

CHICXULUB IMPACT MELTS: GEOCHEMICAL SIGNATURES OF TARGET LITHOLOGY MIXING AND POST-IMPACT HYDROTHERMAL FLUID PROCESSES.

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Introduction: Impact melts within complex impact craters are generally homogeneous, unless they differentiated, contain immiscible melt components, or were hydrothermally altered while cooling. The details of these processes, however, and their chemical consequences, are poorly understood. The best opportunity to unravel them may lie with the Chicxulub impact structure, because it is the world's most pristine (albeit buried) large impact crater.

The Chicxulub Scientific Drilling Project recovered ~100 meters of impactites in a continuous core from the Yaxcopoil-1 (YAX-1) borehole. This dramatically increased the amount of melt available for analyses, which was previously limited to two small samples (N17 and N19) recovered from the Yucatan-6 (Y-6) borehole and one sample (N10) recovered from the Chicxulub-1 (C-1) borehole [e.g., 1,2]. In this study, we describe the chemical compositions of six melt samples over an ~40 m section of the core and compare them to previous melt samples from the Y-6 and C-1 boreholes.

Samples and Methods: The impactite sequence in the YAX-1 borehole includes melt-rich breccias (units 1 through 4), an underlying coherent green impact melt (unit 5), and a heavily brecciated and carbonate-charged basal layer (unit 6) [3]. Four samples were removed from the 24 m thick green impact melt unit, representing the entire interval: YAX-1_861.4, YAX-1_863.51, YAX-1_876.46, and YAX-1_883.13, where the sample numbers indicate depth in the borehole in meters. In addition, two impact melt clasts were removed from overlying suevitic units: a brown impact melt from unit 3 (YAX-1_841.32) and a pink impact melt from unit 4 (YAX-1_857.65). In all cases, the melt samples have microcrystalline textures dominated by Ca-rich pyroxene, plagioclase, and alkali feldspar [e.g., 4,5], although there is also mineralogical evidence of various degrees of hydrothermal alteration in these samples, particularly the addition of secondary carbonate [6,7]. Splits with the fewest fragments of unmelted target material were selected for major, minor, and trace element analyses. The splits were pulverized and homogenized, before being split again for complementary X-ray fluorescence (XRF) and inductively coupled plasma-mass spectrometry (ICP-MS) analyses. These are fractions of the same splits we

used previously for Os isotope studies [8,9]. Although the project sample depths and numbers from units 3 and 4 may correspond to similar sample depths and numbers in reports by other investigators, it is important to note that our results are for isolated melt fragments from polymict breccias, not bulk analyses of the breccias at those depths.

Results and Discussion: Representative major oxide compositions are illustrated in Fig. 1. The melt compositions are highly variable, although generally siliceous (54 to 61 wt. % SiO₂). The range of silica values brackets the silica content in the melt ground-mass composition in the Y-6 borehole (58 wt.%), but is less than that in a bulk analyses of the Y-6 melt and entrained clasts (64 wt.%), and another melt sample from the C-1 borehole (64 wt.%) [e.g., 1,2]. The most pristine melt samples based on mineralogy, YAX-1_863.51 and YAX-1_876.46, are less siliceous (~55 vs. 58 to 64 wt.%) than previous melt analyses. The chemical variation in the new YAX-1 samples coincides with secondary mineralization [6,7], indicating it largely reflects secondary hydrothermal alteration rather than primary compositional differences in the melt.

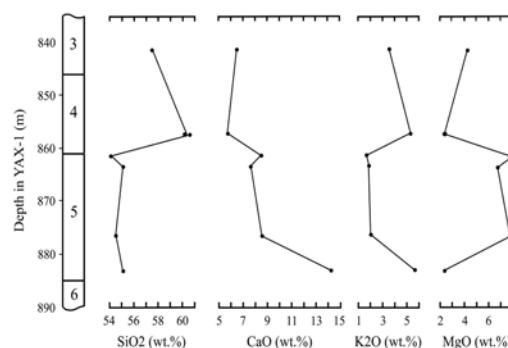


Fig. 1. Abundances of SiO₂, CaO, K₂O, and MgO in six impact melt samples from units 3, 4, and 5 from the YAX-1 borehole.

For example, decreases and increases in SiO₂ abundances are generally offset by opposite variations in CaO abundances. Calcium oxide abundances range from 5 to 15 wt.% and are correlated with observed hydrothermal carbonate, particularly near the lower boundary of unit 5 and, to a lesser extent, the upper

boundary of unit 5. These unit margins have previously been identified as conduits for secondary fluids [4-7]. Similarly, K variations correspond to observed abundances of secondary K-feldspar, which is particularly enriched in the unit 4 sample and the basal unit 5 sample. Although not shown, Na_2O is relatively uniform (3.04 to 4.03 wt.%) in all samples, consistent with the uniform abundance of albite observed in the samples [6,7].

Rare earth element (REE) abundances in the melts (Fig. 2) are generally less than those in granites and greater than those in carbonates, consistent with mixing of materials from a carbonate platform and a granitic crystalline basement. As discussed previously [4,5], the bulk of the melt should be derived from the silicate basement, although mixing ratios have not been quantified using REE-based mass balance calculations because we are still sorting through the effects of hydrothermal alteration. While REE are relatively immobile, subtle variations in Ce mimic those in a variety of lateritic, marine, and hydrothermal regimes. It is not yet clear at what stage(s) during the evolution of the post-impact fluid system the anomalies were produced. It is likely they are associated with varying redox conditions and either the precipitation of carbonate or phosphate, all of which have been inferred from petrologic analyses of the altered sequence [6,7]. A slight increase in the heaviest REE (Yb and Lu) in YAX-1_876.46, which was also observed in a duplicate sample, is similar to that in hydrothermal systems [10]. Despite these variations, the REE abundances are generally similar to those in andesites and estimates of the bulk continental crust [11].

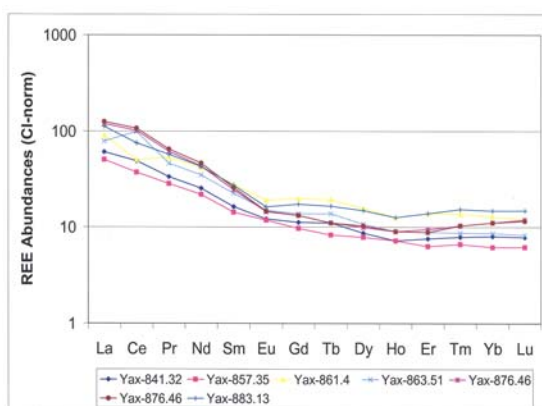


Fig. 2. CI-normalized REE abundances in seven impact melt samples from the YAX-1 core, including one duplicate sample.

The abundances of other representative trace elements are illustrated in Fig. 3. These elements are organized in order of decreasing mobility (from Sr to

Yb), based on observations in other geologic settings. In the case of YAX-1 samples, most elements do not vary by more than a factor of two from 841 to 883 m, the exceptions being Ba, K, P, and Sr. These correspond to variations in the abundances of hydrothermal barite, K-feldspar, apatite, and carbonate we documented previously [6,7].

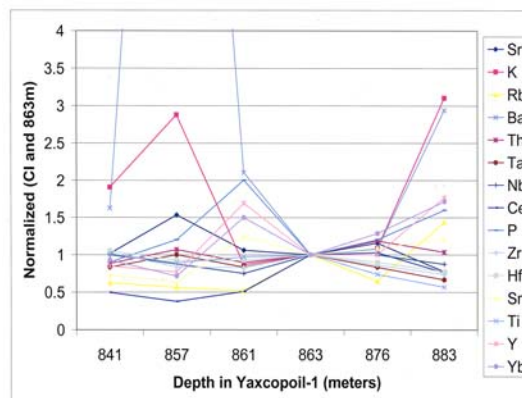


Fig. 3. Trace element abundances in YAX-1 melts, as a function of depth in the core, and normalized to the YAX-1_863.51 sample to show variation within core. The elements are in order of decreasing mobility (from Sr to Yb) seen in other geologic settings.

Implications: The major, minor, and trace element compositions of the YAX-1 melts indicate they have been variously altered and do not represent primary melt compositions. The chemical variations are consistent with secondary mineralogy [6,7] and may further constrain redox conditions and other factors governing the alteration processes. Detailed analysis of these variations relative to the least mobile elements and a good constraint on the abundances of secondary carbonate are needed to unravel the sequence of chemical reactions that occurred and potentially identify a reasonable initial melt composition.

References: [1] Kring D. A. and Boynton W. V. (1992) *Nature*, 358, 141-144. [2] Sharpton V. L. et al. (1992) *Nature*, 359, 819-821. [3] Dressler B. et al. (2003) *EOS*, 84, 125 & 130. [4] Kring D. A. et al. (2003) *LPS XXXIV*, Abstract #1641. [5] Kring D. A. et al. (2003) *MAPS*, submitted. [6] Zurcher L. and Kring D. A. (2003) *LPS XXXIV*, Abstract #1735. [7] Zurcher L. and Kring D. A. (2003) *MAPS*, submitted. [8] Gelinas A. et al. (2003) *LPS XXXIV*, Abstract #1359. [9] Gelinas A. et al. (2003) *MAPS*, submitted. [10] Taylor S. R. and Fryer B. J. (1982) in *Metallization Associated with Acid Magmatism*, 357-365. [11] Taylor S. R. and McLennan S. M. (1985) *The Continental Crust: Its Composition and Evolution*.