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A study of Lonar lake–a meteorite-impact crater in basalt rock

V.S. Taiwade

Khagol mandal, Association of Amateur Astronomer's, Sion, Bombay 400 022

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Abstract. The Lonar lake in Buldhana district of Maharashtra, India, is a meteorite-impact crater. The uniqueness of this crater is that it has been formed in a strata of hard igneous rocks known as basalt rocks. Astronomers compare this crater with those of the moon. Due to its uniqueness and its large size, it has become one of the most important craters in the world. An attempt has been made here to gather and study the information available about this crater. It is intended through this article to draw the attention of the astronomical community at large to this rather rare cosmic phenomenon in the hope that the preservation and development of the crater and its surroundings can be taken up at the earliest.

Key Words : Lonar lake–meteorite–impact erater.

1. Introduction

The Bosumtwi crater in Ghana, Africa, with a diameter of 10.5 km, is one of the largest known meteorite craters in the world, and is probably one million years old. The crater is now filled with water and is known as Ashanti lake. Another very large crater is in Quebec province of Canada which is 3.2 kms in diameter and 360 metres deep; its rim rises 100 metres above the surrounding land. Discovered in 1950, it is known as the New-Quebec crater (Grieve & Robertson 1979). The Lonar crater (Fig. 1) is a circular depression, 1.83 kilometres in diameter and 150 metres deep. The rim of the crater rises about 20 metres above the surrounding land. The crater has now turned into a shallow lake with water draining into it through the crater walls. The next large crater is in the Arizona province of America. Its diameter is 1.2 kms and it is 185 metres deep. The rim of the crater is raised by 50 metres above the surrounding plain. Daniel Barringer, a mining engineer from Philadelphia, has carried out intensive studies on this crater, and so it is known after him as Barringer crater (Fredriksson et al. 1973).

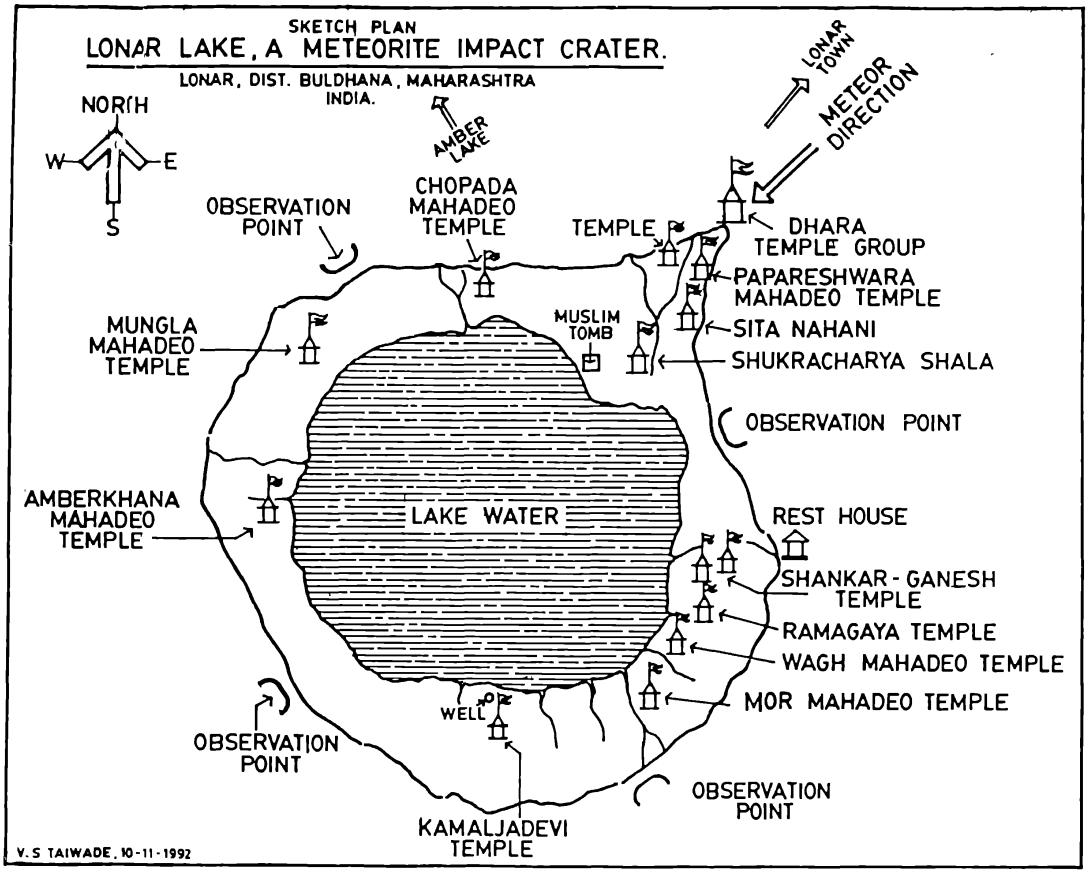

Figure 1. A sketch plan of Lonar lake, a meteorite impact crater.

The Lonar crater is a meteorite-impact crater made in basaltic rocks of the Deccan plateau. This plateau has been formed out of horizontal layers of lava which erupted about 65 million years ago. The lava flows cover nearly 5,00,000 square kilometres and are about 700 metres thick.

Nearly, 50,000 years ago, a meteorite of about 100 metres diameter and weighing about 2 million tonnes, hit the Deccan plateau. Travelling at a velocity of 18 kms per second, the collision of this meteorite generated such an intense heat that it instantly created a molten pool of rocks. It is estimated that the heat generated by the impact was approximately equivalent to that of a 6 megaton bomb. The molten mass of rocks, together with some unmelted material, was thrown out by the rebound force created by the impact. Several other geological changes occurred in the impacted basaltic rocks; this included the instantaneous formation of glass beads and shattered cones. The Lonar lake is a special meteorite-crater, because it is the only one formed in basaltic terrain — a terrain similar to the lunar surface and possibly that of the planet Mercury (Shoemaker 1963; Bhandari 1984).

2. Early studies

That the Lonar crater is gouged out by the impact of a heavenly body, viz. a meteorite, has been proved beyond doubt. The Smithsonian Institute of Washington D.C. USA, the Geological Survey of India and the US Geological Survey, have carried out intensive research work on the Lonar crater about 20 years ago. The results of this work, published by Fredriksson et al. (1973) of the Smithsonian Institute, are extremely valuable in this connection. These studies have involved drilling holes at the bottom of the crater and making a detailed examination of the rock samples obtained from the drilled holes. The rock samples, when tested in the laboratory, have clearly indicated the presence of Maskelynite: when basaltic rocks are subjected to tremendous heat and pressure, the mineral Plagioclase, changes into Maskelynite (Fredriksson et.al. 1973). This is one proof of impact phenomenon. Another proof is the presence of shattered cones in the rock samples of the Lonar crater. When bed rocks are subjected to a high velocity shock, they fail by fracturing themselves in a distinctive conical manner. Shock waves are always transmitted in the rocks in a radial fashion, thereby making numerous cones in them (Dietz 1963).

About a decade ago, a team from Physical Research Laboratory (PRL), Ahmedabad, carried out some excellent research work on the Lonar crater (Bhandari 1984). Glassy black stones approximately the size of an apple were found in trenches dug in at the rim of the crater. These large-size glass beads are porous, and their porosity increases from the centre outwards, which is symptomatic of escaped gases, quick cooling and immediate burial. Earlier to this V.K. Nayak of Sagar University discovered black glass beads at the site, which are round, button-like, or dumb-bell-like in shape. These distinctively shaped fragments are found in the east-west direction outside the crater and are believed to have been fashioned this way by the melting and subsequent cooling of small rocks following the high-velocity collision of the above-referred large meteorite with the Earth. Some of the glass spheres have been examined in PRL using thermoluminescence and some other track-analysis methods for determining their ages. These studies have indicated that the Lonar crater was formed about 50,000 years ago. The rim of the crater is not as high as it is generally observed in the case of other meteorite-impact craters. One reason for this relative lack of depth is the presence of weathered basalt at the impact site. This weathered rock layer would have absorbed most of the shock of the collision and prevented the material from going deeper down. Instead, the molten mass of rocks, together with unmelted materials, was presumably thrown out of the crater by the rebound force created by the hyper-velocity blow. The ejected material of pulverized fragments, including some large stones, has been found as far away as 2 kms from the crater. These stones have not been rounded through erosion by water. On the contrary, they appear freshly broken, attesting to immediate burial following their break-up after collision. Shock features found in the mineral, further support this mechanism. No fragment of the incoming meteorite itself has been found, presumably because it has almost entirely melted away on hitting the Earth (Bhandari 1984).

3. Our visit to crater

The Lonar lake is situated in Lonar town in Buldhana district of Maharashtra (19 58' N, 76 31' E). A group of amateur astronomers from Khagol Mandal, Bombay, including the author, visited this lake in October, 1992. Before our visit, we sought guidance of J.J. Rawal, of Nehru Planetarium, Bombay who has carried out several important astronomical studies of meteorite craters in the world, including that of the Lonar crater.

Our visit was mainly concerned with the observations of the natural setting and vegetation around the crater, collection of rock and water samples from the lake, as also visiting the temples which have come up in and around the crater over the years.

A site study programme was fixed up which included walking around the crater, once near the water level and, another time, at the rim level. The first phase of walking involved a distance of approximately 5 kms and the second phase, about 8 kms. During this walking exercise, we came close to the 'entry point' of the meteorite. It is stated that the Lonar meteorite has made a low-elevation impact with the Earth's surface. During the process of impact and the subsequent throwing back of the pulverized material, a huge depression, with a groove-like formation, in the rim of the crater, was formed. This is the above-referred 'entry point' (Rao 1986). A water spring, present at this point attracts the attention of everybody. A water jet, nearly 45 cm thick, gushes out of the rocks with force and jumps down nearly 7 metres below into a man-made pond. It later joins the lake water.

Our group members descended approximately 150 metres through the depression at the entry point to reach the water level in the lake. At this point in time, we felt ourselves dwarfed by the relative vastness of the crater. We continued our circumambulation around the lake in a clockwise direction. On our way through the surrounding forest area, we observed many an old and dilapidated stone structures belonging to Hindu temples from the 12th century A.D. We put our magnetic needle close to these structures. At a number of places, the needle showed deflections, sometimes small and sometimes large, making us wonder: to what extent can we learn about the impact from the magnetic data? Detailed laboratory investigations of the rocks in and around the crater area, using special magnetic equipment, may shed some light on this phenomenon.

We were informed about the existence of a well in which one-half of water is believed to be sweet and the other half saline. Presently, this well is submerged under the increased level of lake water. The well water may actually be a mixture created by sweet water springs as well as saline water accumulated in the lake over the years through the process of evaporation. This well may thus be a unusual freak of the local geology.

4. Experiments and observations

Our group members collected water samples from the Lonar lake in sterilized glass-bottles. A pH paper, when put into the water, instantly became blue, suggesting a pH of 10.5. Actual laboratory measurements of the lake water yielded a close value of 9.75 to be compared with a pH of 7.8-8.4 for the tap water supplied by the Bombay Municipal Corporation (BMC). Thus the lake water is extremely saline and the samples were found to contain mainly sodium chloride, carbonates and bicarbonates. The percentage of fluorides was also found to be higher in these water samples. Table 1 compares the laboratory analysis of the water sample obtained from the Lonar lake and BMC.

Table 1. Analysis of the water sample from Lonar lake.

	Water supplied by BMC	Lonar lake water
Turbidity	130 units on silica scale	
pH	7.8 to 8.4	10.5 on paper 9.75 on meter
Total alkalinity carbonates and bicarbonates	58 ppm as CaCO3	2373 ppm as CaCO3
Total hardness	62 ppm as CaCO3	101 ppm
"Ca" hardness	34 ppm	20.3 ppm
"Mg" hardness	28 ppm	80.7 ppm
Na K	28 ppm as NaCl	1500 ppm as NaCl 590 ppm as Na 11 ppm as K
Chlorides	17 ppm	2400 ppm
Sulphates	3 ppm as SO3	
Nitrates	1 ppm as NO3	not traceable
Silica	25 ppm as SiO2	3 ppm as SiO2
"Fe" Total	1 ppm	0.36 ppm
Total solids	120 ppm	9045 ppm
Total suspended solids	100 ppm	0664 ppm
Dissolved fluorides		3.55 ppm

Rock samples from the crater and some areas close to its rim were also collected inspected at PRL. We also had discussions with N. Bhandari at PRL regarding various problems related to our studies of the crater. The account of his research work on the crater, which includes a detailed study of its glass spherules, was quite enlightening for us. We were also lucky to have a close observation of a large glass spherule termed as 'glass bombs' available in his laboratory. As already stated, the presence of the glass spherules in the crater area supports the meteorite-impact theory for the creation of the Lonar crater. We observed two types of meteorites under a microscope: one, a stony meteorite and the other, an iron one.

We enjoyed our expedition of walking on the rim of the crater. The first unusual thing we noticed was a circular line of trees in the lake water which is supposed to be the boundary of the lake. Since the level of the lake water has increased in the recent years, these tree trunks have got submerged in this water. The western side of the crater wall is more thickly wooded than the rest of the walls. The Government of Maharashtra has created an artificial lake of about one third the size of the Lonar lake. This subsidiary lake is located about 800 metres away, on the western side of the main lake.

One more simple thing that we noticed was the circular shape of the lake. One can easily identify the curvature in the horizon and also the curvature in the opposite side of the crater walls. These walls are sloping inside, making an angle of 20 to 30 degrees with the vertical. The crater wall, which is exactly opposite to the entry point, is quite stiff, while the walls near the entry point are sloping more gently. This may be another result of the meteorite impact.

Walking on the crater walls was certainly a thrilling experience, more so on account of the changing views of the crater under different light and shade conditions created by the sun rays. At the end of this journey, we approached a small lake which is on the northern side of the main lake. This lake is also of a circular shape with a diameter of about 275 metres. It is located about 700 metres away from the main lake and is called the Amber lake. This small lake is possibly a secondary crater created by the ejected material during impact process of the main crater (Fredriksson et al. 1973). Our magnetic needle, when put close to the Hanuman idol, belonging to the temple situated by the side of the Amber Lake, was instantly deflected, indicating that this stone idol has some magnetic minerals in it as is common with all basalts.

Recommendations : We would like to propose that the Government of India should declare the Lonar lake, as a national astronomical monument and initiate steps to maintain it accordingly.

5. Acknowledgements

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