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Deposition of CaO (lime) on rocks near the temples submerged in the waters of Lonar crater, Maharashtra, India

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ABSTRACT

At Lonar Crater on the northern side, near the water body, the base part of the temples submerged in the waters which were never exposed for the last 22 years due to constant rise of water level, are now exposed due to decrease of water level to a large extent, debris of rocks of unknown origin are found to be covered by a white layer. To investigate in detail whether the white layer on these rocks near the temples otherwise found to be submerged in the waters of Lonar crater and now exposed, are of SiO_2 (silica) origin or Nacl (common salt, sea salt) origin, or any other component, a search was conducted to find the source, its origin and the cause for these phenomena through this study. Representative samples of these rocks from debris near the temple towards the north side of the crater was collected and stored in a polythene bag for further investigation. XRF analysis carried out of two rocks of both sides i.e., of sample No. 1, white layered part 16 elements with their oxides were detected of which CaO (Calcium Oxide i.e., quicklime) – 76.000 being the major content and others such as Fe_2O_3, SiO_2, Al_2O_3, MgO etc., in minor quantities. Similarly, of sample No.2, the white layered part showed that 16 elements with their oxides were detected of which CaO – 85.900, being the major content, and others such as SiO_2, MgO, Al_2O_3, SO_3, Fe_2O_3, P_2O_5 etc., in minor quantities. The original rocks i.e., the black part of both the samples showed that major component was SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, and TiO_2, with other components in minor quantities. For the first time, such a high percentage of CaO (Calcium Oxide i.e., quicklime) has been detected which is found to be deposited on the surface of debris of rocks near the temples on the northern side of the crater. White rusting/white coating of SiO_2 (Silica) has been observed and reported by Jadhav and Mali. This work being of preliminary investigation, a search was conducted to know the cause and how CaO (Calcium Oxide i.e., quicklime) found in such a high percentage deposited on the rocks or the rocks were found to be coated or encapsulated by a white layer of CaO and to record and document this phenomena with detail studies.

Keywords— *Lonar crater, Deposition of CaO on rocks, Submerged temples in waters, Debris of rocks*

1. INTRODUCTION

Formation of a meteorite impact crater on the basaltic rock or volcanic rock is a very rare event in the history of the earth. A crater of approximate 1.83 km and a depth of approximate 150 mtrs was formed around 656 ka[1] on a basaltic plateau or volcanic plateau now known as Deccan Plateau. The crater of meteorite origin formed is situated near a village named Lonar, now also a Taluka place, Buldhana District, Maharashtra, India, the co ordinates of which are $19^0 58$'N and $76^0 30$'E. The crater has attracted researchers and tourist all over the world, because of its uniqueness. The crater has a circular rim, with inner side gorges observed and thick green vegetation is seen from the inner rim to the base near the water body. At the centre of the crater, a water body with highly saline and alkaline nature of water is seen, the green microorganisms like algae are responsible for this color. Rich biodiversity exists surrounding the water body. Two ecosystems exist side by side i.e., fresh water ecosystem and Lonar crater ecosystem (highly saline and highly alkaline nature of water), without disturbing each other[2]. In a large ecosystem exist a small ecosystem [Lonar crater ecosystem]. This is the beauty and uniqueness of this crater. It is only one of its kinds on the surface of the earth. The species found in the water i.e., microorganisms are modified species[3] existing in this extreme condition of the water body.

1.1 Some of the earlier works carried on Lonar Crater; the references are cited

The weathering probably occurred over a period of time much greater than the age of the crater[4]. Investigation on hydrological processes at Lonar crater and its lake could provide useful insights to purported paleo-crater lakes presumably formed in the basaltic crust of Mars[5]. The Deccan Trap at Lonar exhibit shattercones and also carry the soft component whereas at nearby places, Aurangabad and Jalna, they neither exhibit shatter coning nor carry a soft component[6]. In light of the ecological importance of MTB in biogeochemical cycles, the study of such bacteria in hitherto unexplored environmental can be significant[7]. The silt of the lake as indicated show the greatest concentration of Na_2CO_3 and NaCl[8]. Thus, from the foregoing possible explanations, it is apparent that no single explanation provides an unequivocal understanding of the mechanics of plagioclase-maskelynite transformation[9]. Microscopic examination of silt samples revealed the presence of rich organic remains such as algal filaments, fungal hyphae and spores, diatoms etc. [10]. Co abundances in these samples of the more massive glasses do not reflect any appreciable inclusion of meteoritic siderophilic materials[11]. Because of the variability in the target rocks, the apparent increase of Cd with shock in the glasses may be no more than a reflection of target material sampling[12]. But the water sample is having high chlorides, hardness and salinity due to which the alkalinity of the water is in higher range[13]. Instead, it shows sharply varying magnetic anomalies typical of those observed over the Deccan trap[14].

2. OBSERVATION

The rocks near the temples otherwise found to be submerged in the waters, (and now exposed) of Lonar crater of unknown origin, where deposition of a white layer of the unknown component has been observed. On one side the original rock is brown to black and on the other side deposition of a white layer of the unknown component is observed. Figure 1, 2, 3, 4, 7 and 8.

2.1 Scope of work

Rocks near the temples submerged in the waters of Lonar crater were picked to study the phenomena of white layer on the rocks. Why the rocks near the temples are affected by this white layer and to search which type of components are deposited on the rocks.

2.2 Methodology

Representative rock samples from the debris near temples on the northern side of the crater were collected to study the physical phenomena i.e., white layer deposition on the rocks and transferred in a polythene bag for further analysis. The co ordinates are $19^0 58'3530.2''$N and $76^0 30'1815.24''$E. Most of these rocks are found to be covered by a thin white layer of unknown composition; images are shown in figure 1, 2, 3, 4, 7 and 8. The rocks were sent for XRF analysis and then the weight and volume was taken to calculate the density of the rocks and dimensions were also taken. The physical features were noted down (table 1). Water sample was collected in front of Kamalja Devi temple, i.e., near the well named as Sasu-Sunechi Vihir (well). The water was kept for evaporation and when the water was dried, i.e., salts formed, it was collected and sent for XRF (table 8) and physico chemical analysis. (Table 2). Similarly, the rocks and soil towards the northern side of the crater were collected and sent for XRF analysis (table 9, 10, 11, 12 and 13).

2.3 Experiment

The rocks samples collected in a polythene bag, before sending for XRF analysis, the white layered part was scraped with a finger nail and also by pointed biceps to remove the salt, but were not scraped. Hence were sent for XRF analysis. The dimension of the rocks was taken and noted down. After this, the rocks were weighted on a standard balance and the weights were noted down, the volume was taken by a measuring cylinder of borosilicate make by displacement method of water. When both the rocks were immersed in water to take volume, and when the rocks were taken out of the water, it was observed that the color of the rocks was seen to be gray similar to cement color. Afterwards, when the rocks were dried, the original white color had appeared. Density was calculated by using the formula m/v g/cc. (table 1).

2.4 Experimental results

From the results by XRF analysis of both the sides i.e., the original rock, and the white layered part, it is observed that 16 elements and their oxides have been detected. In original rock, the major components in descending order are SiO_2, Fe_2O_3, Al_2O_3, MgO, CaO, TiO_2, K_2O and Cl and in white layered part, the major components in descending order are CaO, SiO_2, MgO, Al_2O_3, SO_3, Fe_2O_3, and P_2O_5 and others in minor quantities. Table 3, 4, 5 and 6. The weight taken on a standard balance, the volume taken and the density was calculated and was found to be 3.03g/cc for sample 1 and 2.95 g/cc. for sample 2. (Table1). The dimensions were also taken, (Table 1). The results of salts by XRF (Table 8) and the physicochemical analysis are shown in table 2 respectively.

3. RESULTES AND DISCUSSIONS

From the results obtained by XRF analysis showed that the oxide content of elements in sample 1 of black side (original rock), the oxide content was found to be SiO_2 - 50.500, Fe_2O_3 - 15.500, Al_2O_3 - 13.300, MgO – 6.690, CaO – 6.620, TiO_2 - 2.980, K_2O – 1.410 and Cl – 1.200 with other oxides in minor quantities, (table 3). Similarly, the white layered part of the same rock showed CaO - 85.900, SiO_2 - 5.130 – MgO – 2.560, Al_2O_3 - 1.800 - SO_3 - 1.710, Fe_2O_3 - 1.200 and P_2O_5 - 1.020 with other oxides in minor quantities (table 4). In sample 2, the oxide content of original rock was found to be SiO_2 - 52.500, Fe_2O_3 - 11.500, Al_2O_3 - 17.500, MgO – 3.130, CaO – 10.400, TiO_2 - 2.290, with other oxides in minor quantities (table 5). Similarly, the white layered part of the same rock shows CaO – 76.000, Fe_2O_3 - 8.350, SiO_2 - 7.130, Al_2O_3 - 2.460, SO_3 - 2.290 and MgO – 1.810 with other oxides in minor quantities Table 6. The basaltic rocks coated by white rusting/white silica coating has been observed and reported by Jadhav and Mali[15]. At first it was thought that the white layer seen on the rocks near the temples on the northern side of the crater, (otherwise found to be submerged in the waters, and are now exposed due to the waters which have receded to a large extent) were of SiO_2 (silica), or of NaCl (sea salt/common salt). But when the analyses by XRF carried out, the results were surprising, because the analyses carried out by different researchers on Lonar crater water body CaO (quicklime) in such a high percentage has not been reported.

Nandi and Deo mentioned in their papers that lastly, nowhere in this region was the occurrence of limestone noticed nor struck in bore holes nor was the silts recovered high in CaO[8]. But from this study it is seen that the rocks of unknown origin, lying near the temples which were always found to be submerged in the waters of Lonar crater which never decreased, for the last 22 years, are now exposed, which are found to be encapsulated or coated by Calcium oxide salts (CaO) or in other words it can be said that deposition of CaO salts on the rocks. As per the images in figure 7 and 8, one side is the original rock and the other side covered by CaO salts of white nature. Basaltic rocks at the crater water body covered by white rusting/white coating were found to be of SiO_2 origin[15]. Figures 9, 10, 11, 12 and 13. But the rocks near the temples on the northern side of the crater found to be encapsulated by a white layer, not of SiO_2, but of CaO salt which is found to be surprising. It is possible that since carbonates and bicarbonates are present in the water body, the layer of white color on the rocks may be due to carbonates of calcium because the percentage of calcium is also found to be very high with respect to other elements.

During the rainy season, the waters of the crater rises, the temples near its periphery, the lower part or the base part of the temples, including the rocks at the periphery of the water body, are found to be submerged in the waters of the crater and when the water decreases in summer to a small extent, these rocks are not exposed. It is to be mentioned here that for the last 22 years, the waters of Lonar Crater kept on rising, no chance of decreasing. From 2017, the waters have decreased drastically, due to which large part of the periphery has been exposed. In 2019, the waters have decreased to a great extent, where large boulders which were never exposed are exposed this year. From this study, it can be inferred that the debris of rocks near the temples, where a layer of CaO salts or carbonate salts of calcium origin has been deposited. i.e., covered by a layer of Calcium oxide (CaO) salts. Nandi and Deo mentioned that the surrounding country rocks are of andesitic origin[8]. If the country rocks are of andesitic basaltic origin then it is possible that deposition of Calcium oxide (CaO) may have taken place on these rocks, which were under water, i.e., never exposed. Andesitic basalts have also been mentioned by Son and Koeberl in their analysis[15]. The rocks of basaltic origin are found to be coated by SiO_2 (silica) [16]. The rocks covered by a white layer of CaO may be of Andesite basaltic origin. Whether the rocks covered by a white layer of CaO salts are of basaltic origin or andesitic origin, both are of volcanic and basaltic origin.

Nandi and Deo further mentioned that V. Ball proposed a theory that the hollow or depression was caused by subsidence of the roof of a large cavern in calcareous rocks, obvious limestone of the lameta series which underlies the Deccan traps[8]. Ball theory was not accepted by Nandi and Deo because no $CaCO_3$ (limestone) nor CaO (quicklime) high in percentage has been detected. Through this study, CaO (quicklime) has been detected which are found on the surface of the rock covered by a white layer which is found near the temples towards the northern side of the crater where the debris of such rocks covered by a white layer of CaO are observed. These may be the deposition of CaO on rocks as per analysis carried out through this study. Nandi and Deo through their analysis of brine from different points have shown carbonates and bicarbonates of sodium present. Through this study, analysis by XRF, oxides of Calcium detected is in highest percentage for which, it can be postulated or suggested that sedimentary rocks of carbonate nature or the rocks of sedimentary origin containing high percentage of carbonates may be present which supplements high alkalinity to the waters, making it highly alkaline, which is reflected in the form of CaO on the rocks. These rocks were always under water and hence due to unexposed were not observed. Ball theory states that they may be limestone of the lameta series which underlies the Deccan traps[8]. It may be true because, CaO has been detected through this study in the highest percentage than other oxides, and the $CaCO_3$ present below the Deccan traps may leach out through the basaltic rocks present at Lonar crater making the water highly alkaline.

Gaikwad and Sasane studied the water quality of a surrounding area of Lonar crater and their analysis report showed that except Lonar crater waters, nowhere in the surrounding area CO_3 has been detected[17], which shows that CO_3 are found only in the waters of Lonar crater and not in the surrounding area. From the analyses of rocks of basaltic origin by different researchers, it is observed that CaO (quicklime) is found to be between 8 to 14%. But nowhere on basaltic rocks of Deccan Plateau analysis carried out showed the presence of CO_3. The rocks found near the temples may not be of basaltic origin, if it were, it would be coated by a white rusting/white coating of SiO_2 origin and not of Calcium oxide (CaO) salts. Since these rocks are encapsulated by CaO, hence it will be a good exercise to search what type of rocks are prevalent that are encapsulated by CaO, it is possible that they may be other rocks than basalts. It is also observed that while entering the crater floor from PWD rest house, the top roof of Ramgaya temple is covered by a white layer of unknown nature. It is possible that since the rocks near the temples are found to be covered by a white layer of CaO salt, the same temple roof may possibly be covered by CaO salt or it may be a coating of SiO_2 (silica). From the figures, observation of the images, CaO deposition rocks can be differentiated from silica coated rocks.

Deshpande in his book on Geology of Maharashtra states that the Tapi-Purna alluvial plain which is mainly composed of clay, brownish to yellowish color, intercalated with several bands of gravel and sand. At places, the pebbles and sand grains are cemented together by calcium carbonate to form a compact conglomerate which is found to be lying over the bed rock and below the alluvial sequence. Conglomerate types of rocks have been observed near temple surroundings at Lonar crater (figure 5 and 6). Deshpande also states that in the Purna alluvium occurrence of salt in some beds below the surface which was supposed to be an interesting feature where below the sequence of clay, sand and gravel, at a depth of some 40m, presence of brine reported stating the presence of salt is indicative of a marine bed below[18]. This is the strongest evidence to prove that below the basaltic lava flows store house of NaCl (sea salt/common salt) may be present and it is possible that $CaCO_3$ (limestone), i.e., sedimentary rocks of carbonate nature may also be present which are being leached out, supplementing, high alkalinity to the crater water body. The outcome of it is the deposition of CaO on rocks seen towards the northern side of the crater, which shows that marine environment existence and sedimentation process had taken place before the great event of volcanic activity which took place some 65 ma, covering the whole of Maharashtra. The remains of it are reflected in the form of CO_3 in the waters and deposition of CaO on rocks, which were always found to be under waters. These types of rocks are mostly seen on the northern side of the crater, where, during the rainy season, the area surrounding the temples, debris of such rocks are present were found to be under waters, which shows that deposition of salts of Calcium are seen on the surface of these rocks, because the water contains high percentage of carbonates than NaCl as per analysis by Jadhav and Mali[2].

It is also to be known that the original rock show oxide composition in table 3 and 5 similar to oxide composition to basalts as analyzed by different researchers, which shows that the rocks encapsulated by CaO may belong to basalt of andesitic origin. The physicochemical analysis of salt (water of Lonar crater brought and evaporated, the remained salt powder form collected and sent for XRF and physicochemical analysis to look for $CaCO_3$ (Calcium carbonate i.e., limestone), the results are given in table 2 and 8. From the physicochemical analysis, it is observed that the pH of the salt is 10.22, highly alkaline, Na_2CO_3 (Sodium carbonate is 31.77 % $CaCO_3$ as calculated to be 0.37 % and Chlorides to be of 31.68 %, which shows that the possibility of nature of water being highly alkaline is solely due to presence of carbonates of sodium and calcium i.e., combine together, because alkalinity is found to be higher than salinity.

Another fact which has been observed is the conglomerate type of rocks, figure 5 and 6, the fragments are found near the temples buried below the soil, which shows that it is possible that the temples were built on these conglomerate type of rocks. No mention has so far been made about these types of rock. Pieces of such type of rocks are observed on the northern side of the crater. These rocks are found to be cemented together. Conglomerate rocks are of sedimentary origin. Hence findings of these rocks near the temples buried below the soil shows that presence of Calcium oxide (CaO) or calcium carbonate (limestone), these conglomerate type of rocks may be of $CaCO_3$, which has also been found in Tapi-Purna alluvial plain as mentioned by Deshpande[(18)], suggesting that below the temples these type of rocks are present. Nowhere at the crater water body, these types of rocks found except near the temples. It is possible that the fragments of these rocks are found to be strewn near and around the temples at the crater water body. It is also to be known that in front of Kamalja Devi temple, there is a well known as Sasu-sunechi Vihir in the local language. This well was last seen by the second author when visited Lonar Crater in the year 1996 and 1997, and after subsequent visits to Lonar Crater, this well was never observed, due to increase in water level, until in 2017 and 2019, the level of water has decreased to such an extent, that this well is now exposed fully, the rocks also which were never exposed, were under water for so many years are now found to be exposed and are covered by a layer of CaO, which shows the presence of CaO in the waters. The northern part of the crater is least affected by tourist and visitors and hence are not found to be contaminated.

In modified silicified ecology at Crater Lake, Lonar, the authors have mentioned that from the observations of basaltic rocks in 1997, near the lake periphery on the northern part of the crater, rocks showing white layer or coating were observed, at first it was thought that these rocks were painted with white color or were manmade. After several visits to Lonar Crater by author two, these rocks covered by white layer were never observed due to the rise of water level for many years. These rocks were supposed to be coated by white rusting process or silica coating[(3)]. Now it is understood that these rocks are not of silica coating or white rusting but are covered by a layer of CaO salts. Comparison of silicified rocks with deposition of CaO on rocks is shown in table 6. Analysis of salt of Lonar crater water has been shown in table 8. It is also to be stated that though the water is highly saline i.e., it contains NaCl salt in waters, yet it is not found to be deposited on the rocks or is not reflected on the surface of the rocks which are found to be submerged in the waters, which needs to be studied in detail. Also, the CaO found in the waters is very less, yet its deposition on the rocks is showing the highest percentage. So NaCl contained in waters is found to be abundant, but its deposition is not found to be reflected on the rocks as per analysis, on the other hand, CaO is found to be very less but its deposition is found to be in large quantities on rocks. This is a big controversy which needs to be studied in detail. CaO existence showing in the form of high pH in crater water and NaCl showing existence in the form of salinity. The CaO which is found to be in negligible quantities in water is found to be largely deposited on rocks and NaCl which is in very high quantities in water is not found to be deposited on rocks.

As per the analysis of white layered part, of the representative samples of rocks by XRF, it is observed that the results showing a high percentage of CaO. The deposition of CaO can be attributed to as CaO found deposited may be of white amorphous in nature. It may not be of crystalline nature. This is also seen for white rusting/white coating of basaltic rocks by silica (SiO_2) because this white rusting or white coating seen on the rocks of silica nature is of amorphous nature[(16)]. If it had been for crystalline nature of silica, the white rusting or white coating would not be possible. Since it is of amorphous nature of it which makes it be deposited or coated on the rocks. Similarly, it is possible that the amorphous nature of CaO which makes it be deposited or precipitated on the rocks. If it had been for crystalline nature, the CaO would not be found to be deposited on the rocks. NaCl (sea salt/common salt) is not found to be deposited on the rocks at crater water body, though it is in highest percentage, it is because NaCl is a crystalline form of sea salt, common salt in nature. It is not amorphous. The above two salts i.e., SiO_2 and CaO are amorphous in nature which are found to be deposited on the rocks, whereas NaCl is not amorphous, but crystalline and hence it is not found to be deposited on the rocks. Hence the coating of silica was possible. Chemtob also reported silica coating on basaltic rocks at Hawaiian volcanic islands[(19)]. Again it is dependent on solubility. Also in both the cases of SiO_2 coating and CaO deposition, the major component is different, but other components are the same as seen in comparison Table 7. The percentage of CaO being highest as per XRF analysis can be attributed to $CaCO_3$ (Limestones), which lie buried below basaltic lava flows. Due to heat factor (i.e., hydrothermal process, geothermal process), $CaCO_3$ may have been dissociated to CaO and CO_2, which is the only possibility of CaO to come and deposit on the rocks at Lonar crater. The hydrothermal process at Lonar crater after meteorite impact has been mentioned by Hagerty and Newsom[(4)]. The existence of limestones [calcium carbonate ($CaCO_3$)] below the basalts has been postulated by V. Ball in his theory as mentioned by Nandi and Deo[(8)].

To search for the source of the high content of CaO deposition on the rocks towards the northern side of the crater, representative rock samples and soil were collected and analyzed by XRF shows CaO values to be similar to that found in basaltic rocks table 9, 10, 11, 12. The soil sample analyzed by XRF shows CaO values 12.700 oxide content, which is similar to basaltic rock value, table 13. Analysis of rock samples, soil sample and salt sample (water evaporated of Lonar crater) did not show high content as that found deposited on the rocks. From this, it can be inferred that the only possibility of CaO depositing on the rocks can be through $CaCO_3$ (Limestone's) buried below basaltic lava as per theory put forward by V. Ball mentioned by Nandi and Deo[(8)]. The heat generated due to the impact of a meteorite or due to heating (hydrothermal process) $CaCO_3$ to its temperature of dissociation, where $CaCO_3$ dissociated to CaO and CO_2. CaO which deposited on the rocks from then is seen today reflected through deposition on rocks, though the debris of rocks may have come during construction of temples in the 11^{th} -14^{th} century[(20)], the deposition of CaO must have taken place earlier than this period because the rocks are of basaltic origin.

All kinds of calcium forms (carbonates, bicarbonates, oxide) or (else source of all those forms of calcium in the form of zoo planktons and phytoplankton, sedimentary rocks and pH of this water as is known is higher) which is in amorphous form is found to be deposited on the rocks which is submerged in the water body. Deposition of calcium on the rock is only the coating of the rock but is not metamorphic change, the physical and chemical characteristic is not changed. It is only encapsulation of rock by calcium salts. But inside the rock, is in the original state.

4. CONCLUSION

From the analysis results by XRF showing the major oxide component to be of CaO (Calcium oxide, i.e., quicklime), the images in the figures showing the original rock covered with white layer seen near the temples which were always submerged in the waters of Lonar crater are now exposed and hence large quantities of such rocks are observed encapsulated by CaO, which proves that Ball theory to be studied again. Debris of such rocks is seen near the temples which are exposed and seen today, which otherwise were never exposed because the waters of the crater kept on increasing for the last 22 years. Big chunks of rocks are exposed, covered by a white layer of CaO. A big chunk of these rocks is seen at the northern side of the crater. From the discussion, analysis and observation of these rocks, it can be concluded that they may be store house of $CaCO_3$ (limestone) rocks below the basaltic lava flows or rocks of lameta series as per V. Ball, mentioned by Nandi and Deo[8], which are being leached out, supplementing high alkalinity to the waters, the result of it is the deposition of CaO on rocks found near the temples at the northern side of the crater. These rocks which are found to be covered by a white layer of CaO may be the andesitic basalts. Such a high percentage of CaO found deposited on the rocks is surprising because analysis of basaltic rocks by different researchers have shown that CaO is between 8 to 14%. As there is no source to supplement such a high percentage of $CaCO_3$ to the waters, where the rocks are finally found to be covered by a layer of CaO or the outcome of it is the result, or is reflected in the form of encapsulation of CaO on rocks. Due to the presence of carbonates, the waters have attained high alkalinity and the source of it can only be possible through the salts where storehouse of sedimentary rocks of carbonate nature may be present below the basaltic lava. This may be absurd, but this is the only source for carbonates to come from below and make the waters highly alkaline, which also solves the fundamental question about the high alkaline nature of crater water. Findings of CaO (Lime), indicates that below the basaltic lava limestones of carbonate nature may be present which supports V. Ball theory.

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APPENDIX

Table 1: Physical Parameters of rocks covered by a white layer of CaO.

Parameters↓/Samples No.→	Rock sample No. 1	Rock sample No. 2
1. Weight in gms	27.2601	132.5888
2. Volume in ml	9	45
3. Density g/cc	3.03	2.95
4. Dimensions	4.0 x 2.3 x 2.0	5.1 x 4.0 x 3.9
5. Surface Feature	One side original rock, the other side covered by a white layer of CaO.	One side original rock, the other side covered by a white layer of CaO.
6. Shape	The white side flattened and the original rock tapered.	Irregular
7. Color.	Original rock black one side, the other side deposition of white layer of CaO.	Original rock light brown one side, the other side deposition of white layer of CaO.
8. Thickness of CaO layer.	Thin white layer seen on the surface.	Thick white layer seen on the surface.

Table 2: Physicochemical analysis of salt of Lonar crater.

S. No	Parameters	Results	Units
1	pH	10.22	
2	Carbonate as Na_2CO_3	31.77	%
3	Calcium Carbonate ($CaCO_3$)	0.37	%
4	Chloride	31.68	%

Table 3: Elements and Oxide composition of rocks near the temple northern side of Lonar crater by XRF in mass %. Sample No.1 (black part)

S. No.	Elements ↓	Mass %	Formula	Oxide Content
1	Si	23.605	SiO_2	50.5
2	Fe	10.841	Fe_2O_3	15.5
3	Al	7.039	Al_2O_3	13.3
4	Mg	4.034	MgO	6.69
5	Ca	4.731	CaO	6.62
6	Ti	1.785	TiO_2	2.98
7	K	1.17	K_2O	1.41
8	Cl	1.2	Cl	1.2
9	P	0.3	P_2O_5	0.687
10	S	0.253	SO_3	0.631
11	Mn	0.173	MnO	0.223
12	V	0.055	V_2O_5	0.098
13	Zr	0.027	ZrO_2	0.037
14	Cu	0.019	CuO	0.024
15	Sr	0.019	SrO	0.022
16	Ba	0.017	BaO	0.019
17	Zn	0.012	ZnO	0.015
18	O	44.72		
	Total	100		99.956

Table 4: Elements and Oxide composition of rocks near the temples on the northern side of Lonar crater by XRF in mass %. Sample No.1 (white layered part)

Sr. No.	Elements ↓	Mass %	Formula	Oxide Content
1	Ca	54.313	CaO	76
2	Fe	5.84	Fe_2O_3	8.35
3	Si	3.333	SiO_2	7.13
4	Al	1.302	Al_2O_3	2.46
5	S	0.917	SO_3	2.29
6	Mg	1.091	MgO	1.81
7	P	0.327	P_2O_5	0.75
8	Ti	0.305	TiO_2	0.509
9	Sr	0.211	SrO	0.25
10	Cl	0.238	Cl	0.238

11	Mn	0.076	MnO	0.098
12	Zr	0.047	ZrO_2	0.064
13	Ba	0.026	BaO	0.029
14	Cu	0.016	CuO	0.02
15	Zn	0.013	ZnO	0.016
16	O	31.945		
	Total	100		100.014

Table 5: Elements and Oxide composition of rocks near the temples on the northern side of Lonar crater by XRF in mass %. Sample No.2 (black part)

Sr. No.	Elements ↓	Mass %	Formula	Oxide Content
1	Si	24.54	SiO_2	52.5
2	Al	9.262	Al_2O_3	17.5
3	Fe	8.043	Fe_2O_3	11.5
4	Ca	7.432	CaO	10.4
5	Mg	1.887	MgO	3.13
6	Ti	1.372	TiO_2	2.29
7	P	0.414	P_2O_5	0.949
8	S	0.37	SO_3	0.924
9	K	0.306	K_2O	0.369
10	Mn	0.116	MnO	0.15
11	Cl	0.14	Cl	0.14
12	Cu	0.018	CuO	0.023
13	Zr	0.015	ZrO_2	0.021
14	Sr	0.015	SrO	0.018
15	Zn	0.012	ZnO	0.014
16	O	46.058		
	Total	100		99.928

Table 6: Elements and Oxide composition of rocks near the temples on the northern side of Lonar crater by XRF in mass %. Sample No.2 (white layered part)

Sr. No.	Elements ↓	Mass %	Formula	Oxide Content
1	Ca	61.388	CaO	85.9
2	Si	2.398	SiO_2	5.13
3	Mg	1.543	MgO	2.56
4	Al	0.953	Al_2O_3	1.8
5	S	0.685	SO_3	1.71
6	Fe	0.839	Fe_2O_3	1.2
7	P	0.445	P_2O_5	1.02
8	Sr	0.308	SrO	0.364
9	Cl	0.151	Cl	0.151
10	Ti	0.024	TiO_2	0.04
11	Mn	0.031	MnO	0.04
12	Ba	0.021	BaO	0.023
13	Cu	0.01	CuO	0.012
14	Zn	0.009	ZnO	0.011
15	Mo	0.005	MoO_3	0.008
16	O	31.19		
	Total	100	99.969	

Table 7: Comparison between silicified rocks and calcified rocks

Silicifed rocks	Deposition of CaO on rocks
1. Major component : SiO_2 (Silica)	Major component : CaO (calcium oxide, quicklime)
2. Other component : Fe_2O_3, CaO.	Other component : Fe_2O_3, SiO_2, MgO, Al_2O_3
3. Color : Milky white	Color : white.
4. Hardness : High	Hardness : Low
5. Nature : Neutral, amorphous	Nature : Alkali, amorphous
6. Nature : Non-corrosive	Nature : Corrosive in nature
7. Metamorphic process of polymorphs of silica.	White layer deposition of CaO on the rocks.
8. Mostly observed on the southern side of the crater water body.	Mostly found on the northern side of the crater water body.

9. Major source: Basaltic rocks.	Major source: $CaCO_3$ from water or from below the basaltic lava.
10. At the final stage, the basaltic rock is finally changed to silica rock.	Rocks not converted to CaO rocks.
11. The process of silicification is slow.	The process of deposition of CaO is fast.

Table 8: Analysis of salt of Lonar Crater by XRF in mass %

S. No.	Element Name	Mass %	Formula	Oxide Content
1	Chlorine	79.6	Cl	79.6
2	Sulfur	3.324	SO_3	8.3
3	Aluminum	3.091	Al_2O_3	5.84
4	Silicon	1.645	SiO_2	3.52
5	Potassium	0.955	K_2O	1.15
6	Bromine	0.636	Br	0.636
7	Calcium	0.412	CaO	0.576
8	Iron	0.25	Fe_2O_3	0.358
9	Copper	0.013	CuO	0.016
10	Zinc	0.012	ZnO	0.015
11	Barium	0.006	BaO	0.007
12	Zirconium	0.004	ZrO_2	0.006
13	Nickel	0.004	NiO	0.006
14	Oxygen	10.048		
	Total	100		100.03

Table 9: Composition of basaltic rocks from Northern side of Lonar Crater by XRF in %. Sample No. 1

S. No.	Element Name	Mass %	Formula	Oxide content
1	Silicon	24.633	SiO_2	52.7
2	Aluminum	7.674	Al_2O_3	14.5
3	Iron	9.932	Fe_2O_3	14.1
4	Calcium	6.432	CaO	9
5	Magnesium	2.255	MgO	3.74
6	Titanium	1.522	TiO_2	2.54
7	Potassium	1.17	K_2O	1.41
8	Sulfur	0.318	SO_3	0.794
9	Phosphorus	0.335	P_2O_5	0.768
10	Manganese	0.122	MnO	0.158
11	Chlorine	0.121	Cl	0.121
12	Vanadium	0.036	V_2O_5	0.064
13	Copper	0.039	CuO	0.049
14	Cobalt	0.027	Co_2O_3	0.038
15	Zirconium	0.02	ZrO_2	0.027
16	Strontium	0.017	SrO	0.02
17	Oxygen	45.417		
	Total	100.07		100.029

Table 10: Composition of basaltic rocks from Northern side of Lonar Crater by XRF in %. Sample No. 2

S. No.	Element Name	Mass %	Formula	Oxide content
1	Silicon	24.259	SiO_2	51.9
2	Aluminum	9.844	Al_2O_3	18.6
3	Calcium	7.861	CaO	11
4	Iron	6.798	Fe_2O_3	9.72
5	Magnesium	2.906	MgO	4.82
6	Titanium	0.917	TiO_2	1.53
7	Sulfur	0.377	SO_3	0.942
8	Potassium	0.537	K_2O	0.647
9	Phosphorous	0.261	P_2O_5	0.598
10	Manganese	0.108	MnO	0.14
11	Chlorine	0.089	Cl	0.089

12	Copper	0.026	CuO	0.032
13	Strontium	0.015	SrO	0.018
14	Zirconium	0.013	ZrO_2	0.018
15	Barium	0.012	BaO	0.013
16	Zinc	0.01	ZnO	0.012
17	Nickel	0.004	NiO	0.006
18	Oxygen	45.963		
	Total	100		100.085

Table 11: Composition of basaltic rocks from Northern side of Lonar Crater by XRF in %. Sample No. 3

S. No.	Element Name	Mass %	Formula	Oxide content
1	Silicon	25.1	SiO_2	53.7
2	Aluminum	10.161	Al_2O_3	19.2
3	Calcium	10.148	CaO	14.2
4	Iron	6.7	Fe_2O_3	9.58
5	Titanium	0.701	TiO_2	1.17
6	Phosphorous	0.392	P_2O_5	0.899
7	Potassium	0.501	K_2O	0.603
8	Sulfur	0.132	SO_3	0.329
9	Manganese	0.107	MnO	0.138
10	Chlorine	0.098	Cl	0.098
11	Copper	0.035	CuO	0.044
12	Strontium	0.017	SrO	0.02
13	Zirconium	0.013	ZrO_2	0.018
14	Barium	0.011	BaO	0.013
15	Nickel	0.005	NiO	0.006
16	Lead	0.002	PbO	0.002
17	Oxygen	45.877		
	Total	100		100.02

Table 12: Composition of basaltic rocks from Northern side of Lonar Crater by XRF in %. Sample No. 4

S. No.	Element Name	Mass %	Formula	Oxide content
1	Silicon	25.381	SiO_2	54.3
2	Aluminum	7.833	Al_2O_3	14.8
3	Iron	10.071	Fe_2O_3	14.4
4	Calcium	4.767	CaO	6.67
5	Magnesium	2.713	MgO	4.5
6	Titanium	1.665	TiO_2	2.78
7	Potassium	0.896	K_2O	1.08
8	Phosphorous	0.317	P_2O_5	0.726
9	Sulfur	0.13	SO_3	0.325
10	Manganese	0.129	MnO	0.166
11	Vanadium	0.051	V_2O_5	0.091
12	Chlorine	0.083	Cl	0.083
13	Copper	0.031	CuO	0.039
14	Zirconium	0.019	ZrO_2	0.026
15	Strontium	0.013	SrO	0.015
16	Zinc	0.011	ZnO	0.014
17	Barium	0.011	BaO	0.012
18	Nickel	0.009	NiO	0.012
19	Oxygen	45.87		
	Total	100		100.039

Table 13: Analysis of soil sample from the northern side of Lonar Crater by XRF in mass %

S. No.	Element Name	Mass %	Formula	Oxide content
1	Silicon	18.884	SiO_2	40.4
2	Chlorine	13.9	Cl	13.9

3	Calcium	9.076	CaO	12.7
4	Aluminum	5.292	Al_2O_3	10
5	Sulfur	3.681	SO_3	9.19
6	Iron	6.148	Fe_2O_3	8.79
7	Phosphorous	1.052	P_2O_5	2.41
8	Titanium	0.731	TiO_2	1.22
9	Potassium	0.847	K_2O	1.02
10	Manganese	0.099	MnO	0.128
11	Bromine	0.079	Br	0.07
12	Copper	0.06	CuO	0.075
13	Strontium	0.032	SrO	0.038
14	Zirconium	0.021	ZrO_2	0.028
15	Zinc	0.018	ZnO	0.023
16	Oxygen	40.08		
	Total	100		99.992

Fig. 1: Deposition of CaO on the rocks situated on the northern side of Lonar Crater

Fig. 2: Deposition of CaO on the rock Situated on the northern side of Lonar Crater

Fig. 3: Rocks covered by a layer of CaO salts seen on the Northern side of Lonar Crater

Fig. 4: Rock covered by a layer of CaO salts seen on the northern side of Lonar Crater

Fig. 5: Conglomerate type of rocks found to be Cemented together observed near a temple at Lonar crater

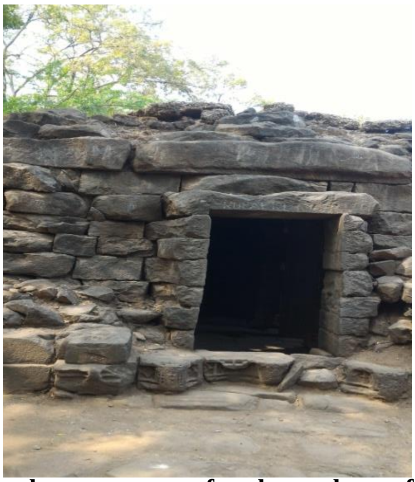

Fig. 6: Conglomerate type of rocks on the roof of temple observed on the south side of Lonar crater

Fig. 7: White layer of CaO seen on the rock Found near the temples on the northern side Of Lonar crater. (sample No.1).

Fig. 8: A white layer of CaO seen on the rock found near the temples on the northern side of Lonar Crater. (sample No.2).

Fig. 9: The whole rock metamorphosed to silica rock. observed at Lonar Crater.

Fig. 10: White rusting/white coating of rocks of silica. The front side is white rusting, the back side is the glassy phase observed at Lonar Crater

Fig. 11. White rusting/white coating seen on the rock observed at Lonar crater

Fig. 12: White rusting/white coating seen on a basaltic the front part is the white coating/white rusting and the back side is the glassy phase of the rock

Fig. 13: White coated seen on a basaltic rock. The black part is the basaltic rock and the white part is the white coating of silica observed at Lonar crater

Fig. 14: White layer of unknown component seen on the roof of Ramgaya Temple. It is possible that it may be of SiO_2 (Silica) coated on basaltic rocks or CaO deposition on the basaltic rocks of may be Andesitic origin

