

# THE DRAINAGE SYSTEMS DEVELOPING ON THE HYDROLOGICALLY ACTIVE IMPACT CRATER, LONAR, INDIA.

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**Introduction:** Lonar Crater is a 1.8-km-wide (rim-to-rim) impact structure formed in a basaltic target of the Deccan Traps. This crater is important for the well-preserved morphology due to its relatively young age (e.g.,  $52,000 \pm 6,000$  years: [1];  $570 \text{ ka} \pm 47$ : [2]), and the fact that it was formed within the basaltic bedrock [3].

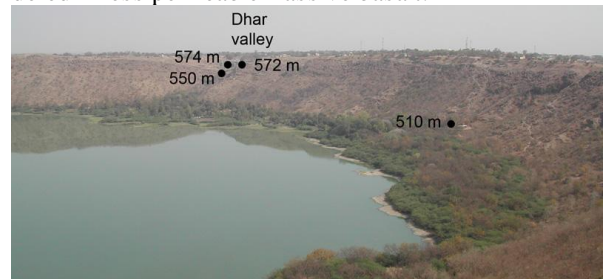
At the present-day Lonar, rich and diverse hydrological processes are observed in and around the crater. The most notable hydrological feature is the perennial Lonar Lake (Lonar Sarovar) (1.2 km diameter) on the crater floor, and this crater lake has been the center of attention for the vast majority of research efforts in the past. Lonar Lake has no stream outlet.

Although the lake has been recognized to be important in the fields of geochemistry and biology, there has been limited discussion on its hydrological processes. Because of the lake level fluctuation linked to the monsoonal climate, it is reasonable to assume that precipitation in the catchment area including the lake surface and evaporation from the lake are the main drivers for controlling the lake level under the today's climatic condition.

Another important but rarely discussed topic, also related to Lonar hydrological processes, is the modification of the rim and the ejecta blanket. The Dhar valley that is incised in the northeast segment of the rim, gullies developing along the inner rim walls, and channels on the ejecta blanket are not only the conduits for water transport but also a crucial component in processes of degradation of the crater, transport of sediment, and eventual deposition. We present examples of such drainages.

**Groundwater emergence along the inner rim walls:** Lonar Crater does not have incoming perennial surface flow from the surrounding plains. Lonar Lake directly receives precipitation in its surface and runoff along the inner rim walls, during the rainy season. The only drainage currently connecting the inner crater and the surrounding plains is the Dhar valley incised in the northeast segment of the raised rim. However, the valley conveys surface flow from the surrounding catchment only during the rains. The groundwater contribution is important for infilling during the rainy season

and for maintenance of the lake during the dry season. There are springs that are active even during dry seasons. Two such springs are located near the head of the Dhar valley (at Gomukh Temple and Paphareshwar Temple), and another in the mid valley. The spring discharge elevations at Gomukh Temple and Paphareshwar Temple are about 574 m and 572 m respectively (**Fig. 1**). The elevation of the spring outlet in the mid valley is about 550 m. The other spring currently known to be active even during dry seasons is located on the east inner rim wall at an elevation of about 510 m (**Fig. 1**). Here, the spring water emerges from under a debris flow deposit. The groundwater discharge is observed as springs on the inner rim walls corresponding to the layers of weathered vesicular basalt, which occur above massive basalt layers. This observation indicates that groundwater movement is lithologically controlled: it passes preferentially through permeable vesicular basalt (aquifer) but is hindered in less permeable massive basalt.



**Fig. 1.** Approximate positions and elevations of springs along the inner rim walls.

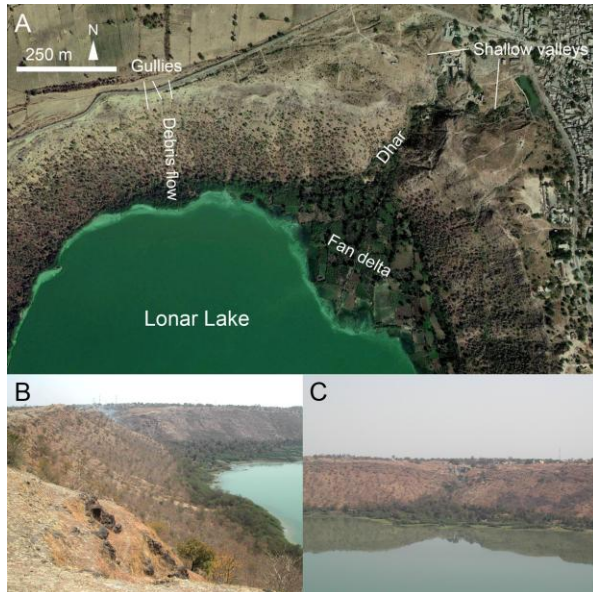
*The hydrological balance of Lonar Lake.* The hydrological balance of Lonar Lake has not been fully understood, but a hypothesis can be made based on our observations. It is certain that the monsoon precipitation in the catchment area including the lake surface is important, and the lake level increases during the monsoon by collecting both surface and groundwater entering the lake. The groundwater contribution should include not only the one emerging through springs on the surface but also the one reaching a deep water table at the level of the lake owing to the inter-

connectivity of the aquifers. During the dry season, the lake continuously receives groundwater input, but the evaporation from the lake exceeds the input, making the lake level to drop.

#### Modification landforms:

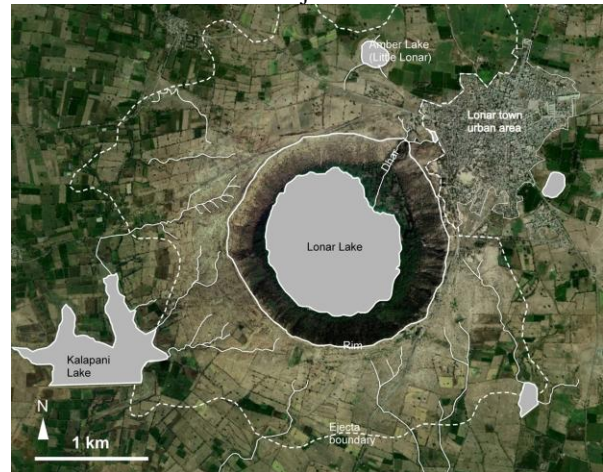
**Inner crater rim.** The inner rim walls are steep (~15–25 degrees), and slumped blocks in contact with the inner rim walls by normal faults ([4][5]) indicate the wall instability in some sections. The drainages inside the crater rim collect rainfall or spring water, transport water and eroded sediment down to the crater floor, in the lake. The inner rim walls are characterized by the presence of gullies and mass wasting features such as debris flows (**Fig. 2A, B**). Similar to other impact craters [6], the gullies were formed by runoff from the rain, which enhances downward mass movement.

The transported debris forms small fans or shore terraces down in the lake. The fan positioned in front of the Dhar valley (**Fig. 2A, C**) accumulates sediment originated from the incised rim and the surrounding plains distributing to the northeast direction outside the crater. The river valley feeder system entering a body of water transports a large quantity of coarse-grained sediment, and the fan formed in this kind of setting is called Gilbert-type delta, a type of fan delta frequently developing in front of a steep mountain front bordering with a standing body of water. The Dhar valley and the fan delta is a sediment transport system moving eroded materials from the surrounding plains and the crater rim to the crater basin floor.



**Fig. 2.** (A) A Google Earth image (Image © GeoEye) showing a debris flow feature associated with gullies and a fan delta formed in front of the Dhar valley. (B) Gullies and a debris flow. (C) A fan delta.

**Ejecta blanket.** A series of shallow channels are identified on the ejecta blanket of Loner (**Fig. 3**). These channels originate, in general, near the rim crest and extend radially away from the crater center. A close inspection of one of such channels on the western ejecta found that it begins as a network of shallow ravines, some of which originate just below the rim crest at an elevation of approximately 580–590 m. The ravine heads coincide with a topographic saddle on the rim, which is about 6–7 m lower than the adjacent rim crests. These ravines expose ejecta-comprising basaltic clasts up to meter scale. The mid-section of the channel is single thread with occasional braiding and relatively straight, and the channel ends in a dammed Kalapani Lake at 545–550 m. The channel is ephemeral in nature, carrying water during the rain. The channels probably resulted from surface runoff, and its erosion contributes to the removal of the ejecta.



**Fig. 3.** Spatial distribution of channels developing on the ejecta blanket. The ejecta boundary is adopted from [5]. The basemap is a Google Earth image (Image © 2012 GeoEye).

**Implications:** The hydrological processes of Loner Lake are potentially an important issue for its application to purported paleo-crater lakes presumably formed in the basaltic crust of Mars. Loner Crater could also provide insights on degradation of other impact craters on hydrologically active planets such as the Earth and ancient Mars.

**References:** [1] Sengupta D. and Bhandari N. (1988). *LPS XIX*, 1059–1060. [2] Jourdan F. et al. (2011). *Geology*, 39, 671–674. [3] Fredriksson K. et al. (1973). *Science*, 180, 862–864. [4] Kumar P. S. (2005) *JGR*, 110, doi:10.1029/2005JB-003662. [5] Maloof A. C. et al. (2010) *GSA Bulletin*, 122, 109–126. [6] Kumar P. S. et al. (2010) *Icarus*, 208, 608–620.