CONTRASTING ALTERATION AND ENRICHMENT OF MOBILE ELEMENTS DURING WEATHERING OF BASALTIC EJECTA AND ANCIENT SOILS AT LONAR CRATER, INDIA. H. E. Newsom¹, S. Misra², S. P. Wright¹ and N. Muttik¹,³, ¹Univ. of New Mexico, Institute of Meteoritics, Dept. of Earth & Planetary Sci., Albuquerque, NM 87131, USA newsom@unm.edu, School of Geological Sciences, University of KwaZulu-Natal, Durban- 4000, South Africa (misras@ukzn.ac.za), ³Department of Geology, University of Tartu, Ravila 14a, 50411 Tartu, Estonia, (nele.muttik@ut.ee).

Introduction – Lonar crater, India is an impact crater site in basaltic target rocks with relevance to Mars and the lunar polar regions [1]. The parent basalts are Fe-rich and surprisingly similar to Martian basalts [2]. The Lonar crater is about 50,000 years old and was formed in the 65 Ma old Deccan flood basalt by impact of a chondritic body, based on recent studies of siderophile elements in melt spherules from the ejecta blanket [3]. The aqueous alteration processes associated with the impact at Lonar can provide insight into Martian surface processes and the formation of the Martian soil. Studies of samples from beneath the floor of the crater suggest only a limited role of hydrothermal activity resulting in deposition of clays or alteration minerals [2]. However, the ejecta blanket (Figs. 1, 2) provides access to soils and ejecta materials similar to those common on many planetary surfaces, prompting our work on the extent of aqueous alteration.

Results – Chemical analysis by X-Ray Fluorescence for major and trace elements of an additional suite of samples from Lonar has been obtained (e.g., Fig. 3). The samples are widely distributed around and within the crater. The ejecta blanket at Lonar extends beyond 1350 m from the rim of the crater extending patches as far as 3000 m. Paleosol samples were collected from beneath the ejecta blanket in several locations. Samples were collected during several field campaigns by H.E. Newsom, S.P Wright, and S. Misra. Some of the paleosol samples are fractionated from the target basalt composition due to loss of alkali elements, and represent the residual products of weathering. While many of the ejecta samples are relatively unfractonated relative to the target basalts, a significant number fall on a trend showing an enrichment of alkali elements due to mobile element transport associated with alteration following the formation of the crater.
Fig. 4. The trace element abundance of Sr normalized to Al₂O₃ for different components demonstrates a similar situation to the data for Na₂O, with some of the paleosol samples substantially depleted in Sr relative to the target basalt, while the ejecta can be enriched in this mobile element.

Fig. 5. Caliche cemented ejecta blanket ~ 0.5 m below the surface, due to the chemical transport of alkali elements.

During weathering of basaltic rocks certain elements are presumed to be immobile, especially titanium and aluminum. Therefore, the data for the samples in this study have been normalized to immobile elements, (for example, Fig. 4). A powerful tool for understanding the chemical fractionations during basalt weathering is the A-CNK-FM (Al₂O₃ – CaO+Na₂O+K₂O – FeO+MgO) ternary plots of Nesbitt and Wilson [4], used extensively for plotting data from the MER rovers [5]. The data from Lonar are plotted in this space in Fig. 3.

Discussion – Now that the chemical data are more complete, several questions can be addressed with more certainty: 1) what is the nature of the alteration and chemical transport in different portions of the ejecta blanket (Figs. 1, 2) and under lying paleosol (Fig. 1) compared to the target basalts? 2) Given the increase in matrix content of distal ejecta, are there substantial components of the paleosol incorporated in the ejecta?

The nature of the alteration processes in surface samples from Lonar crater are demonstrated with the data plotted in Fig. 3. The basalts fall in the center of the field overlapping the dotted reference line from the MgO+FeO corner to the feldspar composition. Of the proximal and distal ejecta and the paleosol samples, many have compositions similar to the unaltered basalts. However, the most weathered or altered samples are some of the paleosol samples that are distinctly depleted in alkali elements (Fig. 3). These samples are also depleted in some trace elements like Sr (Fig. 4) and P. This is the most common result of extensive weathering of basalts [4]. The weathering probably occurred over a period of time much greater than the age of the crater (~50,000 years). In contrast, the proximal and distal ejecta samples overlap the basalt composition, but some of the proximal and distal ejecta samples are enriched in alkali elements. Given the small size of the Lonar crater (1.8 km diameter), it is not surprising that hydrothermal alteration is not observed in the ejecta blanket and even the weathering processes are not as evolved as seen many of the much older paleosol samples. However, the transport and deposition of mobile elements, presumably enhanced by the extensive crushing of the ejecta due to the impact may be a process that will also be important on Mars. The presence of caliche, a carbonate-rich material at the base of the impact deposits supports the role of leaching and chemical transport in the ejecta (Fig. 5).

Regarding the possible incorporation of paleosol material in the distal ejecta, field observations show evidence for the incorporation of clasts of paleosol in the distal ejecta. However, our current results do not support a major component of the paleosol as a well-mixed component of the distal ejecta matrix. For example, the proximal ejecta and the distal ejecta have similar average Na and Sr contents that are greater than the concentrations in the paleosols (e.g., Fig. 4).

Implications – These results emphasize the role of shock and comminution due to impacts in basaltic terrains, thereby enhancing the later ambient or hydrothermal processing of the ejecta material. Thus, in the presence of water, alteration of shocked and disrupted materials from impact craters the size of Lonar crater (1.8 km diameter) or larger can contribute to substantial mobile element transport on planetary surfaces.


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