HYDROTHERMAL PROCESSES AND MOBILE ELEMENT TRANSPORT IN MARTIAN IMPACT CRATERS — EVIDENCE FROM TERRESTRIAL ANALOGUE CRATERS.

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Introduction: Hydrothermal alteration and chemical transport involving impact craters probably occurred on Mars throughout its history. [1]. Our studies of alteration products and mobile element transport in ejecta blanket and drill core samples from impact craters show that these processes may have contributed to the surface composition of Mars [2]. Recent work on the Chicxulub Yaxcopoil-1 drill core has provided important information on the relative mobility of many elements that may be relevant to Mars [3].

The Chicxulub impact structure in the Yucatan Peninsula of Mexico and offshore in the Gulf of Mexico is one of the largest impact craters identified on the Earth, has a diameter of 180-200 km, and is associated with the mass extinctions at the K/T boundary. The Yax-1 hole was drilled in 2001 and 2002 on the Yaxcopoil hacienda near Merida on the Yucatan Peninsula. Yax-1 is located just outside of the transient cavity, which explains some of the unusual characteristics of the core stratigraphy. No typical impact melt sheet was encountered in the hole and most of the Yax-1 impactites are breccias. In particular, the impact melt and breccias are only 100 m thick which is surprising taking into account the considerably thicker breccia accumulations towards the center of the structure and farther outside the transient crater encountered by other drill holes.

SIMS studies of mobile element transport: Clays in thin sections from crater drill cores were imaged and analyzed by microprobe for major elements. Trace elements Li, B, Be, and Ba were measured with the Cameca IMS 4f ion probe, using primary O^- ions, a 10 kV potential; a primary beam current of 10 nA and spot diameter of 8 to 10 µm. Numerous standards were analyzed to verify the ability of the SIMS to analyze water-bearing mineral phases, and to show the absence of matrix effects.

Results: The altered groundmass found between clasts of target rocks contain materials with a desiccation texture characteristic of clays. The chemistry of the clays in thin section and preliminary XRD data on separated clays are consistent with smectite at all depths [4, 5]. The chemistry of these alteration materials range from that of an average montmorillonite composition in the uppermost units (from 800.68m to about 836m), to that of a magnesium rich saponite in the lower units (846.7m to 861.72m).

The clay analytical data show interesting trends as a function of depth in the drill core (e.g. **Figs. 1-3**). The elements Li, B, and Be, FeO generally increase upwards in the samples, with Li > B > Be >FeO while the Ba concentration in the clays decreases upwards. The abundance of Al_2O_3 in the clay material is also significantly higher in the suevite than in lower units, even though Al_2O_3 is not usually considered a fluid mobile component. Li in Unit 2 is enriched by factors of 1.1 to 3.5 relative to the lower units. There is a strong correlation between the abundances of Li, Be, and B (e.g. **Fig. 1**). The correlation coefficients among these elements are Li-B = 0.89, B-Be = 0.71, Li-Be = 0.50.

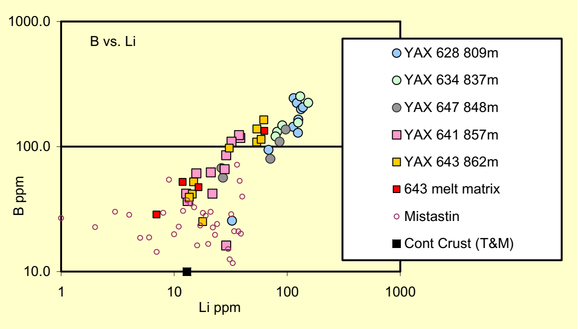

Fig. 1. Boron and lithium abundances in Chicxulub Yaxcopoil-1 matrix clays.

The concentrations of mobile elements determined by SIMS in clays in the Yaxcopoil drill core can be compared with bulk analyses of the impact breccias by Tuchscherer et al., [5]. Although, the types of samples from the core that were analyzed are not identical, a consistent behavior can be seen in the data for a number of mobile elements. For example, in the bulk analyses of the drill core, Tuchscherer et al., [5], documented upward enrichments in the concentration of the trace elements in the relative order Cs > Au > Rb = Zn in stratigraphic units 1 to 4 . The greatest upward increase in this data set is for Cs, which increases a factor of up to 3.7 relative to the lower units, similar to the SIMS data for Li.

Mobile element deposition in sediments above the impactites: Evidence for hydrothermal transport has also been presented by Rowe et al. [6], who studied mobile element concentrations in the sediments overlying the impact breccias. Rowe et al., [6] found that samples of Tertiary biomicrites from depths of 794.01 to 777.02 m have higher concentrations of Mn, Fe, P, Ti, and Al relative samples from higher up in the stratigraphic section. They attribute the observed enrichments to elements mobilized by hydrothermal systems in the impact deposits and deposited in the overlying sediments, analogous to hydrothermal deposits in mid-ocean ridge environments. At the Ries crater, Förstner, [7] found a similar enrichment of mobile elements in the graded sandstones and breccias derived from reworked suevite that was deposited in water in a playa lake environment just above the suevite deposits. The clay-size fraction (< 2 µ) in the lowest sediment sample is enriched in Li, Cd and Na compared to the rest of the sediment higher up in the sediment column.

Discussion: The SIMS data for Li and Be presents a convincing argument for hydrothermal transport. The upper impactite layers are distinctly enriched in these elements compared to the lower units. The data of Rowe et al. [6] for Li and Be show enrichments in the sediments directly above the impact breccias (**Figs. 2, 3**). The explanation for the behavior of these trace elements seems very straightforward, involving partitioning of the trace elements into hydrothermal fluids, with incorporation into clays formed during hydrothermal alteration in the impact breccias, and deposition with the earliest sediments on top of the impact breccias. Our SIMS data for B and the bulk data of Tuchscherer et al., [5] for Cs, Au, Rb, and Zn shows a similar pattern of enrichment to Li and Be in the impact breccias, suggesting that these elements should also be enriched in the sediments above the impact breccias. A mass balance calculation using the bulk data [5, 6] suggests that the extra Li in the sediments above the impact breccias represents less than 7.5% of the remaining Li in the clays in the impact breccias (units 2-5), and the extra Be in the sediments above the impact breccias represents less than 2.2% of the Be in the clays in the impact breccias (units 2-5). Unfortunately, we do not have Li and Be data on bulk samples from the impact breccias.

Implications for Mars: Hydrothermal alteration occurs in ejecta blankets, impact melt sheets and beneath the floor of impact craters of different sizes. The Lonar crater, India, represents nearly the smallest size crater to experience significant hydrothermal processes, but mobile element transport is not seen in our SIMS analyses of the drill cores [8, 9]. Small impact craters in sedimentary targets, like the Bosumtwi and Ries craters, do not seem to have as much impact melt, but hydrothermal processes probably still occur. The drill cores from the Bosumtwi crater Ghana (11 km diameter) that was drilled in September of 2004 will provide new information on hydrothermal processes in an intermediate sized crater emplaced in meta-pelites. Studies of element mobility in drill core samples from the large Chicxulub impact crater shows that if water is available, cratering processes can transport and enrich mobile elements in the surface of planets such as Mars [e.g. 3]. The mobile element transport studies on the Yaxcopoil-1 core suggest that the elements Li and Ce will be the most enriched elements in hydrothermal deposits associated with martian craters, but B, Be, Au, Rb, Zn, Mn, Fe, and P will also be enriched.

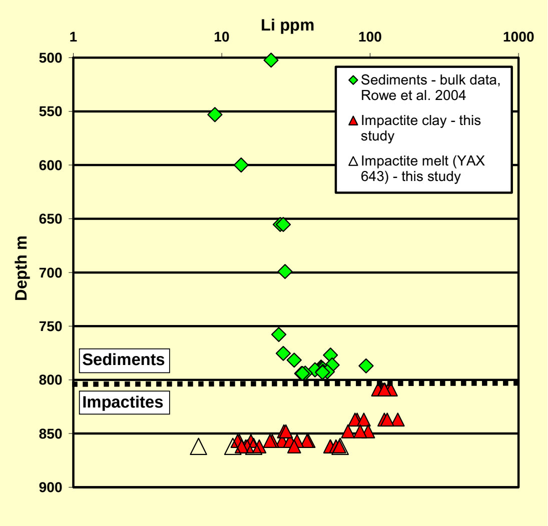

Fig. 2. SIMS results for Li, as a function of depth.

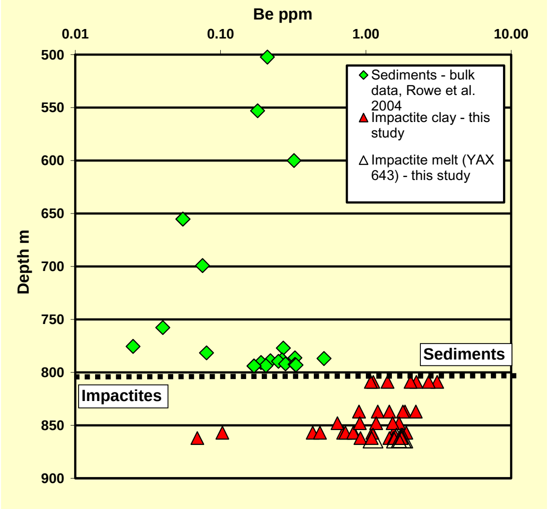

Fig. 3. SIMS results for Be, as a function of depth.

References [1] H.E. Newsom et al., (2001) *Astrobiology*, *1*, 71-88. [2] Nelson M. J., Newsom H.E. and Draper D. S. (2005), GCA in press. [3] Newsom et al., (2005) submitted. [4] Nelson et al., (2004) MAPS. 67th Annual Meteoritical Society Meeting, Rio de Janeiro. Brazil,. Aug. 2-6, 2004, #5214. [5] Tuchscherer M. G., et al. (2004). *MAPS 39*, 899-930. [6] Rowe A. J., et al. (2004) *MAPS 39*, 1223-1231. [7] Förstner V. U. (1977) *Geologica Bavarica* 75:37-48. [8] Hagerty and Newsom and (2003) MAPS, *38*, 365-381. [9] Newsom et al., (2005) Lunar Planet Sci. XXXVI, #1143.

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