HYDROTHERMAL ALTERATION AT LONAR CRATER, INDIA AND ELEMENTAL VARIATIONS IN IMPACT CRATER CLAYS.
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Introduction: The role of hydrothermal alteration and chemical transport involving impact craters could have occurred on Mars, the poles of Mercury and the Moon, and other small bodies [1]. We are studying terrestrial craters of various sizes in different environments to better understand aqueous alteration and chemical transport processes. The Lonar crater in India (1.8 km diameter) is particularly interesting being the only impact crater in basalt. In January of 2004, during fieldwork in the ejecta blanket around the rim of the Lonar crater we discovered alteration zones not previously described at this crater. The alteration of the ejecta blanket could represent evidence of localized hydrothermal activity. Such activity is consistent with the presence of large amounts of impact melt in the ejecta blanket.

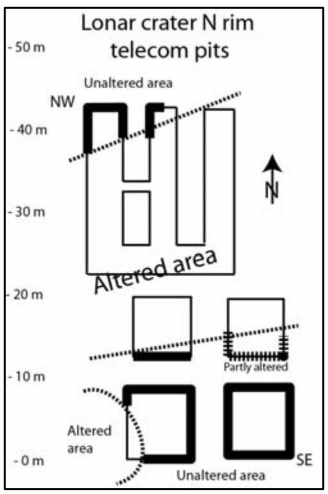

Fig. 1. Map of one area on the north rim of the crater containing highly altered zones at least 3 m deep.

Lonar eject blanket studies: The ejecta blanket at Lonar extends 1350 m from the rim with patches as far as 3000 m. Our recent fieldwork and examination of drill core material from the ejecta blanket suggests that geochemical transport and hydrothermal alteration in small craters is more important than previously realized. Alteration zones in the ejecta blanket consist of areas on the order of 20 to 50 meters in extent that are moderately to highly altered (e.g. Fig. 1). X-ray diffraction studies using Cu/K-alpha radiation of three of the altered samples show strong 14 angstrom d-spacings consistent with smectite clays. Bulk chemical analysis shows a significant depletion of K_2O, and Na_2O in the material from the altered zones compared to the fresher basalt blocks (Fig. 2). An interesting feature of the alteration pattern is the slight depletion of P_2O_5, TiO_2 and Fe_2O_3 in the altered materials. Normalizing to TiO_2, however, would imply enrichments of MgO, Al_2O_3, SiO_2, CaO, and MnO in the altered material. The martian soil is enriched in Ti relative to martian basalts, therefore it is worth understanding the behavior of this element in these environments.

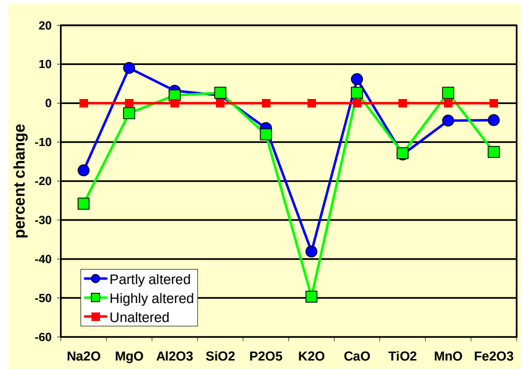

Fig. 2. Chemical composition of altered relative to unaltered samples from the ejecta blanket. Analyses by XRF.

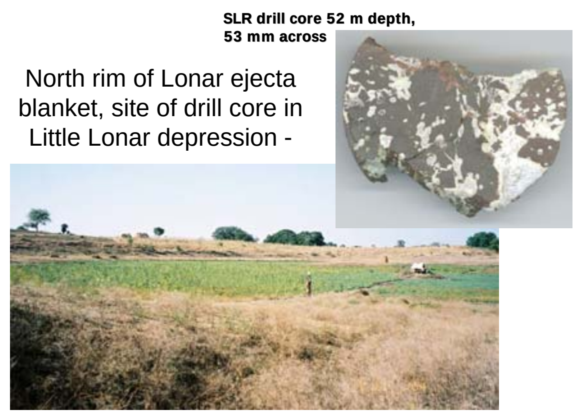

Fig. 3. Little Lonar depression in ejecta blanket. Inset-Drill sample of altered basalt, 52 m depth, with carbonate.

The discovery of alteration zones in the ejecta blanket is consistent with evidence for alteration and carbonate deposition in a drill core north of the crater in the ejecta blanket (Fig. 3). Samples from this drill core were used to conduct bulk rock isotopic analyses of altered and unaltered basalts. The very fine-grained, unaltered basalt, NMNH 116569-84 (SLR 1, 50 m depth), had an oxygen isotope value of $\delta^{18}O_{SMOW}$ = 8.0 $^{o}/_{oo}$ and the heavily altered basalt, NMNH 116569-85 (SLR 1, 52m depth, Fig. 3 inset), demonstrated an oxygen isotopic value of $\delta^{18}O_{SMOW}$ = 7.3 $^{o}/_{oo}$. During high temperature alteration, isotopic fractionation is very small and negative. The observed fractionation of -0.7 $^{o}/_{oo}$ between the altered an unaltered Lonar samples is indicative of high temperature exchange between the altered basalt and the altering fluid [2].

SIMS studies of mobile element transport in impact crater clays: Matrix clays in thin sections from crater drill cores were imaged and analyzed for major elements using a JEOL 8200 EMP and a JEOL

SEM. 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. Secondary ions were filtered with an offset voltage of 105 V and an energy window of 50 V. Concentrations were calculated using measured Trace-Element/$^{30}Si^+$ ratios, normalized to known SiO_2 content. Numerous standards were analyzed to verify the ability of the SIMS to analyze water-bearing mineral phases, and to show that there are no matrix effects compromising the analytical data.

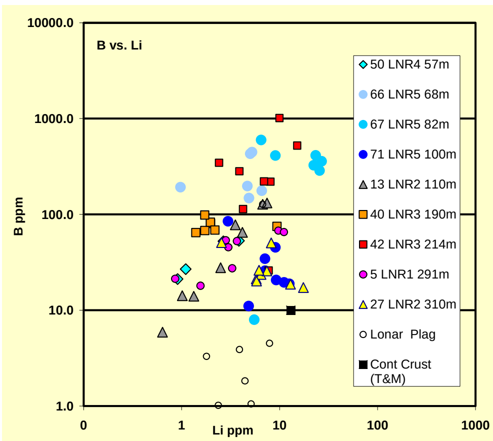

Fig. 4. Boron versus lithium trace element abundances in matrix clays from Lonar drill core samples. Continental crust abundances from [4].

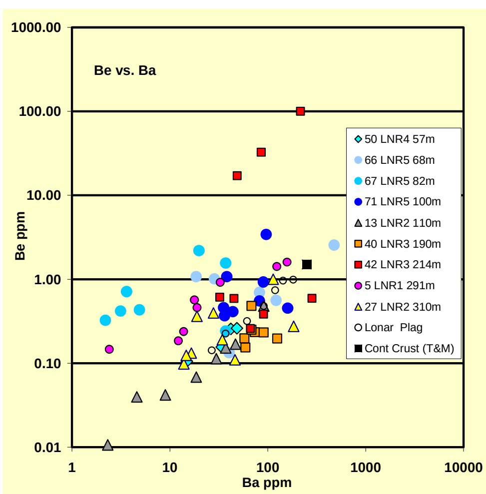

Fig. 5. Beryllium versus barium abundances in matrix clays from Lonar drill core samples.

The data for B, Li, Ba, and Be in nine samples of matrix clays from Lonar drill core samples at various depths shows no strong trend of vertical transport of mobile elements (Fig. 4, 5). Data for Li, Be, and Ba in feldspars have a similar scatter as the clay analyses, but B is much lower in the feldspars (Fig.4).

Discussion: 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. However, the large scatter in the data, with for example, both B and Li varying by two orders of magnitude is likely to be a result of local transport of these elements, presumably by hydrothermal fluids. This lack of evidence for vertical transport stands in strong contrast to our data from the Chicxulub drill core (Fig. 6). 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, while the Lonar samples range in depth over 230 m, and are from 5 different holes in the shocked basement.

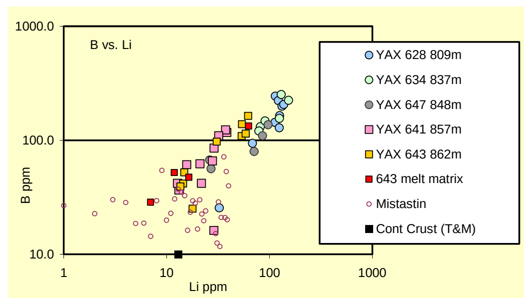

Fig. 6. Boron and lithium abundances in Chicxulub Yaxcopoil matrix clays.

Implications: Our studies of alteration products and mobile element transport in ejecta blanket and drill core samples from impact craters show that cratering can affect the surface composition of planets such as Mars [3]. An important conclusion is that hydrothermal alteration appears to occur both in ejecta blankets and beneath the floor of craters in basalt as small as Lonar. Compared with other terrestrial craters, Lonar represents nearly the smallest size crater to experience significant hydrothermal processes. Small impact craters in sedimentary targets do not seem to have as much impact melt, but hydrothermal processes 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 a larger 11 km diameter crater.

References [1] H.E. Newsom et al., (2001) *Astrobiology*, *1*, 71-88. [2] Hagerty, J. J., and Newsom, H. E. (2003) *Meteoritics and Planet. Sci.*, 38, 365-381. [3] Nelson M. J., Newsom H.E. and Draper D. S. (2005), GCA in press. [4] Taylor S. R. and McLennan S. M. (1985) *The Continental Crust*, Blackwell. Supported by NASA P.G.&G. NAG 5-11496.