CONSTRAINTS FOR MODELING CHEMICAL TRANSPORT DURING HYDROTHERMAL ALTERATION IN LARGE AND SMALL IMPACT CRATERS. H. E. Newsom, Univ. of New Mexico, Institute of Meteoritics, Dept. of Earth & Planetary Sci., Albuquerque, NM 87131, USA newsom@unm.edu.

Introduction: Modeling of hydrothermal alteration has progressed greatly in recent years. One of the next challenges for modeling is to explain the observations of elemental transport observed in terrestrial impact craters. We present data from our work that illustrates some of the evidence for impact craters of different sizes. For the large, 180-200 km diameter, Chicxulub impact crater, data from the Yaxcopoil 1 drill core suggests that some chemical transport has occurred, especially for Li, B, and Be. In contrast, for the small 1.8 km diameter Lonar crater, very little evidence for chemical mobility has been found. Extrapolation models to other planetary bodies, such as Mars, will require an appreciation of the differences in fluid composition.

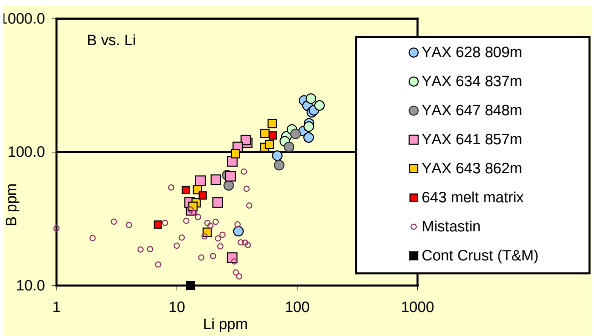

Fig. 1. Boron and lithium abundances in Chicxulub Yaxcopoil matrix clays. The correlation is consistent with fluid mobile behavior of these elements.

Yaxcopoil 1 drill core: The Yaxcopoil-1 (YAX) drill hole is located in the annular trough, about 70 km southwest of the crater center. The Yaxcopoil samples are from an interval less than 50 m thick within the ~ 100 m thick impact melt bearing layers. Matrix clays in thin sections from crater drill cores were analyzed for major elements using a JEOL 8200 EMP, and trace elements Li, B, Be, and Ba were measured with the Cameca IMS 4f ion probe [1]. The concentrations of the elements Li, B, and Be in the alteration material from the matrix of the impactite are enriched upward in the impactite sequence from Unit 5 to Unit 2, as represented by samples from 862 m to 809 m depth, by factors of 3.5 (Li), 2.2 (B) and 1.5 (Be). The correlation between B and Li is consistent with transport of these fluid-mobile elements (**Fig. 1**). The mobile elements Cs, Au, Rb, and Zn are enriched upward in the bulk analyses of Tuchscherer et al. [2]. Barium is depleted upwards in the section, but the formation of barite in the impact breccias probably depleted the Ba concentrations in the fluids and therefore in the altered matrix materials in the upper units.

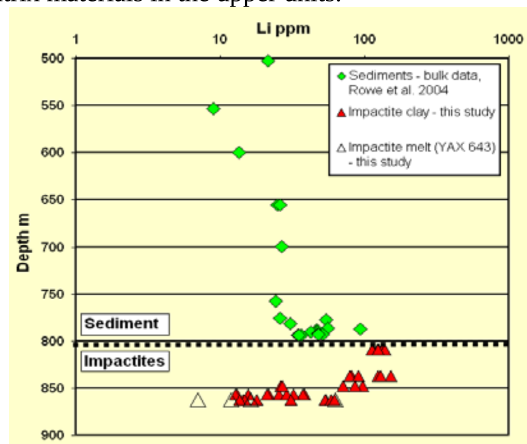

Fig. 2. Lithium as a function of depth in samples analyzed by Newsom et al., [1] and in sediment samples analyzed by ICP-AES [3].

The possibility that vertical transport of mobile elements in the YAX-1 core is due to a post-impact hydrothermal system is supported by the upward enrichments observed in the impactite section, and is consistent with the observed enrichments of mobile elements including Li and Be (**Fig. 2**) in the sediments immediately above the impact breccias analyzed by Rowe et al. [3]. Quantitative consideration of the mass of the mobile elements in the impact melt, the impact breccias and in the overlying sediments suggests that only a small fraction of the mobile elements from the impactites were deposited in the sediments directly above the impact breccias. However, the mobile elements in the sediments do not have to originate in the underlying impactites, but could have been supplied from a different nearby location, including the melt sheet at the center of the crater.

The limited fractionation of Li and B in the altered materials (**Fig. 1**) provides information on the temperature of the fluids involved in the formation of the late-stage altered matrix materials. Based on experimental data from the literature, the similar fractionation of Li and B in the impactites is consistent with a relatively low temperature hydrothermal system during the formation of the altered matrix materials (< 150 ^{o}C). The thin melt sheet at the Yax-1 location, and low temperature of the fluids implied by the trace element data may imply that only limited transport of mobile elements has occurred at this location away from the primary melt sheet within the transient cavity.

Lonar crater floor drill core samples: There is no strong evidence for vertical transport of Li, Be, B, and Ba, in samples from beneath the floor of the small Lonar crater, in spite of the evidence for the presence of post-impact hydrothermal alteration (Newsom et al.,[5]). However, the large scatter in the data, with for example, both B and Li varying by two orders of magnitude may be a result of local transport of these elements by hydrothermal fluids. This lack of evidence for vertical transport stands in strong contrast to our data from the Chicxulub drill core.

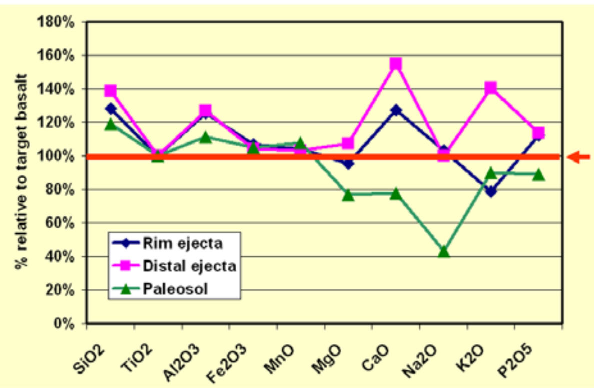

Fig. 3, Major element chemical composition of Lonar materials, compared to target rock basalt (arrow). The materials analyzed by XRF include ejecta from the rim of the crater (n=30), distal ejecta (n=9), and paleosol samples (n=8), normalized to unaltered target basalts (n=18).

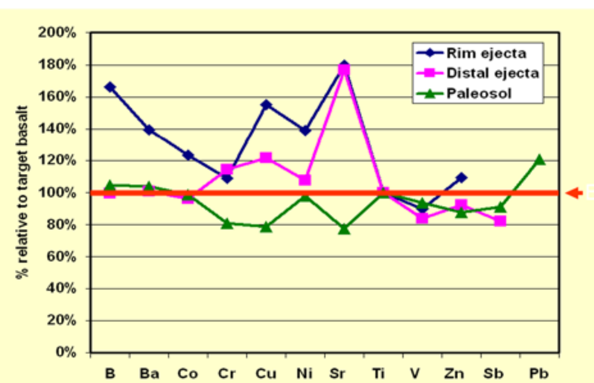

Fig. 4, Minor and trace element composition of Lonar materials obtained by ICP, compared to target rocks and impact melts. The materials analyzed include ejecta from the rim of the crater (n=8), distal ejecta (n=3), and paleosol samples (n=6), normalized to unaltered target basalts (n=6).

Lonar eject blanket studies - The ejecta blanket at Lonar extends beyond 1350 m from the rim with discontinuous patches as far as 3000 m. The large number of accumulating analyses of ejecta blanket materials is being used to address the nature of the alteration and chemical transport in different portions of the ejecta blanket. Samples have been analyzed by XRD and ICP at the University of New Mexico and in India [5]. The geochemical data for the basaltic samples in this study have been normalized to the relatively immobile element titanium. There are interesting differences between the four types of materials compared here (**Figs. 4, 5**). The ejecta samples and paleosol samples are not identical to the target basalts, with the largest difference being a depletion of Na. In contrast, the ejecta samples are not depleted in Na, but are enriched in some elements. Both groups of ejecta are enriched in Si, Ca, K, and Sr, while the proximal rim ejecta is also enriched in B, Ba, Cu and Ni.

Interpretation: The paleosol samples from several areas around the crater represent a much more advanced state of chemical evolution than the ejecta samples, which are probably much younger. The contrasting chemistry of the ejecta suggests a much less advanced state of alteration, but still representing a substantial difference from the target rocks. The physical process of creating the large volume of fine-grained matrix material present in the ejecta may be the most important aspect of promoting chemical alteration by aqueous processes. The presence of caliche, a carbonate-rich material at the base of the impact deposits, supports the role of leaching and chemical transport. Clearly some alteration and transport under ambient conditions has occurred. In terms of possible hydrothermal effects, the enrichments of B, Ba, and Cu in the proximal rim ejecta and not in the distal is intriguing.

Conclusions: Our studies suggests that the Chicxulub impactites away from the central melt sheet experienced low-temperature hydrothermal processing, and limited transport of some elements, including Li, Be and B. At Lonar crater, there is little evidence for any chemical transport, although some modification of the ejecta by enrichment of Si, Ca, K, and Sr may have occurred. This type of information provides constraints on future modeling of the nature of aqueous and hydrothermal processes for craters of different sizes.

References [1] H.E. Newsom et al., (2006) *MAPS 41*, 1921-1949. [2] M.G. Tuchscherer et al. (2004), *MAPS 39*, 899-930. [3] Rowe et al., *MAPS 39*, 1223-1231. [4] H.E. Newsom et al. (2005) *Lunar Planet Sci. XXXVI*, #1143. [5] S. Misra et al. (2006) *LPSC 37th*, # 2123. Supported by NASA P.G.&G. NNX 08AL74G.