

STABLE ISOTOPES AND HYDROTHERMAL FLUID SOURCE IN THE YAXCOPOIL-1 BOREHOLE, CHICXULUB IMPACT STRUCTURE, MEXICO. L. Zurcher¹, D. A. Kring¹, D. Dettman², and M. Rollog², ¹Lunar and Planetary Laboratory, University of Arizona, 1629 E. University Blvd., ²Department of Geosciences, University of Arizona, 1040 E. Fourth St., Tucson, Arizona 85721.

Introduction: We present new results of a detailed C, O, and H stable isotope survey on carbonate and silicate fractions of samples collected from the hydrothermally altered impactite units at Yaxcopoil-1 (Yax-1). Previous stable isotope studies on Chicxulub crater impactites include [1-4]. In this investigation, we treat stable isotopes in concert with mineralogical and geochemical data. Combined results allowed us to place constraints on the physico-chemical parameters of the hydrothermal fluid, which we used to deduce its most likely source.

Hydrothermal Alteration at Yaxcopoil-1: Petrographic and electron microprobe results conducted previously [5] suggested a slightly alkaline andesitic composition for the impactite units at Yax-1, with Na-bearing augite and S-rich apatite that pointed to assimilation of evaporite in addition to siliceous target materials. This work also put forward that impactites were permeated with secondary calcite and halite before being affected by early diopside after primary augite thermal metamorphism, feldspar metasomatism, and late smectite after chlorite and calcite replacement. Mineralogical data revealed a high fluid salinity, and a drastic increase in fluid f_{O_2} from the oil-bearing target carbonate below to the andesitic impactite host above. The lack of mineralogical zoning about the impact melt at Yax-1 further suggested that this unit was not the thermal driver for the hydrothermal system, implying that alteration resulted from the combined effects of a pre-existing saline brine and impact- or melt sheet-induced heat generated elsewhere in the Chicxulub crater.

Stable Isotope Results: $\delta^{18}O_{SMOW}$ and $\delta^{13}C_{PDB}$ isotopes from both silicate and carbonate fractions at Yax-1 contrast with isotopic data obtained at other localities in the Chicxulub crater.

Silicate fraction $\delta^{18}O$ values from phyllosilicate mixtures range between 10 and 23‰, with several nearing local Cretaceous limestone (~26‰). However, major $\delta^{18}O$ lows occur over the most intensely altered depth intervals (813 to 833m and 868 to 883m). These values are well above the oxygen signature determined for the impact melt at the Chicxulub-1 (C-1) borehole (~8‰; [6]), and

for black glass at the K/T boundary in Haiti (~6‰; [7]). A similar but less extensive $\delta^{18}O$ shift occurs in siliceous samples from the Yucatan-6 (Y-6) borehole (~10-13‰; [1]). δD values from this study exhibit a narrow range between -34 and -54‰, and closely mirror $\delta^{18}O$ values.

Carbonate fraction $\delta^{18}O$ values vary between 22 and 30‰, and most $\delta^{13}C$ values exhibit a narrow range between -1 and +2‰. $\delta^{18}O$ values are heavier than silicate fractions, and some are even heavier than local limestone. $\delta^{18}O$ and $\delta^{13}C$ values of carbonate fractions are on average higher in the upper part of the impactite section. Yax-1 carbonate $\delta^{18}O$ and $\delta^{13}C$ values are also heavier than values of carbonate-dominated samples from Y-6 (11 to 20‰ and -1 to -5‰, respectively; [1]).

Discussion: The carbonate fraction isotopic data are shown in Figure 1.

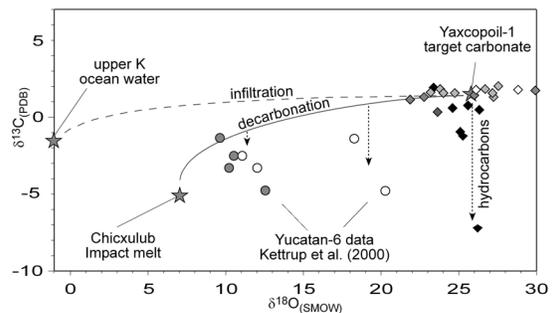


Figure 1: $\delta^{13}C$ versus $\delta^{18}O$ values of carbonate fractions.

The data show that the hydrothermal solution exchanged its isotopic composition with the target carbonate. Thus, the fluid had a near-neutral pH and contained dominantly an oxidized carbon species (i.e., CO_2 ; [8, 9]). $\delta^{13}C$ shifts to lighter values toward the bottom of the impactite section (black diamonds), however, point to a hydrocarbon fraction contained in the solution that was likely derived from the oil-bearing carbonates below. Examination of the spread in $\delta^{13}C$ and $\delta^{18}O$ values from this study and Y-6 (circles) of [1] further suggests that both infiltration and decarbonation reactions took place (see dashed and solid curves). This is consistent with observed calcite-filled vugs and veins (infiltration), and loss of CO_2 during diopside after augite thermal metamorphism (decarbonation). Moreover, the spread in heavier-than-limestone $\delta^{13}C$ and $\delta^{18}O$ values at Yax-1 point

to dissolution and reprecipitation of calcite from progressively ^{13}C - and ^{18}O -enriched CO_2 [10].

The silicate fraction isotopic results are displayed in Figure 2.

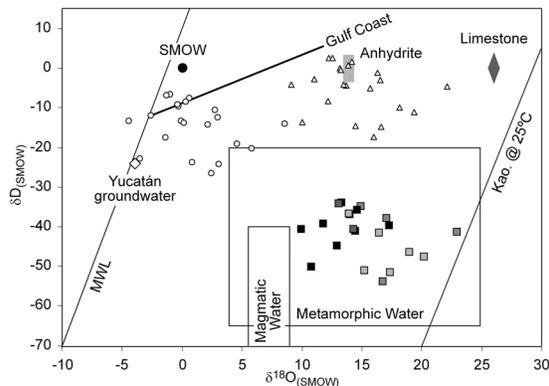


Figure 2: δD versus $\delta^{18}\text{O}$ values of silicate fractions.

Most of the raw rock data (filled squares) plot well to the left of the kaolinite line at 25°C , implying that low-T post-hydrothermal processes such as sea or meteoric water downward circulation did not significantly modify the original phyllosilicate signatures. Available fluid inclusion data from Yax-1 [11] suggest that the hydrothermal solution was a high salinity, hydrocarbon-bearing brine deposited between 100°C (calcite) and 270°C (quartz). The bulk of smectite after chlorite replacement occurred between the deposition of early quartz and late calcite. Thus, fluid isotopic signature scenarios may be constructed from the temperatures and the waters in equilibrium with these two hydrated phases. Figure 2 illustrates the calculated water in equilibrium with chlorite (open triangles) at 270°C [12, 13]. The plot shows that the fluid exhibits a minor $\delta^{18}\text{O}$ - and a major δD -shift toward lighter and heavier values, respectively, implying that seawater could be an end-member. Relative to ocean water, however, the salinity of the solution was substantially higher, and its redox state within the target carbonate was reducing. Cretaceous anhydrite (light-gray rectangle) with a typical $\delta^{18}\text{O}$ value of around 14‰ [14], in contrast, coincides well with the calculated fluid data, and is consistent with the abundant evaporites contained in the target rocks. For a scenario where the isotopic signatures are related to smectite rather than chlorite, calculated waters in equilibrium with smectite (open circles) at 100°C [15, 16] plot on and to the right of the meteoric water line. Effects of evaporation and high salinity explain the isotopic shift to heavier values [17] relative to groundwater isotope ratios from the northern part of the Yucatán Peninsula

(open diamond; [18]). The models above place plausible upper and lower limits on the source of the hydrothermal solution at Yax-1.

Conclusions: Stable isotope results, as well as fluid inclusion, mineralogical, and compositional data are most consistent with a saline basinal brine source for the hydrothermal fluid at Yax-1 [i.e., 19, 20]. Oil field brines like the one present in the Gulf Coast (black heavy trend) were originally thought to represent connate water or seawater trapped in pores of buried unmetamorphosed sedimentary rocks. However, isotopic studies since [21] have shown that fossil meteoric waters are also a major constituent of oil field brines. These formation waters have increased in salinity because of solution of evaporites and membrane filtration. In the impactite sequence, however, higher temperatures indicated by fluid inclusions and mineralogy suggest addition of impact-induced heat, and a substantial increase in the oxidation state of the fluid during reaction with the more mafic host rock.

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