INITIAL ASSESSMENT OF THE EXCAVATION AND DEPOSITION OF IMPACT LITHOLOGIES EXPOSED BY THE CHICXULUB SCIENTIFIC DRILLING PROJECT, YAXCOPOIL, MEXICO.

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Introduction: The Chicxulub Scientific Drilling Project (www.icdp-online.de) recovered a continuous core from a depth of 404 m (in Tertiary cover) to 1511 m (in a megablock of Cretaceous target sediments), penetrating ~100 m of melt-bearing impactites between 794 and 895 m. The Yaxcopoil-1 (YAX-1) borehole is ~60-65 km from the center of the Chicxulub structure, which is ~15 km beyond the limit of the estimated ~50 km radius transient crater (excavation cavity), but within the rim of the estimated ~90 km radius final crater. In general, the impactite sequence is incredibly rich in impact melts of unusual textural variety and complexity, quite unlike melt-bearing impact formations from other terrestrial craters.

Impact Lithologies: A coherent 24-m thick green impact melt lies near the base of the impactite sequence above one or more megablocks of target sediments. Thus far we have examined four samples from the top to the bottom of this green melt zone: YAX-1_861.4, YAX-1_863.51, YAX-1_876.46, and YAX-1_883.13, where the numbers following YAX-1 indicate the depth of the samples in meters. The green melt is generally massive in appearance, but contains flow lines on both macroscopic and microscopic scales that are suggestive of glass; nevertheless, all the melt is aphanitic and no glasses were observed. The melt is dominated by microcrystalline (2 to 50 µm) Ca-rich pyroxene ($Wo_{46-50}En_{41-35}Fs_{11-15}$), plagioclase ($An_{36-58}Ab_{60-40}Or_{2-9}$), and alkali feldspar ($An_{0-12}Ab_{98-9}Or_{2-90}$). These compositions are similar to those in the melt recovered from the Yucatan-6 borehole ~50 km from the center of the crater [1-3]. The YAX-1 green melt also contains primary apatite, primary and secondary magnetite, rutile (or secondary anatase), secondary barite, secondary calcite, and secondary phyllosilicates. In the core, granitic clasts up to 4.5 cm and mafic clasts up to 6.5 cm were observed. In thin-section, small amounts of shocked and unshocked clasts are entrained in the melt, including quartz and quartzite with planar deformation features and ballen structures after cristobalite, isolated altered feldspar and mafic minerals, and mafic lithics.

The green melt is also brecciated and highly altered along its margins where the contacts were conduits for carbonate-rich fluids. While the core was being recovered, a 10 m-thick carbonate-charged and brecciated green impact melt unit with larger clasts of target material, including a 34 cm granite, was logged below the principal 24-m thick green melt unit. This may be the basal portion of the green melt unit, rather than a distinct melt unit.

Above the green melt unit are a series of melt-rich breccias that are an unusual agglomerate of melt clasts, ranging from distinctly brittle melt fragments to flowed bodies. A 15 m-thick unit was logged immediately above the green melt unit with abundant and sometimes very large (up to 20 cm) clasts of banded melts. In sample YAX-1_857.65 the melt is dominated by microcrystalline (<20 µm) pyroxene ($Wo_{46-51}En_{43-37}Fs_{10-13}$), plagioclase ($An_{48-56}Ab_{48-41}Or_{5-2}$), and alkali feldspar ($An_{0-9}Ab_{1-42}Or_{49-99}$), with minor apatite, primary and secondary magnetite, secondary ilmenite, rutile (or secondary anatase), similar to the green melt although the color (shades of rose) is different. The melt entrained small amounts of shocked and unshocked clasts of quartz, feldspar, sandstone, metaquartzite, and granite. These melts exist in a breccia that is variously clast and matrix supported, the latter of which appears to have been a conduit for post-impact fluids and is now charged with secondary alkali feldspar and subordinate carbonate.

A 23-m thick melt-rich breccia is next in the sequence, which we examined in YAX-1_829.56, 831.345, 836.34, and 841.32. This unit is dominated (up to 82%) by fragments of altered (see [7]) silicate impact melt, generally with microcrystalline textures (<10 µm equant pyroxene, <50 µm long feldspar needles), although some fragments appear to have been partly to wholly glassy before being replaced by phyllosilicates and calcite. Primary minerals in the microcrystalline melts include pyroxene ($Wo_{48-51}En_{42-35}Fs_{10-14}$), plagioclase ($An_{50-59}Ab_{39-45}Or_{2-5}$), alkali feldspar ($An_{0-1}Ab_{0-10}Or_{100-88}$ and $An_5Ab_{94}Or_1$), magnetite, and Fe,Ti-oxides. Some of these silicate melts contained immiscible carbonate melt, gas vesicles (some of which were subsequently filled with secondary calcite and silicates), and flow-aligned crystals. The melt entrained feldspar, quartz, magnetite, armalcolite-sphene assemblages, lithic metaquartzites, micritic carbonate, shale, and crystalline mafics.

Parts of the unit are clast supported, although the amount of matrix increases from ~15 to ~24% with depth. The matrix is composed of calcite, an altered silicate phase, and magnetite. The melt fragments have several different colors. Some green melt fragments, similar to the green melt unit below, are up to 17 cm long. Brown melt samples have microcrystalline textures, schlieren, and clasts of shocked target lithologies. In one case green melt surrounds a black melt fragment which, in turn, encloses a granitic inclusion. Mineralogically the different colored microcrystalline melts look the same (as seen through the haze of alteration) and also resemble the melts in the Yucatan-6 borehole. The colors may be a consequence of variable iron oxidation or the presence of phyllosilicates, rather than large chemical variation in melt compositions. The base of this unit is charged with carbonate and it appears the contact between the units was a fluid conduit.

Above this unit is a 15 m-thick unit with less melt, but logged as a suevite. It is matrix-supported, with a variety of melt, sedimentary, and crystalline clasts up to 7 cm. Secondary carbonate permeates portions of the matrix and fills a 7 cm cavity. The uppermost impact unit is 13 m thick, a finer-grained version of the same material, and has been reworked, presumably by currents on the seafloor of the Gulf of Mexico, possibly induced by the impact. Secondary carbonate also permeates the matrix of this unit and forms a 2 cm-wide vein.

Excavated Components: The melts are dominated by silicate compositions, indicating they were excavated from the crystalline basement beneath the ~3 km-thick carbonate and evaporite platform sequence in the target area. Surviving clasts of crystalline materials include isolated quartz, feldspar, magnetite, and altered mafic minerals, and lithic clasts of granite-granodiorite, metaquartzite, shale, and unidentified mafics. Small amounts of immiscible carbonate melt in silicate melt fragments and clasts of micritic carbonate in the breccias indicate limestone was also excavated, some as melt. The siliceous and feldspathic lithologies are similar to those seen in the Yucatan-2, Yucatan-6, and Sacapuc-1 boreholes [1-5]. The mafic lithologies are new, although there were chemical and isotopic hints of mafic target components in the Yucatan-6 core [3, 6]. Conspicuously missing in the melt-rich breccias are clasts of anhydrite (or even secondary anhydrite, both of which were present in Yucatan-2 and Yucatan-6 breccias [1,2]), possibly because of differentiation during the excavation, transportation, and/or deposition of target material.

Transport, Deposition, and Modification: Material that lies outside the peak ring may have been ejected on ballistic paths that generated intense turbulent mixing or slid off the rising and then collapsing central uplift, perhaps to slosh back and forth between the rim of the crater and the peak ring. Collapse of large crustal blocks during the modification stage (and potentially later if there was additional settling) can also brecciate and rework deposits.

All the YAX-1 melts cooled quickly to form glassy to microcrystalline textures. Schlieren indicates melts were being mixed, but they were not mixed to the extent found in large central melt sheets. The melts solidified before the mixing process was complete, likely reflecting excavation from the transient crater and transport as small, discrete melt volumes. Minor amounts of melt encasing melt indicate some collisions and turbulence during transport. These streams of melt were fragmented after solidification, producing angular fragments or shards, although ribbony, fluidal fragments also survive.

In the case of the melt-rich breccias, the melt was shattered after it solidified and then mixed with carbonate-rich matrix components or was invaded by fluids precipitating secondary calcite. Because portions of the breccias are matrix supported, some carbonate had to be part of the original deposit, rather than having been introduced entirely by secondary fluid processes.

The 23 m-thick melt-rich breccia was deposited at temperatures too low (<1000 °C) for the melt fragments to be plastically deformed. Fragments of melt with gas vesicles and small once-glassy melt shards were not flattened, nor is there any indication of foliation as in a welded ash flow. Temperatures were also less than a few hundred degrees Celsius, because the carbonate-rich matrix did not form a carbonatite-like melt and micritic carbonate clasts in the carbonate-rich matrix were not resorbed.

The green melt was deposited and solidified as a coherent melt unit and was subsequently brecciated.

The entire sequence was also altered by post-impact fluid processes, which we describe in more detail elsewhere [7,8].

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Acknowledgements: We thank the International Continental Drilling Program, Universidad Nacional Autonoma de Mexico, and the Chicxulub Scientific Drilling Project for producing the Yaxcopoil core. This work was supported by NSF grant EAR-0126055.