GEOLOGIC MAPPING OF BOTH ALTERATION MINERALOGIES AND SHOCK STAGES OF EJECTA LOBES AT LONAR CRATER, INDIA USING GPS, LAB SAMPLE ANALYSES, AND HIGH RESOLUTION IMAGERY

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Introduction: Lonar crater is an ~1.8 km diameter impact crater (Fig. 1) located in Maharashtra state, India [1]. This well-preserved impact crater is emplaced in the basaltic Deccan Traps, which makes it a good Earth analog for studying post impact modification of craters on Mars. The approximate crater age is 570 ka [2].

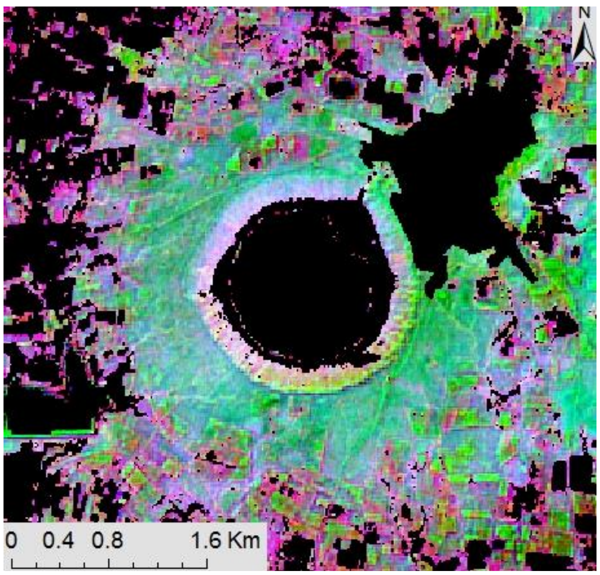


Figure 1. ASTER false color composite image of Lonar Crater using band ratios. Iron bearing minerals are shown in red, vegetation in green, and OH-bearing minerals such as clays in blue. Water, vegetation and urban have been masked out.

Goals: Planetary analog fieldwork at Lonar is in the near future concerning both rovers and astronauts. We aim to create a high-resolution geologic map that will compare well with Shoemaker's geologic map of Meteor Crater, AZ [5]. Where mapping lithic breccia and suevite breccia, it was decided to field map the extent of lithic ejecta lobes and their precise aleration mineralogy, as several alteration types were found. These include: fresh basalt, gray basalt, hematite basalt, zeolite basalt, green amygdule basalt, iddingsite basalt, chalcedony basalt, baked zones or "bole", and others. The altered basalts represent the earliest ~65 Ma basalt flows that were aqueously altered by groundwater before impact. Figure 3 focuses on just one alteration mineralogy shown in red: "Gray Basalt Red Matrix" (GBRM).

The formation of gullies and drainage patterns on and around Lonar crater help to constrain post-impact modification processes of a more hydrologically active Mars. Surface runoff most likely controls the formation of the drainage channels of Lonar crater, which originated at the crater rim and extend radially [3,4].

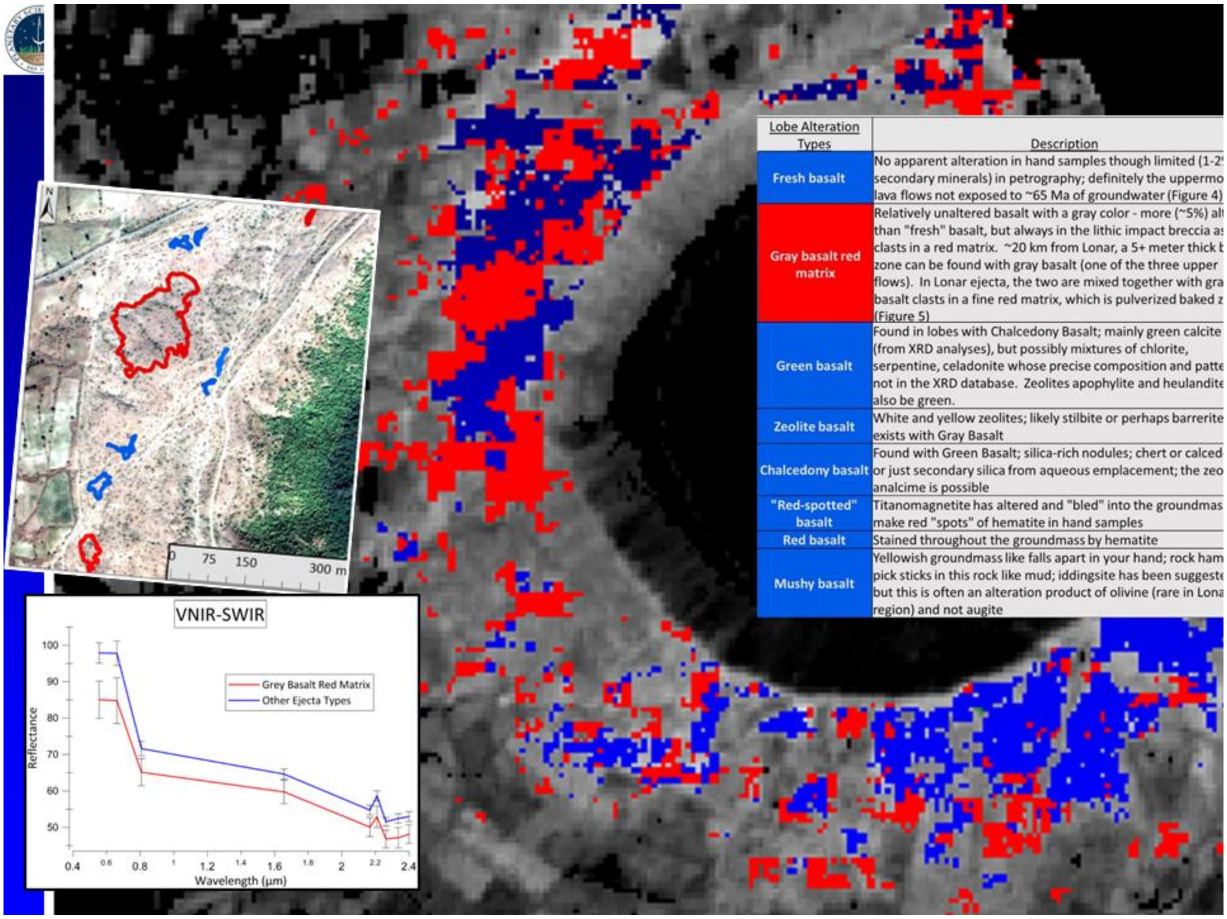
Figure 2. Field image taken to west near bottom of Figure 3 showing boundary of grassy, "clast free" ejecta in foreground versus "cobble field" in background that is described here under "Field Data". A gulley separates the two. See man at upper right at bottom of cobble field for scale.

Methods: A ~1 m/pixel resolution Quickbird image [7] was georectified in ArcGIS 10 using a Landsat 8 image as the base. The georectified Quickbird was used as an overview image as well as for mapping drainages.

Using the Quickbird image and a Digital Elevation Model from [7], the drainage patterns mapped by [6] were expanded. Channels in the interior walls of the crater were mapped if they appeared to have a visual hydrological connection to exterior drainages.

An ASTER Band math false color composite image (Fig. 1) was created using ENVI Classic 5.0. The band ratios are as follows: Red = B4 (1.6-1.7 µm) / B3 N (0.78-0.86 µm); Green = B3 (0.78-0.86 µm) / B2 (0.63-0.69 µm); Blue = B4 (1.6-1.7 µm) / B5(2.145-2.185 µm). The red highlights iron-bearing minerals, blue highlights OH- and clay bearing minerals, and the green is vegetation. The image was equalized to increase the contrast between the ejecta and surrounding farmland. Attempts to mask pixels corresponding the farmlands, vegetation, a reservoir, the lake, and the lakeside are ongoing. The goal is to quantitatively compare pixels of ejecta preserved by the Indian Department of Forest.

GPS points from previous field work obtained using a hand-help GPS were overlain on Quickbird and ASTER images were used in mapping a ejecta distribution, drainage and notable features on and around the



crater. Extensive farming activity in the surrounding area make the exact boundary of the ejecta blanket using satellite imagery difficult to determine.

Field Data: Whereas the Department of Forest has called for the preservation of near-rim ejecta, the uppermost surface and mostly all of the edges of the continuous ejecta blanket (CEB) have been destroyed by farming over the last thousand years. Further, the largest blocks of impact breccia clasts have been removed by ancient man (Dravidians ~1100 years ago) to build temples and other man-made structures.

The fine, red matrix of the impact breccia that is found with ~50% of Gray Basalt lobes is likely due to their pre-impact stratigraphic relation, as red *bole* or baked zone overlies Gray Basalt in outcrops 5 to 30 km away from Lonar. The bole is pulverized to become the matrix of the lithic breccia with nondescript Gray Basalt being the clasts. Another common "lithologic association" seen in lithic ejecta lobes include clasts of basalt containing (separately) iddingsite, hematite, and green amygules. We suggest these pre-impact alterations were mixed as ejecta lobes.

Figure 3 (above) 10 categories of altered basalt have been labelled/categorized for this study, but only one is focused on here and shown in the field on the lower left. "Grey Basalt Red Matrix" is shown in red on the table, the ASTER image, the 1-m "Google-Maps" image of the west ejecta, and the spectral plot. All other "Alteration Lithologies" are shown as blue.

Results: An integrated map of remote sensing and field data such as Figure 3 will be presented following the synthesis of the additional field data collected. This will include the location of ejecta types in the field and the distribution of channels and gullies surrounding Lonar crater. Remote multispectral spectra of Fe-bearing and OH-bearing pixels will be compared to laboratory VNIR-SWIR spectra of variously altered basalt described here, including those high in hematite, augite, and clays.

References: [1] Fredriksson K. et al. (1973) Science, 180, 862-864; Fudali R. F., et. al. (1980) Moon and the Planets 23:493-515 [2] Jourdan et al. (2011) Geology 39.7, 671-674 [3] Komatsu et al. (2014) Planet. and Space Sci., 95, 45-55 [4] Maloof et al (2010) GSA, 122.1-2, 109-126 [5] Shoemaker (1960) Princeton PhD dissertation