Quenched morphologies in impact glass from Lonar crater, India: role of water?

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Introduction

Figure 1: A view of Lonar Crater from the north rim in December 2016.

Lonar Crater located in Maharashtra (76.52°E, 19.98°N, ~563 m amsl.) , India, is a simple impact crater with a diameter of 1.8 km and the hypersaline lake formed in it lies at about 137 m below the raised rim of the crater. A previous study described the impact glasses from Lonar with respect to their geochemistry and microtextures [1]. In this work, we provide more insights into the microtextures of impact glasses from Lonar, upon the crystal morphologies which indicate quenching due to water.

Methods

Samples of impact glass were collected from near the Amber Lake (fig. 2 and 3), north of Lonar Crater. These samples were retrieved from debris flow deposits, possibly reworked ejecta, near the north eastern exterior of the crater wall. Ex-situ samples of shocked basalts were also collected from the rim of the crater and used for petrographic analyses. Electron Probe Microanalysis (EPMA) was carried out at Indian Institute of Technology, Bombay, with a CAMECA SX5. The instrument was equipped with 5 Wavelength Dispersive Spectrometers. Quantitative analysis used a 15 μm beam, 15 KV accelerating voltage and 20 nA sample current and a counting time of 10s. The standards used for calibration were albite (Na), diopside (Mg,Ca), Th-glass (Si), corundum (Al), orthoclase (K), rhodonite (Mn), hematite (Fe), barite (Ba), chromium trioxide (Cr), Rutile (Ti) and metal (V).

Figure 2: Google Earth image of Lonar Crater. Location of Amber Lake is marked with a square.

Figure 3: Impact glass in suevite breccia near Amber Lake, north of Lonar Crater. Diameter of the coin is 2.7 cm.

Figure 4: Samples of impact glass from north of Lonar Crater.

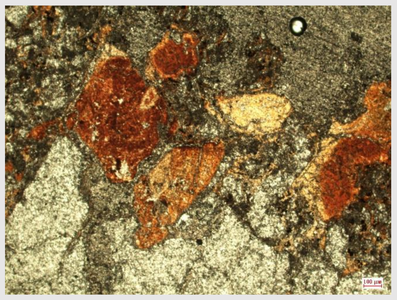

Figure 5: Photomicrograph showing partial conversion of plagioclase to brown glass in shocked basalt of Lonar Crater.

Results

Mineral	Ti- Mag	Opx	Cpx	Glass	Plagioclase
No. of analyses	4	2	12	15	8
SiO2	1.07	47.39	49.83	51.97	49.82
TiO2	26.71	0.72	1.20	2.26	1.20
Na2O	0.07	0.12	0.31	2.42	0.31
MgO	1.05	6.72	12.64	5.27	12.63
Al2O3	1.49	0.71	2.34	13.72	2.34
K2O	0.04	0.10	0.09	0.60	0.09
CaO	0.31	5.90	15.07	10.21	15.07
FeO	63.41	36.89	17.52	12.83	17.51
BaO	0.17	0.00	0.01	0.03	0.01
V2O3	1.16	0.03	0.12	0.10	0.12
MnO	0.52	0.79	0.35	0.21	0.35
Cr2O3	0.01	0.00	0.03	0.01	0.03
Total	95.99	99.36	99.51	99.64	99.49

Table 1: Average composition of Lonar impact glass

Mineral Phases

Back Scattered Electron (BSE) images (fig. 6) of the impact glass show presence of grains of Ferroan-Augite, a very small amount of Pigeonite, and a dominance of plagioclase plus complete glassy phases. The glassy phases were identified (Table 1) based on comparison with geochemical data presented in earlier publications on impact glasses from Lonar [1, 2, 3] The glasses are geochemically similar to the target basalts from Lonar [1,3]. BSE images show devitrification textures like quenching where crystallites of plagioclase have started to nucleate [1]. Basalts from the crater which have experienced lower grades of shock pressures compared to the impact glass show presence of brown glass which is compositionally similar to the impact glass (fig. 5). Other than feldspars and pyroxenes, the impact glass shows presence of skeletal crystals of Ti-Magnetite (fig. 6). Formation of such dendritic magnetite crystals may be attributed to the rapid cooling of the molten rock and reabsorption of Fe from the magnetite into the melt.

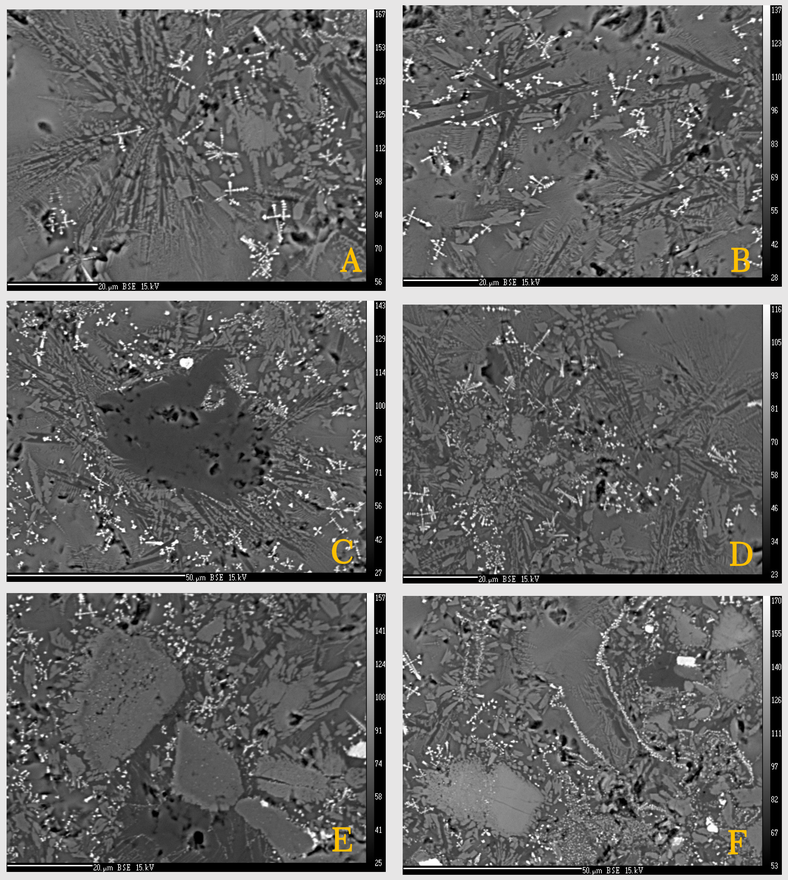

Figure 6: (A-F) BSE images of impact glass. The glass shows presence of quenched laths of plagioclase which have formed from devitrification of glass. The bright skeletal crystals are Ti-Magnetite and the lighter grey subhedral grains are clinopyroxenes. The glassy groundmass of the rock is chemically similar to Lonar basalts.

Discussion

The texture of impact glass is mostly holohyaline, with presence of plagioclase microphenocrysts. These plagioclase laths occur as slender, elongated 5-10 μm crystals with swallow tails and fan spherulitic textures which commonly represent undercooling conditions [4,5]. These textures and crystal morphologies are analogous to those reported from natural igneous settings like pillow lavas and experimentally produced textures of underwater-cooled basalts, spinifex textured rocks, etc. that have been attributed to quenching with water [4,6]. We thus conclude that the textures of Lonar impact glass indicate a role of free water in the formation of the morphologies. Whether the origin of this water is phreatic or meteoric is yet to be investigated. Presence of natural aquifers in the Deccan basalts is not uncommon due to the vesicular, lobate and jointed nature of the Deccan Traps [7] and may account for a phreatic origin of the water, whereas stratified ejecta deposits near Amber Lake argue for the presence of surface water. Furthermore, if concentration of water around the spherulites is calculated, the kinetics and chronology of spherulite formation in the glass can be determined and compared to volcanic glass [8].

References

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