SHOCKED SOILS AND BAKED ZONES FROM A BASALTIC TARGET PROVIDE INSIGHT INTO MARS SAMPLE RETURN AND DETECTIONS OF IMPACT GLASS

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Summary: In addition to (bedrock) basalts shocked to a range of shock pressures [1], pre-impact soils and baked zones at Lonar Crater, India were involved in the impact process [2]. This is a report on those and implications for trapped gases (a goal of Mars sample return) and detections of impact glasses in Martian central peak craters [3].

Introduction: Clasts of shocked basalts in a fine-grained matrix make up a ~1 m thick impact melt-bearing breccia unit overlying a ~8 m thick lithic breccia unit composed of unshocked basalt clasts. However, other materials involved in the impact event at Lonar are discussed here: former baked zones (from volcanic processes) now found as rarer clasts in both units; and shocked soil clasts in the upper unit that mirror "rip up clasts" of soil in the lithic breccia [1, 4]

Field: Local clasts (perhaps 1 in ~10,000) in the lithic layer of the ejecta blanket are redder in color, indicating iron oxidation (Figure 1). From comparison to nearby stratigraphy ~10 km away from the impact site (Figure 2), these are suggested to be remnants of pre-impact "baked zones" where ~65 Ma basaltic lavas thermally metamorphosed underlying soils, sediments, and perhaps slightly older (by ~1000 years) basalt flows.

Additional red clasts are found in the impact melt-bearing ejecta layer (formerly called "suevite"). The majority of these are Class 2 shocked basalts containing maskelynite, but are noticeably redder with hematite and other oxides found in petrography. Also found are the higher classes of shocked basalt (Classes 3-4-5 [1]) and low-density, frothy, pumiceous samples described below.

Sample: Light gray, frothy samples were imaged with back-scattered electrons (BSE) on the JSC SEM. Unshocked soils were imaged for comparison (Figure 3). In the shocked soil, BSE images reveal inclusions of unmelted, remnant unshocked soil (Figures 4 and 5) amidst a schlieren texture. Layers of soil horizons of carbon (likely calcite) and silica are apparent in the hand sample. These have a schlieren texture in petrography.

Implications for Mars: Contact metamorphism, independent of impact and the shock wave, is suggested to be a vital process for preserving trapped gases. A goal of Mars sample return, whether humans are involved or not, is the collection of lithologies that contain atmospheric information from the time of deposition: chemical sedimentary rocks and, to a lesser extent,

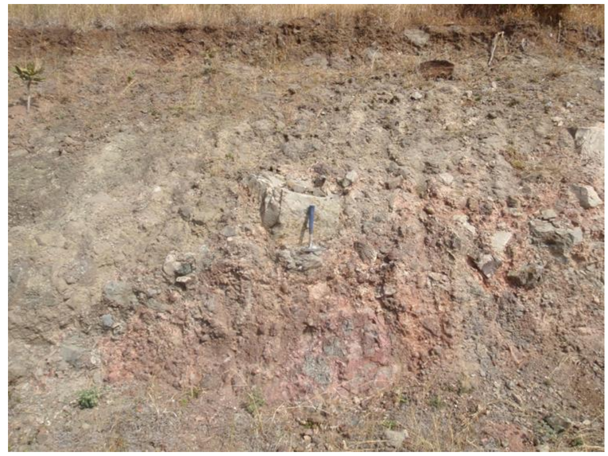

Figure 1. Region of lithic breccia ejecta at Lonar composed of pre-impact "baked zone" now fractured and emplaced in the lithic breccia unit. Photo is ~10 m.

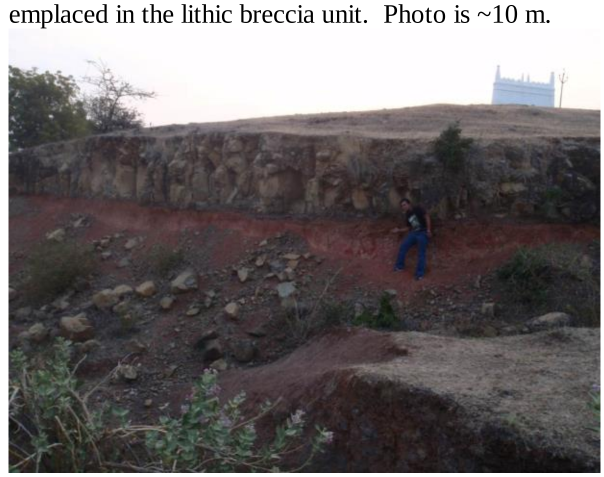

Figure 2. Example of the same baked zone away from Lonar Crater.

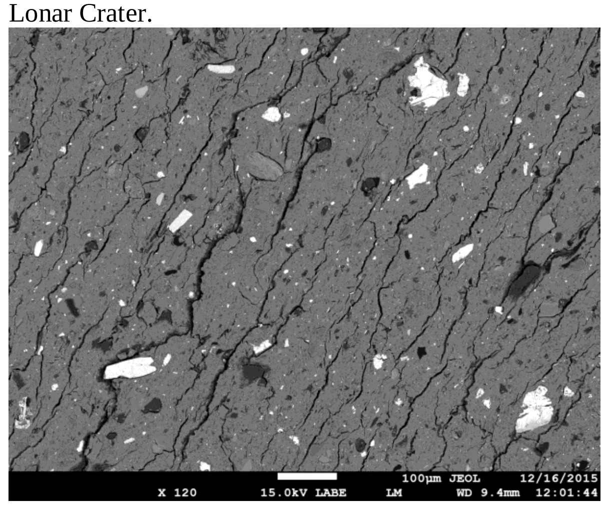

Figure 3. BSE image of unshocked soil. Note dessication textures as the black, clay-rich sample dried.

igneous rocks. In the Deccan region, the time span between individual basalt flows was miniscule. But on Mars, where Amazonian lava flows have "baked" older Noachin and Hesperian lithologies, the act of thermal metamorphism should preserve climatic information and gases during the baking event and hopefully from the original deposition of the older sediments. This will have to be unraveled by future investigators of samples returned from Mars' baked zones. Further, vesicles in shock Classes 3 and 4 [1], in addition to Class 5 "impact melts" should trap atmospheric gases. An example is shown as Figure 6, as vesicles are apparent in the petrography of a Class 3 shocked basalt with flowing glass with a foam-like texture and fractured augites.

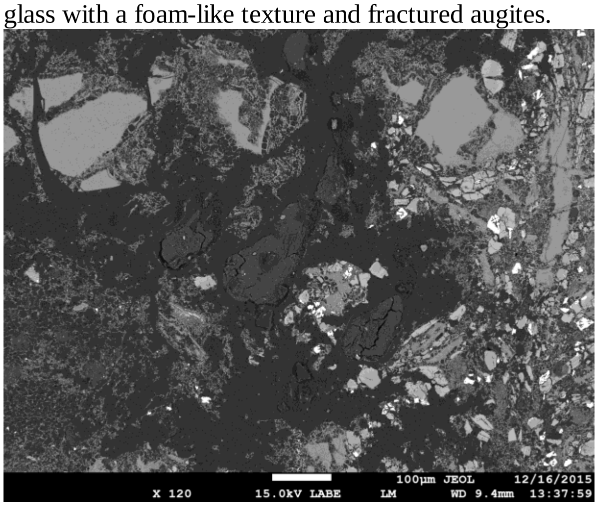

Figure 4. BSE image of shocked soil. Note melted and vesiculated labradorite glass in gray at top and right of of image with three off-black inclusions of unshocked soil across center of image. Note the dessication texture of the three unshocked soils similar to Figure 3. Figure 5 below is a close up of the third inclusion.

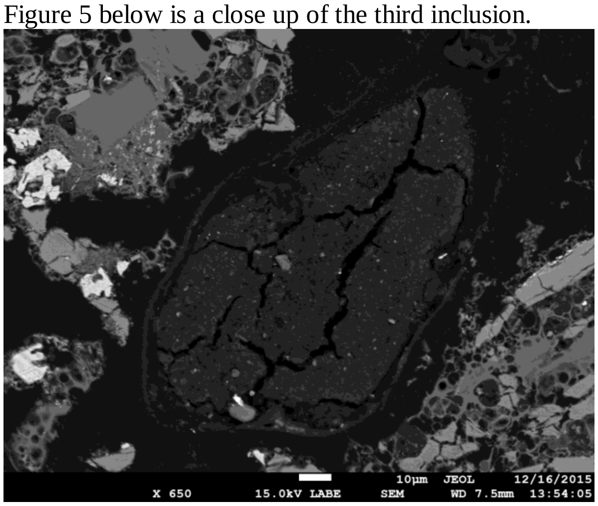

Figure 5. The third of three inclusions of unshocked soil seen across the middle of Figure 4. Note "halo" of melt here, and similar textures from center to top center of Figure 4.

Putative impact glass has been detected using VNIR data of glass produced in a laboratory [3]. This raises questions as to the nature of the impact glass, which could be any of the shock Classes [1] up to complete impact melts (aka Class 5 [1]). Generally, in the terrestrial impact cratering record, uplifted central peaks are composed of impactites created at lower shock pressures such as shatter cones (2-20 GPa; at Sierra Madera) or maskelynite (20-40 GPa; at Manicouagan). Whereas feldspars do not have spectral features in the VNIR region, the occurrence of feldspars in these central peak outcrops might indicate if these are Class 5 basaltic impact melts mixed with fractured basalts (as [3] detects clinopyroxene and olivine with the basaltic glass) or Class 2 maskelynite-bearing basalts. The presence of glass in Martian central peaks might indicate a material with more volatiles and a lower yield strength such as paleo-soil or a baked zone being exposed.

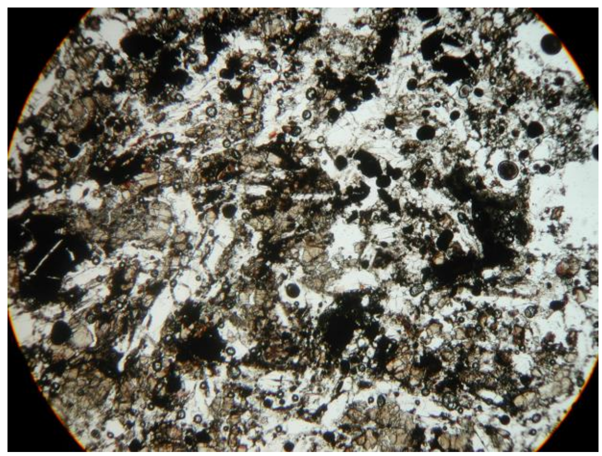

Figure 6. Petrographic image in plain-polarized light showing a few glassy needles (former labradorite that is now Class 2 maskelynite) amidst pockets of flowing labradorite glass (aka Class 3) under 5X magnification. Cross-polarized light (not shown here) shows that the glasses are isotropic. Vesicles can be seen on this thin section that should trap the volatiles during the impact event.

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References: [1] Kieffer et al. (1976) *LPSC*, 1391-1412 [2] Wright (2016), "Shocked Soil: A rare impactite", *GRL*, submitted [3] Cannon and Mustard (2015) , *Geology, 43*, pp. 635-638 [4] Maloof et al., *GSA Bulletin, 122*, pp.109-126