EMPLACING IMPACT MELT IN THE CHICXULUB PEAK RING. David A. Kring[1], Philippe Claeys[2], Ulrich Riller[3], Long Xiao[4], Gareth S. Collins[5], Ludovic Ferrière[6], Kazuhisa Goto[7], Michael Poelchau[8], Auriol Rae[9], Naotaka Tomioka[10], Michael Whalen[11], and the IODP-ICDP Expedition 364 Science Party, [1]USRA-Lunar and Planetary Institute, 3600 Bay Area Blvd., Houston TX 77058 USA (kring@lpi.usra.edu), [2]Analytical, Environmental and Geo-Chemistry, Vrije Universiteit Brussel, B-1050 Brussels, Belgium, [3]Institut für Geologie, Universität Hamburg, Hamburg 20146 Germany, [4]Planetary Science Institute, School of Earth Sciences, China University of Geosciences (Wuhan), China, [5]Dept. of Earth Science and Engineering, Imperial College London, London SW7 2AZ UK, [6]Natural History Museum, 1010 Vienna, Austria, [7]Tohoku University, International Research Institute of Disaster Science, Sendai 980-0845 Japan, [8]University of Freiburg, Geology, Freiburg 79104 Germany, [9]Department of Earth Science and Engineering, Imperial College London, London SW7 2AZ UK, [10]Kochi Institute for Core Sample Research, Japan Agency for Marine-Earth Science and Technology, Nankoku, Kochi 783-8502 Japan, [11]Department of Geosciences, University of Alaska Fairbanks, Fairbanks, AK 99775 USA.

Introduction: The Chicxulub crater is the best preserved peak-ring impact site on Earth, but it is difficult to study because it is buried beneath several hundred meters of sediment. Recently, the International Ocean Discovery Program (IODP) and International Continental Scientific Drilling Program (ICDP) drilled into the crater to determine how a peak-ring crater forms. Initial results [1] favor a dynamic collapse model for an overheightened central uplift, which is consistent with observations at other terrestrial craters [2] and similar to a Displaced Structural Uplift model inferred from geologic mapping and hydrocode simulations of the exquisitely exposed Schrödinger peak ring on the Moon [3]. Shock-metamorphism in the recovered peak ring core indicate shock pressures of ~10 to 35 GPa, which are consistent with hydrocode modeling of dynamic collapse [1]. The core also contains, however, several intervals of impact melt rock and melt-bearing breccias that reflect higher shock pressures and temperatures. Here, we examine those melt and melt-bearing units to determine if they are consistent with the dynamic collapse model or require other processes.

Distribution of Melt in the Core: IODP-ICDP Expedition 364 recovered core from 505.7 to 1334.7 mbsf from borehole site M0077A (21.45° N, 89.95° W) [1]. After penetrating post-impact sediments (Unit 1), the top of the peak ring was encountered at 617.33 mbsf, beginning with a 104-m-thick polymict, melt-bearing breccia (Unit 2 suevite) with a calcitic matrix that may represent a plume of carbonate ash ejected from the target. The most abundant clasts in the breccia are impact melt fragments, consistent with observations of the ICDP Yaxcopoil-1 borehole (e.g., [4]) and expected in large impact craters with disproportionately larger volumes of melt than smaller craters (e.g., [5]). That unit has been sub-divided (2A, 2B, 2C) based on sedimentary and matrix features [6]. An impact melt rock, Unit 3, extends ~26 m to a depth of 747 mbsf. It is dominantly a clast-poor impact melt rock, but clast-rich intervals occur at ~722, ~732-734, and ~744 mbsf. It has been subdivided to reflect a change from green schlieren-bearing black melt (3A) to a basal ~9.5 m-thick coherent black melt unit (3B) [6].

Those units cover granite and related basement lithologies within the uplifted peak ring. Thin, <1 m-thick impact melt horizons were logged within the granite. A thicker (~4 m) series of melt and melt-bearing breccia horizons were logged at ~1000 mbsf and ~58 m of melt and melt-bearing breccias dominate the lower 100 m of core. The total thickness of the basement interval sampled by the borehole is 588 m.

Clast Content: There is a diverse array of sedimentary, metamorphic, and igneous target clasts within those units. Sedimentary lithologies are carbonate, chert that in many cases is visibly associated with and derived from carbonate, shale, sandstone, and red siltstone. Metamorphic lithologies are gneiss, mylonite, schist, amphibolite, and quartzite. Marble was also logged, but thin-section studies are needed to determine if it is a target unit or shock-modified carbonate. Igneous lithologies include granite, granodiorite, diorite, dacite, felsite, and mafic clasts that were variously logged as gabbro, diabase, and dolerite. Carbonate and granite are the most abundant lithologies. Many of these lithologies have been found in previous borehole samples from the Chicxulub crater (see review by [7]). Conspicuously missing is anhydrite, which was rare but observed in a PEMEX series of Yucatán boreholes located just outside the crater rim [8,9]. Red siltstone, dolerite, dacite, and felsite are the first occurrences in Chicxulub breccias, although the siltstone is a well-known unit within the Maya block.

Sedimentary, metamorphic, and igneous target lithologies are found in the uppermost units, but carbonate was not logged in the bottom eight cores (from ~722 to ~747 mbsf) of the Unit 3 impact melt rock, and granite dominates the clast assemblage at the base of that interval. Thin melt horizons within the granite only have clasts of (locally derived) granite. However, the horizon at ~1000 mbsf contains clasts of melt, granite, granodiorite, dolerite, and gneiss. The basal interval of melt and melt-bearing breccias also has a diverse array of metamorphic and igneous clasts, but no sedimentary clasts.

Discussion: Let us consider, first, the units that cover the granitic core of the peak ring. A primary distinction among the impact melt rocks and melt-bearing breccias is the presence of sedimentary clasts in the uppermost units (2A-C, 3A) and their absence in the lower unit (3B). That difference may reflect fundamentally different depositional processes that are discernible only because the Chicxulub crater was excavated from a layered target. The Yucatán Platform, or Maya block, is composed of a ~3 km-thick sequence of carbonate platform sediments, red siltstone, quartzite, and an underlying granitic basement (Fig. 4 of [7]). A projectile 10 to 17 km in diameter would have penetrated the 3 km-thick sediments, preferentially lofting those lithologies into a vapor-rich plume that subsequently collapsed to cover breccias produced from deeper lithologies along the crater walls. That two-layered breccia sequence is reminiscent of the breccias at Meteor Crater, where a ~30 to 50 m-diameter projectile penetrated an ~9 m-thick layer of red Moenkopi siltstone, preferentially lofting that unit with fragments of the projectile in a fallback breccia that covers a breccia composed of material from two lower strata in the impact target [10].

For the melt-bearing horizons within the granite, we consider four hypotheses. (1) The impact melts in the granite may have been injected into the walls of the transient crater and transported with the bounding granite during uplift and collapse into a peak ring. This seems unlikely, however, because the granite is heavily sheared while the impact melt rocks and melt-bearing breccias are not. The melts were introduced after most (albeit not all) of the deformation of the peak ring had occurred.

The impact melts in the granite may have instead been (2) produced by melting along shear planes and faults in the basement. That is a likely source of the thin, <1 m melt horizons, which only contain clasts of granite. However, there is a wide variety of clasts in the thicker melt-bearing units at ~1000 mbsf and at the base of the borehole that would require transport of multiple lithologies (granodiorite, gneiss, dolerite) an unknown distance along an intrusive conduit and emplacement in granite. We cannot discount, however, (3) the infusion of melt [11] from adjacent melt pools along open fractures in the peak ring. The melts at the base of the borehole lie at a greater depth than impact melt in the adjacent crater trough, although that source may require transport through fractures over a distance of at least 2 km, without quenching, while mixing with clasts from multiple peak-ring lithologies.

An alternative hypothesis (4) is prompted by the lack of sedimentary clasts in the deeper impact melts. If the dynamic collapse and Displaced Structure Uplift models are correct, then as the peak ring collapsed and deformed outward, it may have overrun and flowed over surficial melt-bearing components before the fallback breccia with its sedimentary clast components landed. The repetition of impact melts within the granitic sequence implies there was internal shearing within the granite as it displaced outward, allowing it to cover breccias at least twice.

Conclusions and Future Tests: If the peak ring was deformed over melt-bearing surficial breccias, then that would reflect the same type of shear inferred from mapping of the peak ring in the Schrödinger basin [3]. To test these melt emplacement concepts further, a microscopic assessment of clast content should be conducted of melt horizons to confirm an absence of sedimentary components in deeper horizons. In addition, a kinematic study of shear features in the peak ring granite should be conducted to see if they are consistent with the dynamic collapse model.

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