STABLE ISOTOPE RECORD OF POST-IMPACT FLUID ACTIVITY IN THE CHICXULUB CRATER AS EXPOSED BY THE YAXCOPOIL-1 BOREHOLE. Lukas Zurcher[1], David A. Kring[1], David Dettman[2], and Mark Rollog[2], [1]Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd., Tucson, Arizona 85721 (kring@LPL.arizona.edu), [2]Department of Geosciences, University of Arizona, 1040 E. Fourth St., Tucson, Arizona 85721.

Introduction: Cavities of secondary calcite and veins of secondary anhydrite and quartz in the Yucatan-6 borehole drilled into the Chicxulub structure suggested the impact generated a hydrothermal system [1, 2]. Based on work at other craters, mostly Siljan and Puchezh-Katunki [3, 4], we estimate this system could be several kilometers deep in the center of the crater and may extend to the rim, albeit at potentially shallower depths and cooler temperatures. Calculations of conductive cooling suggest the system may have been long-lived, up to 10^5 to 10^6 years [5, 6]. The first continuous core through impactites within the crater was recently recovered by the Chicxulub Scientific Drilling Project, providing a new opportunity to evaluate post-impact hydrothermal activity between the peak ring and rim of the crater.

Yaxcopoil-1: The Yax-1 borehole recovered continuous core from a depth of 404 m to 1511 m, penetrating Tertiary cover, ~100 m of impactites, and one or more megablocks of Cretaceous target sediments. The borehole is located ~60-65 km from the center of the Chicxulub impact crater and ~20 beyond the limit of the estimated ~50 km radius of the transient crater, on nearly the same radial line as the Yucatan-6 borehole. The impactites are diverse, consisting of melt-rich polymict breccias and a coherent green melt unit that was brecciated after solidification [7]. The units have been affected by fluid-dominated alteration processes, producing a mineralogical measure of post-impact activity [8]. To complement the mineralogical evaluation of the fluid activity, a series of stable isotope analyses of whole rocks, carbonate fractions, silicate fractions, and isolated impact melts were made to determine the source of the water in the system and, at this stage of the study, a qualitative assessment of system temperatures.

Oxygen Isotope Compositions: We analyzed a series of samples from within the impactite sequence, which ranged from a depth of 794 to 895 m [7, 8]. We also analyzed two samples from a depth of 1398 m, which represents a block of target carbonate and a dolomitic dike that crosscuts the block [9].

Oxygen isotope compositions as a function of depth are shown in Fig. 1. Many of the impactites had silicate and carbonate components, so oxygen isotopes were measured in both. The carbonate in the samples is in the form of clasts of target material, matrix, and secondary precipitates. The original composition of target carbonate is best represented by sample YAX-1_1398.53 (where YAX-1 identifies the borehole and the remaining numbers the depth of the sample in meters), which has $\delta^{18}O$ = 26.31 per mil. A secondary carbonate vein that crosscuts the uppermost impactites YAX-1_800.43) has $\delta^{18}O$ = 28.00 to 29.17 per mil.

Silicate fractions have $\delta^{18}O$ values generally in the range of 11 to 17.5 per mil (YAX-1_813.41, 821.76, 828.28, 829.36, 841.32, 861.4, 863.51, and 876.46). This includes 3 isolated clasts of crystalline basement material (YAX-1_821.76, 828.28, and 829.36), which have $\delta^{18}O$ values of 16.99, 14.90, and 16.19 per mil, respectively. All of these values are well above the $\delta^{18}O$ value expected of crustal silicates. In addition, they are far above the value previously established for the crystalline target material at Chicxulub. Analyses of glassy impact melt ejected from the crater and recovered in Haitian K/T boundary deposits indicate the silicate target lithologies have a bulk $\delta^{18}O$ = 6 per mil [10], which is typical of continental crust. Excursions to even higher values of $\delta^{18}O$ are seen in some silicate fractions (YAX-1_819.83, 832.83, and 883.13), where values are 20.99, 22.94, and 18.59, respectively. Carbonate fractions are generally isotopically heavy (up to 10 per mil) relative to silicate fractions, with the exception of YAX-1_832.83.

This pattern suggests the impactites exchanged oxygen with a post-impact fluid that was in equilibrium with an isotopically-heavy reservoir, which is likely represented by local carbonates. A similar shift in $\delta^{18}O$ among silicate melts in the Yucatan-6 borehole was also seen [11]. The exchange was greatest in samples YAX-1_819.83, 832.83, and 883.13. The first and third of these samples with anomalously high $\delta^{18}O$ values occur near contacts between different impactites in the core sequence, which were probably a conduit for fluids where water-rock ratios were greater, consistent with fracture abundances and mineralogical evidence [8]. Sample YAX-1_832.83 is not near one of these unit boundaries, but does have one of the most carbonate-rich matrices of any of the breccia samples.

Correlation with Carbon Isotopes: Complementary carbon isotope analyses were also determined on the carbonate fractions of several samples (Fig. 2). The general trend in the data suggests infiltration and cementation is responsible for the spread, dominated by fluids in equilibrium with a marine limestone. This implies a locally derived fluid, rather than magmatic input or carbonatite melt event. The fractionation of isotopes also implies warmer temperatures from the heaviest to the lightest $\delta^{18}O$ values. Taken at face value, the spread in the $\delta^{13}C$-$\delta^{18}O$ trend among the Yax-1 samples represents a spread of 40 °C around 300 °C, assuming a Cretaceous sea water $\delta^{18}O$ of –1. The temperatures are not correlated with depth, possibly reflecting the heterogeneous nature of veins and the effects of fluids permeating the sequence. Again, taken at face value, isotopic compositions measured in the Yucatan-6 borehole [11] represent fluids perhaps as hot as 400 °C. Alternatively, the decrease $\delta^{13}C$ and $\delta^{18}O$ values from right to left (Fig. 2) could also point to a modest influx of cold meteoric water. Hydrogen isotope analyses are being conducted to determine which interpretation is more likely.

Finally, petroleum found in a clastic dolomitic dike in sample YAX-1_1398.53, in a megablock of Cretaceous limestone far beneath the impact melts, has typical $\delta^{13}C$ values of –22.52 and –22.64 in two splits of the sample.

Conclusions: Temperatures and water-rock ratios were sufficiently high for silicate impact melts and clasts of crystalline target lithologies to exchange oxygen with a fluid that appears to have been in equilibrium with locally derived limestone. It is still not clear what the source of the fluid is (sea water or meteoric), but hydrogen isotope analyses should resolve this issue and allow better constraints to be placed on the fluid system.

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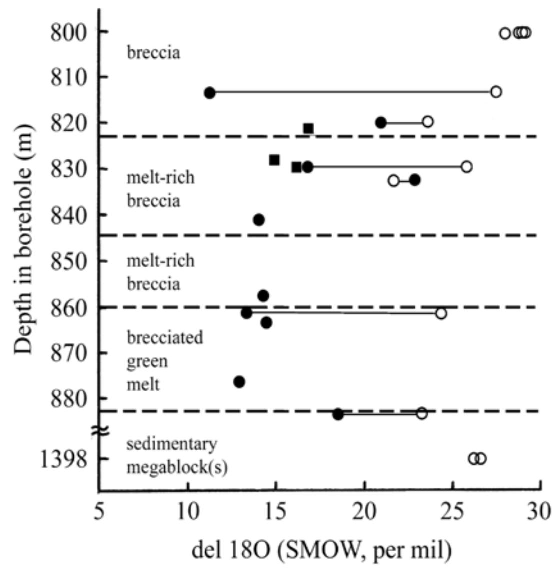

Fig. 1. Oxygen isotope compositions of silicate fractions (solid symbols) and carbonate fractions (open circles) as a function of depth in the Yaxcopoil-1 borehole, including three crystalline basement clasts (solid squares). Positions of boundaries between units that were logged during drilling are marked with dashed lines.

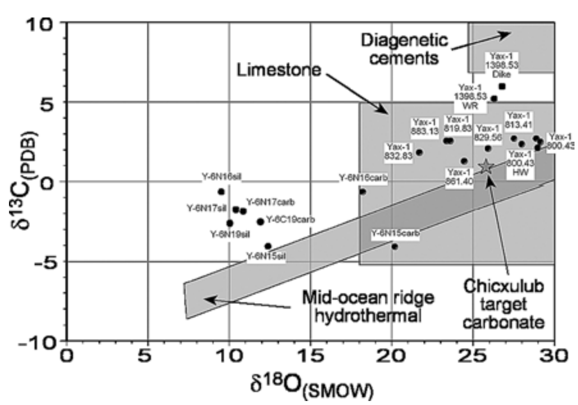

Fig. 2. Correlated carbon and oxygen isotope compositions of the carbonate fractions of samples from the Yaxcopoil-1 borehole (Yax-1; our data) and a set of samples from the Yucatan-6 borehole (Y-6; Kettrup et al. [11]).