 mbsf to 1334.73 mbsf. Results from the expedition show that the peak ring is largely composed of uplifted and fractured granitic basement rocks. Analysis of the fractures in the granite can provide insight into the mechanisms for rock movement, fault geometries, level of deformation, and timing constraints [1].

CT Background: The core has been imaged using three-dimensional dual energy X-ray computed tomography (CT) at 0.3mm resolution. CT scanning was carried out at the Weatherford Laboratories in Houston, Texas and was processed by Enthought Software in Austin, Texas. CT scans produce a 3D model of the core, allowing for observation and analysis of the internal structure of the core without altering or damaging them. Features such as fractures and faults can be accentuated using Enthought's Virtual Core visualization software.

Dual energy CT imaging uses a high-energy beam and a low-energy beam which can be processed to calculate density and average atomic number of the sample, respectively [2; see Hall et al., this conference]. The images are in grayscale, low density and atomic number areas show up dark or black, and high value areas are light or white. Open fractures appear black and mineral filled fractures appear dark grey to white.

In addition to the CT images of the core, there is an accompanying dataset of acoustic images from the borehole, which provides a 360-degree image of the wall of the drilled borehole. The slimline tool used for acoustic imaging is coupled with a 3-component magnetometer and accelerometer that gives the magnetic north orientation for the acoustic imaging dataset. Although the downhole acoustic image is lower resolution, prominent features such as well-defined fractures and dikes are visible in the borehole image. Careful identification of such features in both CT and image log allowed us to adjust the depth and rotation of the recovered core relative to the borehole wall.

Adjustments to Images: The acoustic image of the borehole was adjusted for depth to eliminate discrepancies between the borehole image and the recovered core. The borehole depth was adjusted with the CT scans of the core as a reference frame using the depth-shift editor in the Virtual Core software. Features found in both the cylinder unwrap of the borehole image and the cylinder unwrap of the CT scans were paired, and the depth of a feature in borehole was matched to the depth of the same feature in the CT scan. The most prominent features to match were bedding planes, contact points between impact melt and granitic rocks, as well as high angle fractures. Dipping features present themselves as sinusoids in the cylinder unwrap view. When matching complete sinusoidal features, the midpoint the sinusoid was matched to avoid distortion caused by differences in diameter of the borehole and core, causing the sinusoids in the borehole image to appear larger amplitude, (Figure 1). If only part of a sinusoid was visible, then peaks or troughs were matched. Over 300 features have been matched between borehole image and CT scans.

After the borehole image was adjusted for depth the CT scans of core were rotationally aligned using the borehole image as a reference frame. The cylinder unwrap of the borehole image has magnetic south set to zero degrees, which is the center of the image. Immediately after drilling the core was marked in 3 m sections with a black line running down the length of the core liner to indicate north, this black line was then used to orient the core during the CT scanning process with the black line pointing up. Ideally the original alignment of the core was preserved in the CT images, however there were frequent sections that did not match between the borehole images and CT scans. Possible opportunities for core misalignment include issues of visibility of the black line to CT technicians and rotation of the core during initial transportation on the rig before the black orientation line was marked.

Sections of core in the CT scan were rotated using the alignment tool in Virtual Core. This alignment was achieved by matching features such as dipping beds, sharp lithologic contacts and fractures found in both the cylinder unwrap of the borehole image and the CT scans. In addition to matching features between the borehole image and the CT scans, segments of core in the CT scan were matched to neighboring segments by matching the one end of the core to another, either by lining up neighboring fractures, or matching the breakage pattern from the end of one core to the next, or both. Figure 2 shows a screenshot of the alignment tool. The yellow line denotes the original placement of the core, and its distance from the center shows the approximate rotation angle. Note that this section has been aligned by fractures and a dike visible in the borehole image and CT scan and is further constrained by fractures in the section above. Each time a section of core was rotated, the identifying features, most commonly fractures, were recorded. The depth, type of feature, and a certainty rating were noted. The certainty rating ranged from 1 to 5 with 5 being most certain and 1 being least certain. Certainty varied based on clarity of the features in both the CT scan and the borehole image, and the dip of the feature. An inclined bedding plane or dipping fracture will be more easily matched than a relatively flat one. Some sections had several matching features while others had one or in unconstrained sections, none. Further adjustments to the alignment of the core will need to be performed on areas with lower certainty ratings and fewer matching features. In particular, core from depths of 619 mbsf to 849 mbsf are poorly constrained due to high levels of core fragmentation and poor clarity in the borehole image, areas similar to this require further alignment.

Future work: An important first step to categorizing fractures is determining whether or not the fracture was induced by drilling, the impact, or another process. If a fracture is filled or found in both the borehole and the CT scan, a drilling induced fracture can be ruled out. Fractures found in the CT scans will be qualitatively and quantitatively categorized in terms of fracture density, particularly if fracture density varies with depth or with proximity to impact induced melt dikes, whether the fracture is open or filled, singular or in a cluster of fractures with the same dip, as well as measurements of fracture widths, strikes and dips.

References: [1] Morgan J. V. et al. (2016) *Science*, 354, 878 – 882. [2] Siddiqui, S. and Khamees, A. (2004) *SPE* 90520

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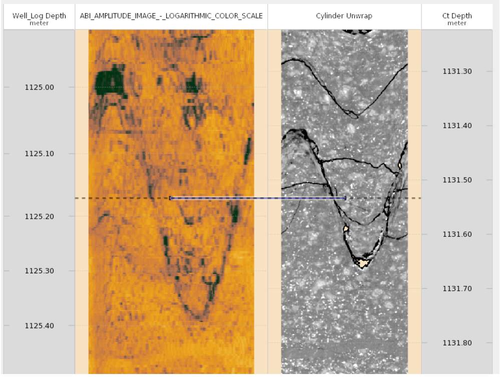

Figure 1: Interface of the depth-shift editor. The fracture in the borehole image (left) is matched to the same fracture in the CT scan (right). The depth of the borehole image has been adjusted to the CT depth.

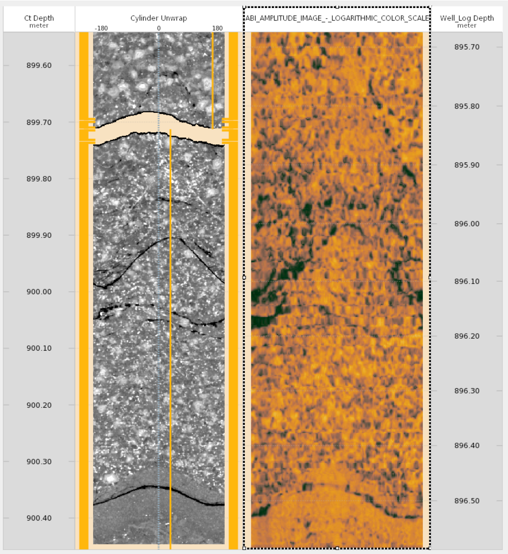

Figure 2: View of the alignment tool in Virtual Core. The CT scan (left) is rotated to align with the borehole image (right).