MAGNETISM OF THE CHICXULUB CRATER LOWER PEAK RING.
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Introduction: In 2016, International Ocean Discovery Program (IODP) and International Continental Scientific Drilling Program (ICDP) Expedition 364 conducted scientific drilling into the peak ring of the Chicxulub impact crater, just offshore from the Yucatan Peninsula in Mexico. The drilling operation successfully recovered cores from depths of 505.70-1334.73 meters below sea floor (mbsf), consisting of peak ring rocks overlain by post-impact sediments. Expedition 364 was the first drilling effort to sample the peak ring of the crater including the granitoid basement which was uplifted from >3 km depth. Felsic basement granitoids are crosscut by pre-impact dolerite dikes as well as impact melt rocks and suevite [1]. Chicxulub crater, the best-preserved peak-ring structure on Earth, offers opportunities to use paleomagnetism in order to better understand impact cratering processes. In particular, determining the types of remanence present within peak ring lithologies provides insight into the competing effects of impact heating, shock, and post-impact hydrothermalism on the magnetic signatures of impact craters.

Sampling and Methods: During the Expedition 364 Onshore Science Party (OSP), non-azimuthally oriented samples were collected from the lower peak ring for paleomagnetic and rock magnetic analyses. Measurements of natural remanent magnetization (NRM) as well as progressive alternating field (AF) demagnetization were conducted up to peak fields of 85 mT using a 2G Enterprises superconducting magnetometer in the Rutgers Paleomagnetism Laboratory. Magnetization directions were obtained for the lowest and highest coercivity magnetization component in each sample using principal component analysis [2]. Magnetic hysteresis (to determine grain size) and high temperature susceptibility measurements (to establish Curie temperatures and ferromagnetic mineralogies) were conducted using a Princeton Instruments vibrating sample magnetometer and an AGICO Kappabridge susceptibility meter, respectively, at CEREGE (Aix-en-Provence, France).

Paleomagnetic Results: A total of 138 lower peak ring samples were demagnetized, including 122 target rocks (granitoids and pre-impact dikes) and 16 impactites (suevites and impact melt rocks). Throughout all peak-ring lithologies, the following magnetization components are well-defined: a low coercivity (LC) component blocked below ~7 mT (up to 13.5 mT) in the vast majority (120 out of 138) samples, and a medium (MC) or high coercivity (HC) component blocked below 50 mT and 85 mT, respectively. Some impactite samples contain single-component HC magnetizations.

Target rocks: Out of the 122 total (116 granitoid and 6 dolerite) samples analyzed, 114 contain a negative polarity LC component. The average inclination of the LC components is -39.8˚± 24.6˚ (mean ± 1 standard deviation). A total of 112 of the 122 total granitoid samples contain MC or HC components persisting up to a maximum of 85 mT (the highest AF level applied), with inclinations ranging from -49.1˚ to 54.6˚ (average value of -4.1˚ ± 20.9˚) (Fig. 1).

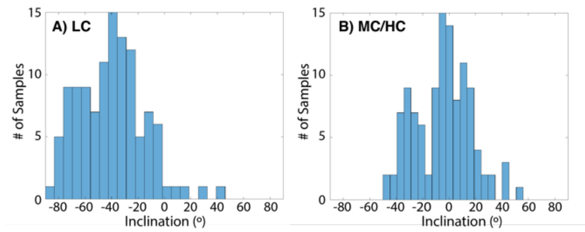

Fig. 1: Histograms showing inclination values for (A) LC componenets and (B) the highest coercivity magnetization component present (either MC or HC) in target rock samples.

Impactites: A total of 16 impactite samples were measured. Only 5 samples contained LC components (average inclination -33.1˚ ± 24.7˚), which were cleaned using AF demagnetization up to 8 mT. All 16 samples contained HC components persisting up to 85 mT with an average inclination of -29.5˚ ± 15.7˚.

Rock Magnetic Properties: Our magnetic hysteresis and high temperature susceptibility measurements collectively indicate that the main ferromagnetic mineral in both the impactites as well as the basement granitoids and dolerite dikes is (Ti)magnetite (Curie temperatures of 500-580˚ C, depending on the sample). However, a continued decrease in susceptibility after 580˚ C to temperatures >600˚ C in a some samples suggests that maghemitization may occasionally occur.

Discussion and Conclusions: Granitoids at the Chicxulub impact site likely experienced a variety of impact-related remagnetization events that influenced their total NRM. At the time of impact, shock waves with pressures up to 20 GPa [3] moved through target rocks, likely imparting them with shock remanent magnetization (SRM). Subsequently, as part of crater modification and peak ring formation, target rocks were uplifted from depths >3 km and were rotated inclination-wise by ~80˚ [4]. As rocks moved upward through the geothermal gradient, cooling from their original temperatures at depth (~100˚ C), they may have acquired a thermoviscous remanent magnetization (TVRM). Granitoids were also intruded by impact melt and suevite dikes causing the surrounding rocks to gain a TVRM. Finally, the heat of the ~3.5 km impact melt sheet near the peak ring sustained a high temperature (up to ~400˚ C at times) hydrothermal system moving within fractures and pore spaces of granitoids that persisted for at least 200 kyr (and possibly up to 1.5-2.3 Myr) after the impact [5,6]. During this period, the rocks may have acquired TVRM or a chemical remanent magnetization (CRM) from the precipitation of magnetic minerals.

Although a rapidly declining LC component is clearly defined in 90% of samples measured, it is unlikely to be a SRM as the shock wave was the first of many events that could have reset magnetization. Given the post-impact conditions, TVRM or CRM from the pervasive hydrothermal system are expected to be the cause of most magnetization components observed in the lower peak ring. However, ongoing thermal demagnetization experiments will further test for the presence of SRM, which is more easily identified in heating experiments [7], as well as TVRM and CRM. Pre-impact dolerite dikes do not have similar inclinations as adjacent granitoids, suggesting that both lithologies have been variably reset by post-impact hydrothermalism on a short depth scale (< 1m). In contrast, impactites and adjacent granitoids have similar inclinations, suggesting a shared magnetic history (either reflecting a baked contact or similar hydrothermal conditions) (Fig. 2).

By comparing the NRM intensities and demagnetization behaviors of our samples with those of laboratory-induced SRM and TVRM, we may be able to use paleomagnetism to further refine the range of temperatures and shock pressures experienced by the granitoids. As the conditions of shock, heating, and hydrothermalism within this sequence are characterized, a clearer picture will develop of how large impact events rework the environment here on Earth as well as on cratered bodies within the universe.

References: . [1] J. V. Morgan et al. (2016) *Science, 354,* 878-882. [2] J. L. Kirschvink (1980) *GJR, 62*, 699-718 [3] A. S. P. Rae (2017) *LPS* XLVIII, Abstract 1934. [4] A. S. P. Rae (2017) *AGU*, Abstract P23H-03. [5] O. Abramov and D. A. Kring (2007) *Meteorit. Planet. Sci., 42*, 93-112. [6] S. M. Tikoo et al., (2017) *LPS* XLVIII, Abstract 1491. [7] S. M. Tikoo et al., (2015) *JGR Planets, 120,* 1-15.

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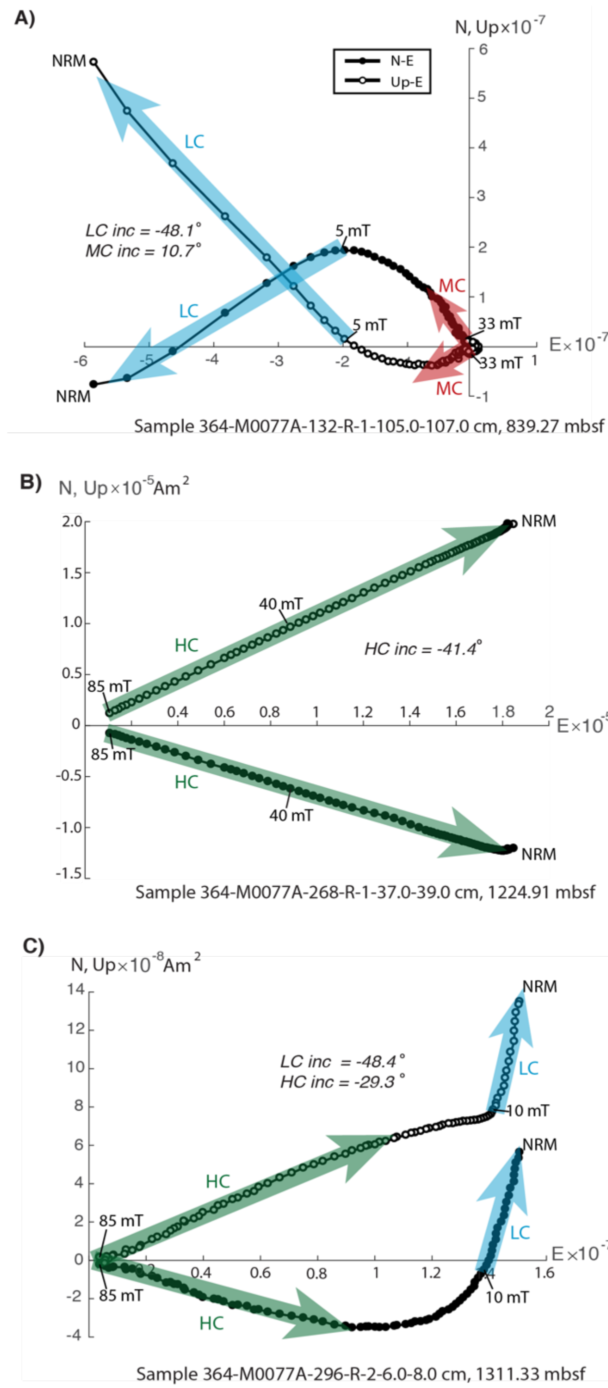

Fig. 2 . Zijderveld diagrams of AF demagnetization of NRM in 364-M0077 samples (a) 132-1-413; granitoid near dolerite dike (b) 268-1-855; suevite dike and (c) 296-2-944; granitoid near suevite dike. LC, MC and HC components are shown with arrows.