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Study of Cavity filling Quartz Grains from the Ejecta Blanket at Lonar, Buldhana District, Maharashtra, India : An Evidence of Meteoric Impact

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Abstract

Lonar Crater in Buldhana district, Maharashtra, India, is one of the youngest and the only preserved impact craters in Deccan Trap basalts. It has attracted attention of several geoscientists and environmentologists not only from India, but all over the world. Quartz is a durable and resistant mineral; however, when subjected to a shock compression develops fractures and planar microstructures called planar deformational features or PDFs. Planar deformation features, or PDFs , especially in quartz grains are narrow planes of glassy material arranged in plane parallel sets having a specific orientation and are easily recognized under a petrological microscope or Scanning Electron Microscope. On these lines, it is observed that the microphotographs and the Scanning Electron Microscopic images of the cavity filled quartz grains now present in the Lonar ejecta exhibit both straight as well as bent planar deformation features (PDFs). Thus, the development of planar deformational features on the quartz grains can be utilized as a supplementary evidence for a meteorite impact at Lonar.

Keywords: Lonar crater**,** planar deformational features, cavity filled quartz, ejecta matter, meteoritic impact.

Introduction

Lonar Crater in Buldhana district, Maharashtra, India, is one of the youngest[1] and the only preserved impact craters in Deccan Trap basalts[1]. The location map of Lonar is shown in figure-1. It has attracted attention of several geoscientists and environmentologists not only from India, but all over the world. The crater is nearly circular, bowl-shaped, with 1.83 km diameter and is approximately 130m deep from crater rim to the water level at the center of the lake depression. Earlier researchers like Orlebar[2], LaTouche[3], Blanford[4], Medlicott and Blandford[5] and Nandy and Deo[6] referred the crater site as of a volcanic origin. However, based on extensive field investigations, petrography and geochemistry, Beals et. al.[7], Lafound and Diez[8], Venkatesh[9], Nayak[10], Fredriksson et. al.[11], Fundali, et. al.[12], Nayak[13], Sengupta et. al.[14], Poornachandra Rao and Bhalla[15], Haggerty and Newsom[16], Ghosh[17] and Maloof et. al.[1] conferred it to be of a meteor impact origin.

Planar deformation features, or PDFs, are narrow planes of glassy material arranged in plane parallel sets having a specific orientation and are easily recognized under a petrological microscope or Scanning Electron Microscope. According to Engelhardt and Bertsch[18], planar deformation features (PDFs)[19] could be observed and classified into five different types: a) Decorated planar elements, b) non-decorated planar elements, c) Homogeneous lamellae, d) Filled lamellae, and e) planar features.

In basalts secondary minerals like zeolites and quartz occur as cavity filling commonly in the amygdaloidal basalts, like the ones occurring at Lonar. These cavity filling minerals are formed post emplacement and cooling of the basalts. However the Lonar impact has been dated by 40Ar/39Ar isochron age to be 656 ± 81 ka in age[21]. This shows that the impact has occurred much later than the formation of these Quartz and other cavity filling minerals.

Quartz is a durable and resistant mineral. However, when subjected to a shock compression develops fractures and planar microstructures[19-26]. Open, parallel fissures with a typical spacing of more than 15–20 µm apart are referred as planar fractures or as pf's. In contrast, individual planar features of amorphous material which are less than 2 µm narrow individual planar features are termed as the planar deformational features or pdf's [24,27,28].

There have been studies by many workers on maskelynite from Lonar and other impact sites[29,30]. However even after extensive literature study by the authors, it was found that no work on pdf's of such cavity minerals has been conducted. Hence the present work can form a new avenue of research in study of Lonar crater and its origin.

Geology of the area: According to the District Resource Map of the Buldhana district[31], the Deccan Trap basalts flows belongs to the Sahyadri Group which is further divided into Ajanta, Chikhli, and Buldhana Formations respectively. The Ajanta Formation is represented by two 'aa' and eight compound 'pahoehoe' flows; Chikhli Formation by three Aa and three 'pahoehoe' flows, while three Aa and three compound 'pahoehoe lava flows represents the Buldhana Formation. Ghosh and Bhaduri[17], have differentiated six flows at Lonar Crater of approximately 8 to 40m thick. According to their investigations, the lava flows are separated by the presence of thin paleosols, or the chilled margins. Geological map of the area is shown in figure-2.

Figure-1

Location map of the Lonar crater, Buldhana district, Maharashtra, India. (After District Resource Map Series, 2000)

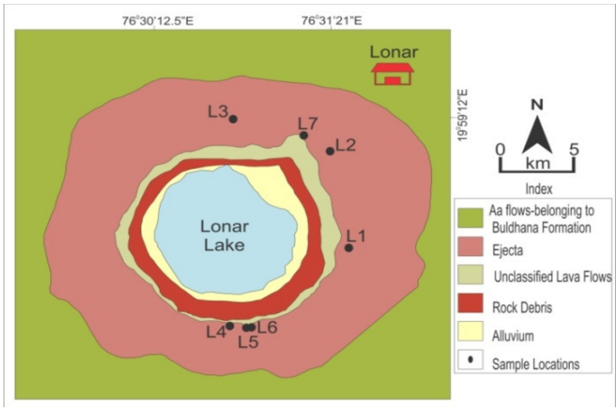

Figure-2
Location of sample sites of the ejecta matter at Lonar, Buldhana district, Maharashtra, India (Modified After: DRM, Buldhana district, Maharashtra, Geological Survey of India, 2000)

Methodology

In general, the basalt flows at Lonar Crater are found to be of compact, vesicular and amygdaloidal in nature. The amygdales are found to filled with a rich assemblage of secondary minerals especially quartz, calcite and zeolites. It is believed that, if the target rock and its ejecta matter provide evidences of a high velocity meteoritic impact, then the cavity filling minerals, especially quartz within the amygdales must have also been subjected to the high velocity meteorite impact, preserving the effects of stresses within them. Taking this into account an initial survey was carried out around the rim of the crater and sampling sites were identified. Eight ejecta sampling sites were identified all around the rim of the crater and samples were collected. The sampling sites are as shown in figure-2 above. The samples at the sites were found to be loose, dry and friable. At places, the development of calcretes within the ejecta matter has made these deposits slightly indurated and easy to collect. Figure 3 is a field photograph of the ejecta matter at Lonar. Thin sections were prepared for such indurated material to be observed under petrological microscope.

Figure-3
Exposure of the ejecta matter at Lonar crater. Note the non-stratified material within which angular fragments can be observed

Some of the friable matter was subjected to sieving through a coarse and medium sand size mesh. The sieved matter was cleaned with the help of dilute hydrochloric acid. The sample was washed several times, dried and the cavity filling quartz grains were picked and separated using a binocular microscope. About 20 secondary were subjected to Scanning Electron Microscope studies (SEM) at Physics Department, University of Pune using Joel Instrument JSM-6360 (SEM with energy dispersive spectrometer). Around 10 to 15 secondary quartz grains were also mounted on the glass slide using Canada balsam and were observed under petrological microscope.

Thin section analysis: The calcretized ejecta when viewed under a petrological microscope exhibits a typical clay-rich micritic matter within which coarse to fine grained angular fragments of plagioclase feldspar, pyroxenes, secondary quartz, basalt rock fragments, serpentine, and yellowish to greenish glassy matter are observed as in figure- 4. Cementation of the earliest stage is represented by perpendicular arranged fibrous and isopachous cement spar around the fragments are readily observed. The fibrous cement spars are typically associated with hard ground surface and from this association it is inferred that prolonged exposure of sediments by the prevalent slow or non-deposition. The next generation of cementation is expressed by the presence of pore-filling, fine equants of spar. At places straight and undulating veins of sparry calcite within the clay-rich micrite is commonly observed.

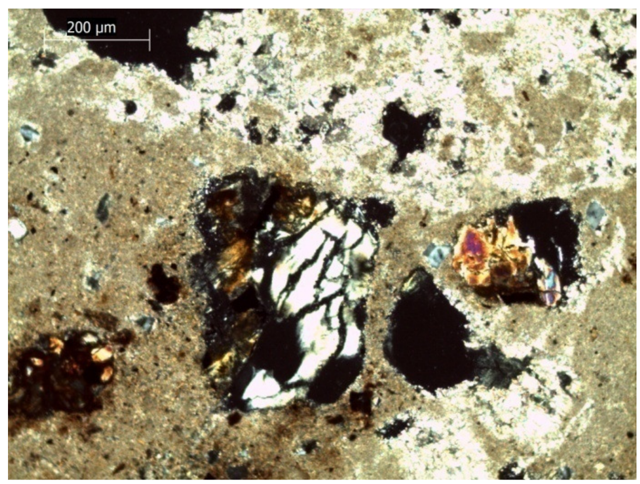

Figure-4
Thin section of the calcretized ejecta matter at Lonar. Note the shattered nature of the mineral fragments within a clay-rich micritic material

Planar deformational features of the secondary quartz: The shocked secondary quartz grains are found to be angular to sub-angular in nature. Under petrological microscope, the planar deformational features in these cavity filling quartz grains are found to be continuous and/or discontinuous, parallel to sub-parallel in nature and range 0.01µm to 0.02µm apart In between the planar deformational features minor cracks at right angles can be observed in figure-5a. Figure-5b exhibits development of continuous to discontinuous planar deformational features which are found to be 0.01µm apart. Some fluid inclusions are easily recognizable. Development of closely spaced, discontinuous, parallel to sub parallel, bent planar deformational features are found to be spaced 0.01µm to 0.03 µm apart in figure 5c. In Figure 5d, two to three discontinuous planar deformational features can be seen. These larger planar deformational features are found to be cut across by numerous closely spaced fractures.

In general, the Scanning Electron Microscope (SEM) images reveal continuous, parallel to sub-parallel as well as bent Planar deformational features as shown in figures 6a to 6d. Figure 6a is an angular cavity filling quartz grain with a moderate relief and exhibits closely spaced, parallel set of planar deformational features which are found to be cut by a second set of closely spaced bent deformation features as in figure-6b. In figure-6c, the quartz grain exhibits moderate relief and the development of continuous, parallel, closely spaced planar deformational features of amorphous silica material. Quartz grain with moderate relief with the development of both parallel and bent planar deformational features can be observed in figure-6d.

Results and Discussion

From the above research work it is observed that the microphotographs and the Scanning Electron Microscopic (SEM) images of the cavity filling quartz grains from Lonar ejecta exhibit both straight as well as bent planar deformation features (PDFs)[18]. Thus, the development of planar deformational features on the cavity filling quartz grains in the ejecta matter can be utilized as a supplementary evidence for a meteorite impact at Lonar.

The record of terrestrial meteorite impacts is highly fragmentary[32], as the vast majority of impact structures are removed by erosion or tectonic activity[32,33]. According to Cavosie et. al.[32] and Erickson[33], as a first step towards understanding the preservation of the shocked minerals, especially quartz, zircon and monazite in sedimentary systems, they analyzed modern sand from the Vaal River in South Africa[32]. Their results demonstrate the preservation potential of detrital shocked minerals for identifying the presence, timing and target rock age for ancient impact events that may be otherwise missing from the rock record.

Roig et.al.[34] demonstrated that detrital shocked minerals[33] eroded from large impact structures can be transported and preserved in siliciclastic sediments. The goal of their study was to evaluate if a detrital shocked mineral record is created during the erosion of a small impact structure.

All the above research works point out to the importance of study of minerals especially detrital shocked minerals for understanding the terrestrial impact structures. In Lonar crater this is the first attempt made to utilize studies on cavity filled quartz from ejecta matter, by studying the different kinds of deformation features for understanding its impact origin.

Conclusion

The development of planar deformational features on the cavity filling quartz grains as observed from petrographic and SEM analysis can be utilized as a supplementary evidence for a meteorite impact at Lonar. However, in the present study indexing of the crystallographic orientation of the planar deformational features of the secondary quartz has not been carried out, and is the subject matter of ongoing research work.

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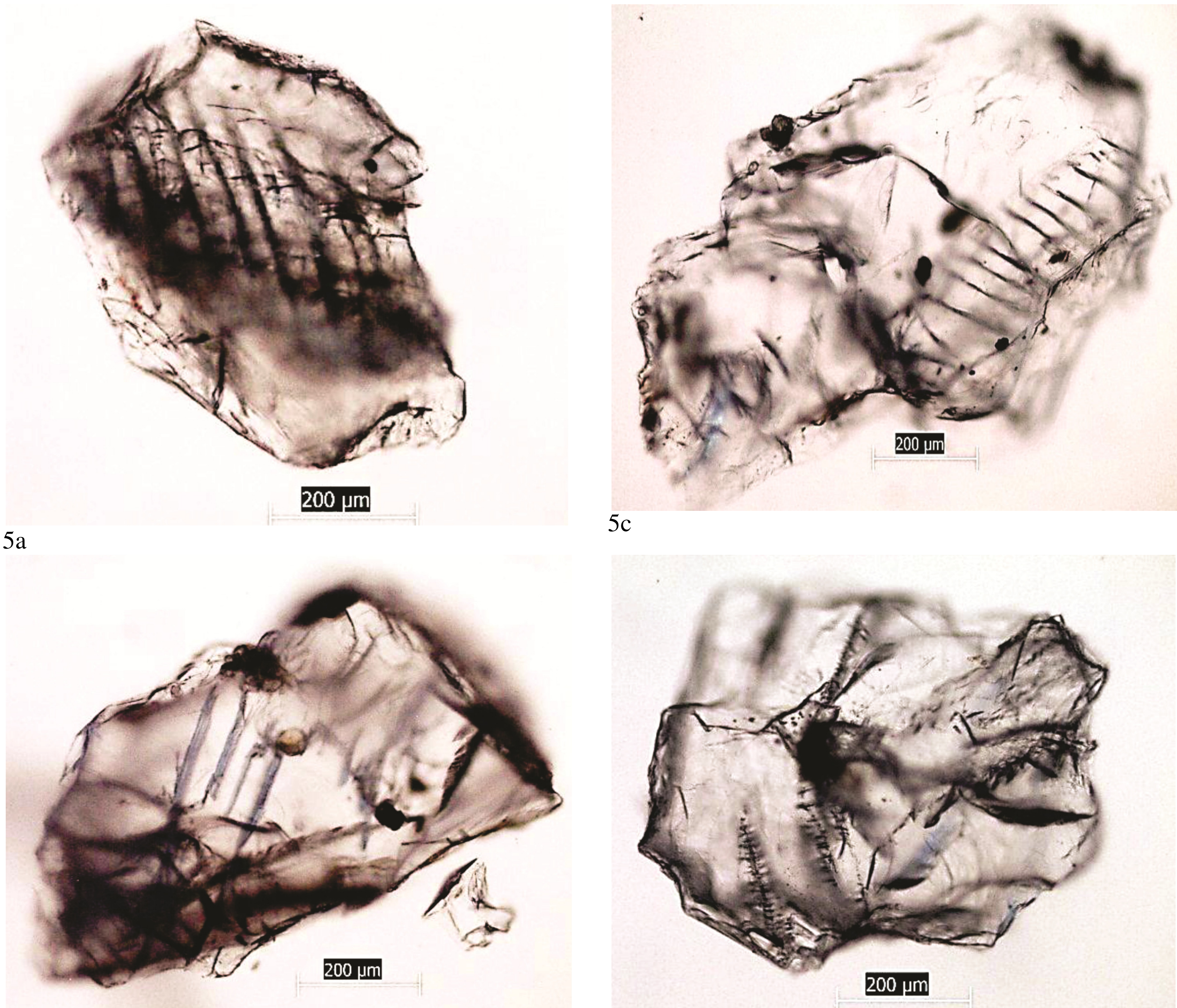

5a 5c 5b 5d

Figures-5a to 5d
Photomicrographs of the planar deformation features of the secondary quartz grains

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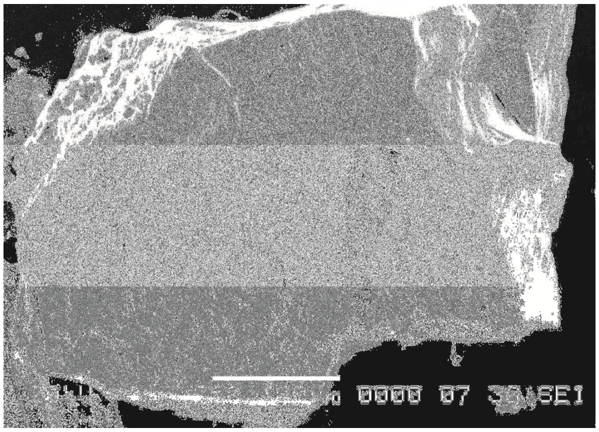

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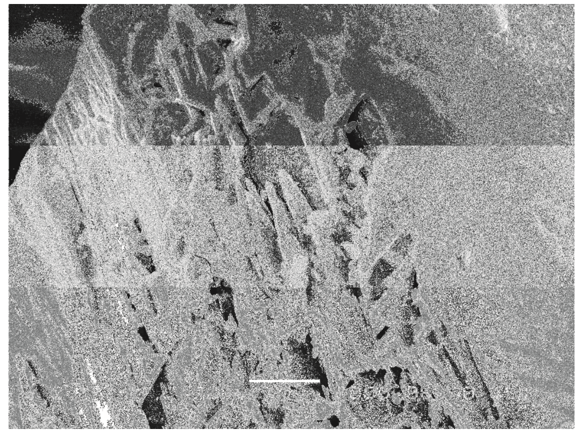

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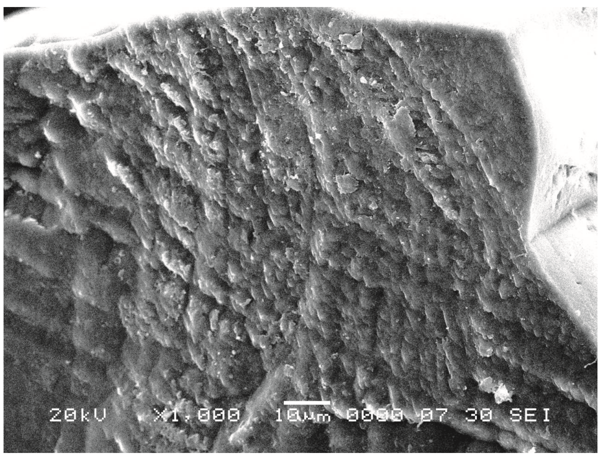

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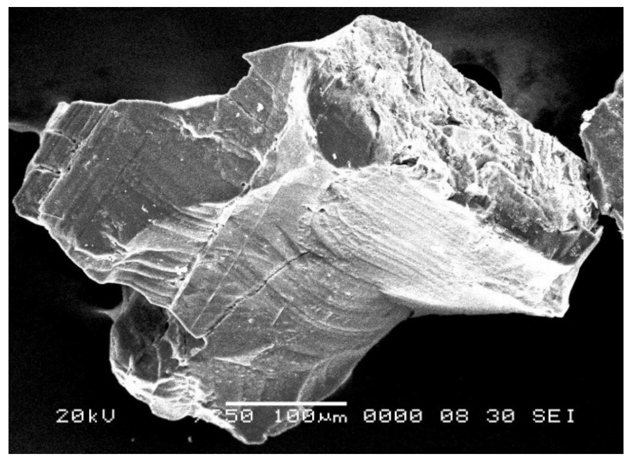

6d

Figures-6a to 6d
SEM photographs of the planar deformation features (straight and bent) on the secondary quartz grains.

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