GAMMA (γ) – RAY MAPPING OF EJECTA AROUND LONAR ASTEROID IMPACT CRATER, INDIA.

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Introduction: The morphology of impact craters on the planetary surfaces that provides the best evidences on trajectories of impactor asteroids is the distribution of ejecta around craters [1]. Although, proper mapping of ejecta around planetary craters by remote sensing techniques provides useful information on the evolution of these structures, this approach is difficult for terrestrial craters because the original distributions of ejecta around these structures is often modified by weathering. To overcome this limitation, we explore the possibility of γ-ray mapping of ejecta, using a portable G-M pulse counting system of United Kingdom Atomic Energy Division (Type 975011-1) with G-M probe type 978005-1, taking Lonar impact crater, India (**Fig. 1**), as an example. Additionally, absorbed γ-dose rates of selected Lonar samples, including target rock, palaeosol, impact-melts and ejecta, were also computed from U, Th and K data [2] that were measured using a NaI (Tl) sensor [3] at the National Geophysical Research Institute, Hyderabad, India, for comparative study.

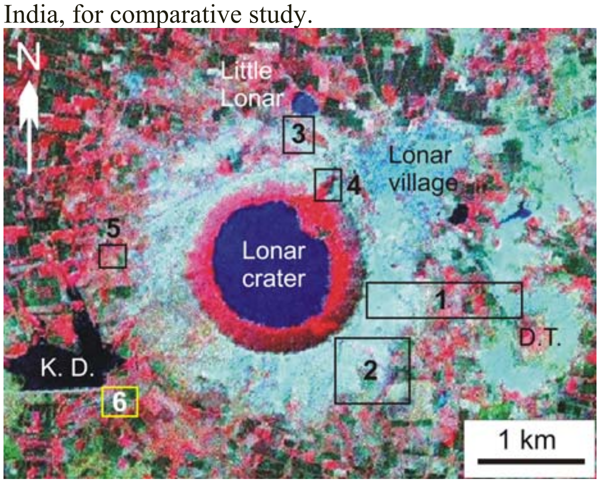

Fig. 1. False-coloured composite Landsat 7 image [14] of Lonar crater, India. Bright zone encircling the crater rim is ejecta; palaeosol is represented by reddish black area in surroundings. K.D.- Kalapani dam, D.T.- hillock Durga Tegri, boxes show study areas.

Lonar crater: The ~1.8 km diameter, Lonar crater [Fig. 1] is the only well known terrestrial impact crater that was formed completely in basaltic target (Deccan basalt, ~65 Ma) at ~52 ky ago [4-6]. Along the circumference of the crater, expect for a small sector in the NE, there is a continuous rim raised ~30 m above the adjacent plains, whereas the crater floor lies ~90 m below the pre-impact surface; the crater rim is surrounded in all directions by a continuous ejecta deposit that extends outward with a very gentle slope of 2-6^{o} to an average distance of ~1350 m from the crater rim [7]. The impactor was a chondrite that hit the pre-impact surface from the east [8, 9]. The low degree of geochemical alteration [10, 11] and relatively pristine surface configuration of the crater [12] are perhaps due to semi-arid climatic condition that has prevailed since the formation of this structure [8]. The black-coloured palaeosol that lies between target basalt and ejecta was developed by in-situ weathering of Deccan Traps during last ~ 65 Ma and represents a more advanced state of chemical weathering than the younger ejecta deposit [13].

Field observations: The γ-radiation of fresh target-basalts were measured at the west of crater (areas 5 and 6 in fig. 1), and was found to vary between 11 and 15 counts/minute (c/m). In relatively weathered basalts in the upper 50 m of crater wall section at the NE (area 4 in fig. 1), the values ranged between ~18 and 26 c/m. The highest range of γ-radiation between ~15 and 29 c/m was observed in the very weathered basalts from the lower part of this section. The most weathered palaeosol cover on the Deccan Traps yielded γ-radiation between 15 and 23 when measured from Durga Tegri and Kalapani dam sections (Fig. 1). The unaltered ejecta were measured in many areas around the crater (areas 1, 2, 3, 5, 6 in Fig. 1) and the γ-radiation of ejecta varied between 24-30 c/m. The impact-melt bomb bearing ejecta, now present in small pockets at the east of crater, however, showed similar count rates between ~26 and 33 c/m.

A section ~2 km in length and ~200 m wide from the hillock Durga Tegri at the east to the crater rim (area 1 in Fig. 1) was selected for measurement. A systematic investigation showed that there was ~1½ times increase of field γ-radiation from palaeosol to ejecta when the section was traversed from the east to west.

Laboratory observations: The average of Th (ppm), U (ppm) and K (wt%) contents of the Lonar samples are given in table 1. Except for a few exceptions, palaeosol has the highest Th and U contents over other members of the Lonar crater. The average Th content of the palaeosol is ~2 and ~1.6 times higher over the impact-melts and spherules, and the target-basalts and ejecta, respectively. The average U content of the palaeosol is nearly double to those of other members. When absorbed **γ-** dose rate (D) of the Lonar samples were computed from the estimated abundances of ^{232}Th, ^{238}U, and ^{40}K in the samples [after 2], the palaeosol has the highest D values (average ~16 nGy h^{-1}), followed by impact-melts and spherules (~10 nGy h^{-1}), and ejecta and target basalt (~8 nGy h^{-1}) (Fig. 2). The limitation of this computation, however, is that the effects due to radiation dose of ^{226}Ra cannot be evaluated for these bulk D values.

Table 1. Average Th, U, K and computed D values of Lonar samples (numbers in brackets are standard deviations), IM- impact-melt, B- target basalt, S-impact spherules, P- palaeosol, E-ejecta, data- present analyses and from [10, 11].

Sample	No.	Th (ppm)	U (ppm)	K (wt%)	D (nGy h^{-1})
IM	71	2.52 (0.40)	0.63 (0.31)	0.46 (0.10)	9.90 (1.99)
B	26	1.89 (0.48)	0.67 (0.38)	0.32 (0.15)	8.58 (2.77)
S	7	2.53 (0.27)	0.55 (0.17)	0.40 (0.11)	9.50 (1.23)
P	9	4.07 (2.02)	1.09 (0.54)	0.47 (0.35)	16.45 (7.74)
E	19	2.04 (0.47)	0.58 (0.37)	0.24 (0.10)	8.42 (2.03)

Discussion: The application of radioactivity is perhaps the least known technique in evaluating asteroid impact craters. Earlier reports on radioactivity measurements on the Ivory Coast tektites and Bosumtwi impact crater were not satisfactory because crater-rocks and tektites showed similar abundances of Th, U and K [15]. Our field investigation on radioactivity around Lonar crater, however, confirms that this method can effectively be used to map distribution of ejecta around any crater if the target is relatively old in age, so that the differences in γ-radiations between the target and overlying ejecta become sensitive. Our data on field measurements around the Lonar crater show that the γ-radiations of the weathered basalts are ~1.7 times more than the fresh basalts; the ejecta has higher count rates over the palaeosol (~1.5 times); computed absorbed **γ-** dose rates (D) from the estimated abundances of ^{232}Th, ^{238}U, and ^{40}K in the samples also confirm that palaeosol, impact-melts and spherules, and the ejecta have distinctly different D values except for a few exceptions. So it can be concluded that radioactivity mapping (**γ** counts) by direct measurement by a portable G-M pulse counter can help to get a better understanding of ejecta distribution around any terrestrial impact craters on relatively old target rocks rather any conventional mapping using field or satellite imagery techniques. Further elaborate study on Lonar crater is in progress.

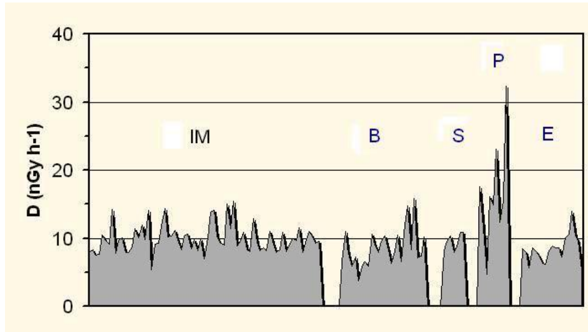

Fig. 2. Bar diagram showing absorbed γ-dose rates (D) of Lonar samples computed from estimates abundances of ^{232}Th, ^{238}U and ^{40}K, abbreviations and data as in table 1.

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