CONSTRAINTS FOR EMPLACEMENT CONDITIONS OF THE CHICXULUB IMPACT CRATER'S UPPER PEAK RING SECTION (747−617 MBSF) IN IODP-ICDP EXPEDITION 364 DRILL CORES.

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Introduction: International Ocean Discovery Program (IODP) and the International Continental Scientific Drilling Project (ICDP) Expedition 364 recovered drill cores from the 66 Ma, ~200 km Ø Chicxulub impact structure's peak ring [1,2]. The ~718 m thick impactite section in the 1335 m deep hole is characterized by two major lithological units, a Lower Peak Ring (LPR) composed of shock metamorphsed granitic rocks intercalated by subvolcanic dikes, suevite and impact melt rock that is overlain by an Upper Peak Ring (UPR) section of impact melt rock and suevite.

This study summarizes petrographic observations that constrain emplacement processes for the ~130 m thick section of impact melt rock [747−722 meters below sea floor (mbsf)] and sorted suevite (~709−617 mbsf) [2].

Methods: At Arizona State University, 15 samples fromt the UPR were analyzed in petrographic thin sections using optical microscopy, Raman spectrosopy, and electron microprobe analysis (EMP); X-ray intensity mapping and high-resolution imaging were used to quantitatively identify and characterize diagnostic impact-metamorphic features in zircon ($ZrSiO_4$).

Results: The UPR can be subdivided into a lower section of impact melt rock that is in contact with brecciated and shock metamorphosed granite of the LPR. The dark impact melt rock shows variable amounts of liquidus phase phenocryst plagioclase and pyroxene ($En_{39\pm4}$ $Fs_{15\pm2}$ $Wo_{46\pm3}$, n=9). It contains greenish-brown swirls of assimilated debris and exhibits brecciation (Fig. 1A). The groundmass of these brecciated impact melt rocks (Fig. 1B) contains secondary sparitic calcite, phyllosilicates, titanite, and garnet with andradite-rich cores ($Ca_3Mg_{0.07}Al_{0.6}Fe_{1.33}Ti_{0.4}Si_{2.6}O_{12}$) and grossular-rich rims ($Ca_3Mg_{0.08}Al_{1.71}Fe_{0.2}Ti_{0.01}Si_3O_{12}$) (cf. [3]). The impact melt rock is succeeded by coarse, sorted suevite. This coarse sorted suevite grades into a finer sorted suevite. In the uppermost 5 m of the suevite section, cross-bedding is apparent and a sharp boundary with tan carbonate siltstone ocurs at 617.34 mbsf. The suevite groundmass is variable. In the lower part of the section, it is dominated by a mixture of zeolite, SiO_2, and calcite. Relics of an earlier generation clastic groundmass occur as fine-grained, phyllosilicate-rich inclusions in rounded impact melt clasts, e.g. at 644 mbsf. The uppermost suevite contains well preserved microfossils and a micritic calcite groundmass. In the lower suevite, microfossils are typically restricted to components in cm-size Ca-carbonate clasts. Other Ca-carbonate clasts frequently show recrystallized textures into ~5 um-size euhedral crystals and concentric ring structures (Fig. 1C), suggesting recovery from severe heating.

Vitric impact melt occurs at the contact of the Upper Peak Ring basal impact melt rock with the Lower Peak Ring granite at 747 mbsf, at the contact of sorted suevite with impact melt rock near 709 mbsf, and throughout the sorted suevite as clast components that frequently show delicate shard shapes of broken vesicle rims (Fig. 1C). Variably crystallized impact melt occurs as sub-rounded to angular clasts as well. Basement clasts are less common than the impact melt clasts in the suevite section. They include igneous and metamorphic rock types that are strongly overprinted by secondary alteration.

In the 15 thin sections 147 zircon crystals occur 3 to 174 µm in size; 35% of these $ZrSiO_4$ grains are components of crystallized impact melt clasts and one third belongs to lithic clasts; less than 3 % of these grains occur in a clastic groundmass, significantly less than in suevites of the Yaxcopoil-1 (Yax-1) drillcores [4]. In BSE images, less than 20% of these grains exhibit features diagnostic of impact metamorphism. Among those, granular textures associated with relict ZrO_2 that suggest recovery from decomposition due to impact-induced heating above 1776 ºC dominate over planar elements that are harder to diagnose in mostly small grains. However, some zircons that occur in a mafic clast exhibit planar features and ZrO_2 domains. Also, zircons associated with garnet-bearing brecciation zones in impact melt rock exhibit unusually delicate decomposition features.

Preliminary Raman spectroscopic analyses on some of these zircons did not identify the presence of the high-pressure polymorph reidite.

Discussion: At least a part of the UPR has been interpreted as an impact-tsunami deposit that was emplaced immediately after the impact [5,6]. The hyaloclastite-like brecciation of a portion of the UPR's impact melt rock (Fig. 1A) could be evidence for the interaction of seawater with hot impact melt. Similar brecciation features also occur in an impact melt rock unit of the Yaxcopoil-1 drill cores in Chicxulub's annular moat that have also been linked to phreatomagmatic-like water-impact melt interaction [7,8]. This study could not confirm previous identification of carbonate impact melt [9]. However, the unusual decomposition texture and the presence of Ca-rich garnet records an unusual high temperature process that affected the impact melt rock after it had solidified [3].

Experimental studies of impact melts with similar composition to those of Chicxulub found rapid quenching from >1200 °C to below 650 °C stunts the crystallization of pyroxene and plagioclase phenocrysts [10]. This places a maximum constraint on the post-depositional temperature regime for the sorted suevite at 617 to 709 mbsf.

Zircon crystals are useful to constrain very high impact-related pressures and temperatures [11]. Compared to a study of zircons in a ~100 m thick impact-melt rich section in Chicxulub's annular moat [4], a lower proportion of diagnostic impact metamorphic features was found in the samples from the UPR. However, a similar prominence of high-temperature annealing features such as granular textured zircon and ballen-SiO_2 is present both at the UPR and the impact-melt rich section in Yax-1. The lower proportion of groundmass zircons in the UPR suevites may confirm the secondary nature of this groundmass compared to the suevite groundmass at Yax-1.

However, some zircons crystals at the UPR exhibit features that are unusual and may relate to alteration conditions instead of reactions to high pressures and/or temperatures. Also, a difference between the annular moat and the UPR units is the scarcity of ZrSiO4-clasts in the groundmass of the UPR.

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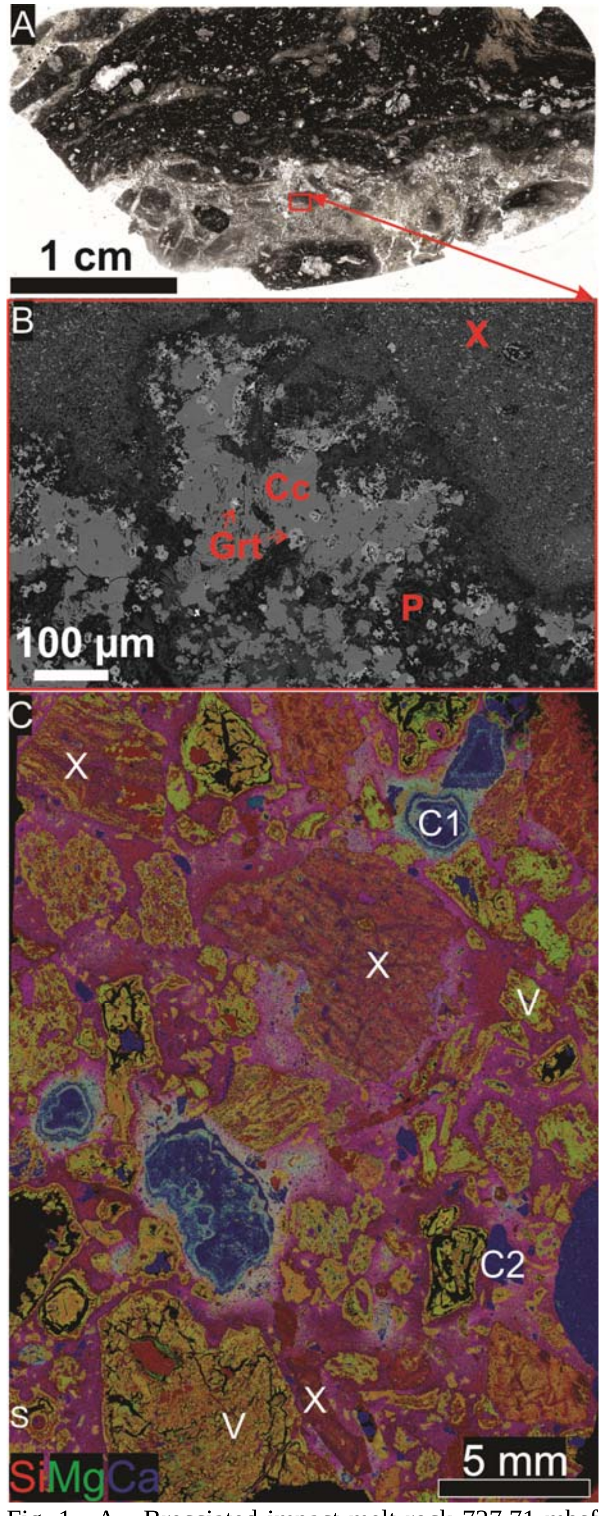

Fig. 1. A - Brecciated impact melt rock 727.71 mbsf thin section scan; B - Garnet (Grt)-bearing domain rich in calcite (Cc) and phyllosilicates next to impact melt rock (X), BSE image; C - Suevite 674.32 mbsf X-ray intensity map, note two Ca-carbonate types (C1 and C2); impact melt particles: V-vitric, X-crystallized, S- shard.