POTENTIAL OF FIELD AND SAMPLE DATA OF LONAR CRATER, INDIA TO BE ASTROBIOLOGICAL ANALOGS

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Questions: Where would we look for life on Mars? What measurments do we make of soils and altered basalts to look for biological processes? Do deposits from pre-impact aqueous and post-impact hydrothermal habitable environments have identifiable mineralogical signatures (*e.g.*, phyllosilicates, evaporitic minerals, lake sediments, *etc.*)? What about a post-impact lake? Can ejected samples with evidence of a pre-impact habitable environment, such as soils and porous "baked zone" deposits in the target rock basalts, retain mineral-chemical signatures representative of this environment? Can the post-impact climate be determined from the chemistry and mineralogy of surficial weathering including soil vs. paleosol chemistry, and the nature of the erosion of the crater, for example fluvial versus debris flow formation of gullies?

Of Note: This abstract is written with a "carbon chauvinism" in that we expect carbon and water to be chemicals of astrobiological significance. However, the use of these materials as analogs allows for other elemental and chemical systems to be explored.

Brief Summary: Lonar Crater, India [1] consists of essentially two "types" of basalt (fresh flows on top of altered flows), and the altered basalt from depth is now available as clasts in the impact breccia unit. Altered basalt was created by aqueous alteration prior to impact. Further, shocked soil displaying flowing carbonate is found as breccia clasts. These materials reprsesent excellent analogs to test instrumentation sent to Mars and those in laboratories that examine veins in Martian meteorites, which are interpreted to be soils and alteration.

TIMELINE / GEOLOGIC HISTORY

Prior to impact, the region around Lonar Crater was already a "Mars-like" environment (Table 1) in terms of silicate composition, though not volatile composition. Deccan basalt was emplaced ~65 Ma, and the lower basalt flows were aqueously altered by abundant groundwater run-off. By "stripping off" the crater's ejecta and examining the topography of the region with the crater ejecta volume removed, we can imagine the pre-impact topography as low-lying with probably a creek, stream, or pond that are found throughout the region. Note a pond near the NE ejecta and town of Lonar, along with a reservoir with dam in SW ejecta.

Impact ~570 ka [4] resulted in ejecta being deposited over a formerly low-lying, thick, black, marsh deposits in the SW ejecta but NE of the reservoir in the SW ejecta (Figure 1). The aqueously-altered basalt that was only at depth, and hence not available for sampling by a field geologist or rover, is now deposited as clasts in two impact breccia layers: a thicker, ~8 m lithic breccia of unshocked clasts and an overlying ~1 m thick impact melt-bearing breccia (formerly, "suevite") that contains all levels of shock metamorphism [1]. In this, impact has served as a "drill core" to bring up such alteration at depth. An example of a shocked basalt with alteration is shown (Figure 2). Ground ice (or Noachian groundwater) and brines have been proposed for biological significance for Mars [2]. In addition to various altered basalt (Table 1), "bake zone" deposits indicating a brief time in-between flows, along with a shocked soil (Figure 3) have been found.

age	**"strata":**
formed ~65 Ma – 570 ka	**thin layer of soil**
emplaced ~65 Ma	**3 flows of "fresh" basalt – contain the primary minerals listed below**
emplaced ~65 Ma, then aqueously altered by groundwater	**3 flows of "altered" basalt:** **primary → secondary** **augite, pigeonite → chlorite, serpentine, celadonite** **labradorite → zeolites** **volcanic glass → palagonite** **titanomagnetite → hematite** **deposited: quartz / silica calcite, hematite**

Table 1. Pre-impact stratigraphy is listed along with primary and secondary minerals. Lower flows are likely subjected to more aqueous alteration over ~65 million years prior to impact ~570 ka [4]. Groundwater level is suggested by a white line. All three of these materials have been shocked to various pressures to exist as clasts in the upper impact breccia unit, and the lower, altered basalts exhibit "decompression cracks" [3] described here at Class 2 shock pressures.

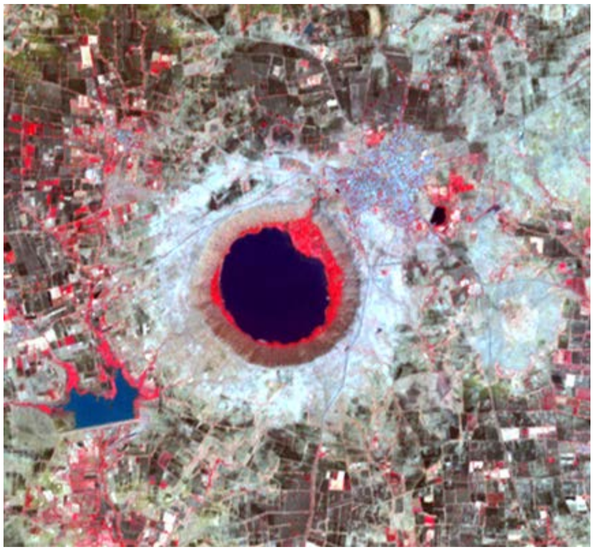

Figure 1. ASTER VNIR image of 1.8 km Lonar Crater showing vegetation as red and blue/black as water bodies. A bright “halo” represents near-rim ejecta that has been recently (~570 ka [4]) pulverized, whereas farms of dark soil surround the crater. The regional (~200 km^2) topography and hydrology will be shown for clues into the nature of the pre-impact surface.

SAMPLE ANALYSES

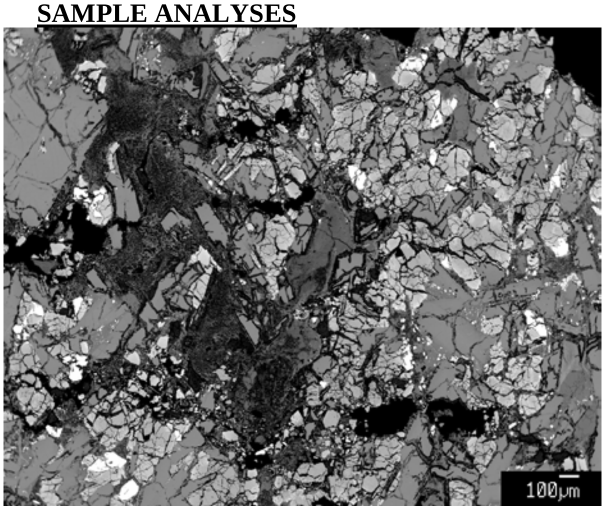

Figure 2. BSE image of a typical altered basalt shocked to Class 2 pressures. Phyllosilicates have a feathery texture and glass exists as both maskelynite and whole-rock melting.

Shocked Soil: One light gray clast from the suevite breccia has a frothy, “fluffy” appearance with very low density. Petrography revealed a texture not like basalt: schlieren calcite amongst an occasional augite or labradorite grain (Figure 3). The majority has poor petrographic properties suggestive of oxides and alteration products. A comparison to petrography of unshocked soil revealed its protolith. Isotopic geochemistry of the shocked soil, including C^{14}, are forthcoming to compare to unshocked soil and examine the effects of shock on the preservation of biota.

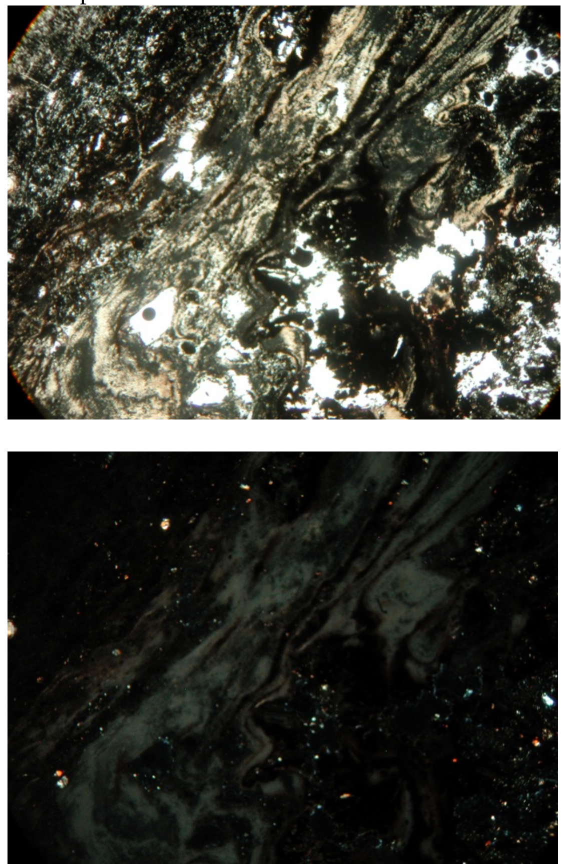

Figure 3. Photomicrographs with 5X magnification of plain (top) and cross-polarized (bottom) light showing shocked soil LC09-316.

Conclusion With three processes analogous to Mars (basaltic volcanism, aqueous alteration, and shock), Lonar Crater shocked basalts are excellent analogs for analyzing results from instrumentation sent to Mars, along with the interpretations of soil and alteration being incorporated into some Martian meteorites such as EET79001 and the Nakhlites, respectively. Early petrographic and electron microprobe images reveal of range of shock pressures of various protoliths such as fresh Deccan basalt, altered basalt, and what is interpreted as a consolidated soil or a sample from weathering horizons in-between individual basalt flows. We suggest that areas surrounding formerly-hot impact melts (“Class 5”) in the impact melt-bearing breccia are the best areas to look for biological activity in the ejecta. Whereas the initial geologic characterization of these materials has been performed, insight into biological activity is forthcoming.

References: [1] Kieffer et al. (1976) *7th LPSC*, 1391-1412 [2] Michalski et al., *Nature Geoscience*, in press [3] Wright (2013) *LPSC 44*, #1010 [4] Jourdan et al. (2011) *Geology 39*, 671-674 doi: 10.1130/G31888.1