MICRO-FTIR AND MICRO-RAMAN SPECTROSCOPY OF A SHOCKED BASALT FROM THE LONAR CRATER, INDIA.

S. J. Jaret[1], T. D. Glotch[1], and S. P. Wright[2] [1]Department of Geosciences, Stony Brook University, [2]Department of Geology and Geography, Auburn University, steven.jaret@stonybrook.edu

Introduction: During impact events, extreme pressure, temperature, and strain rates casuse irreversible damage to target materials. The collective progression of changes ("shock metamorphism") is most well studied in tectosilicates, specifically quartz and feldspar. As several extra-terrestrial planetary surfaces have large basaltic provinces, shock effects in plagioclase feldspars are of particular interest.

Shocked plagioclase is classified into 5 stages, according optical petrographic characteristics (Table 1). Spectral studies of shocked plagioclase (Raman, [1]; IR, [2-4]]) have shown that deformation to the crystal lattice due to shock is refected in the spectra. Specifically, increasing shock pressure correlates with shifts in characteristic peak positions and peak broadening.

Table 1. Petrographic Classes of Shocked Basalt

Class	Petrographic Indicator	Estimated Shock Pressure (GPa)
0	No optical deformation to plagioclase or pyroxenes	<10
1	Plagioclase is fractured and shows minor undulatory extniction	10 - 20
2	Plagioclase is transformed to maskelynite. Grains range from partially isotropic to completely isotropic.	20 - 40
3	Plagioclase is converted to thermal glass. Flow textures are present	40-60
4	Plagiocalse is converted to vessicular glass. Pyroxene grains are fractured and granulated.	60-80
5	Whole rock melt and vaporization	> 80

From [5-6]

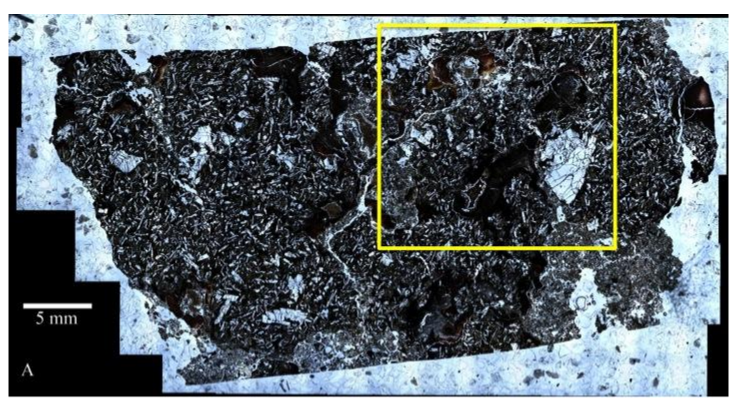
For this study, 14 probe-ready polished thin sections of Lonar basalts and 1 section from non-Lonar Deccan basalt (AJ-101) were obtained [7]. Of this sample set, one Class 2 basalt (LC-09-253) was selected for a comparison of optical microscopy, micro-Raman, and micro-FTIR spectroscopy.

Methods: Optical microscopy was conducted using a standard Olympus petrographic microcope. Within this thin section, 13 individual grains were selected for spectral analysis. Micro-FTIR spectra were collected with a Nicolet iN10MX FTIR microscope, equipped with a liquid nitrogen-cooled MCT array detector capable of acquiring images between 715 and 7000 cm^{-1}. Micro-Raman spectra were collected on a WiTec alpha300R confocal imaging system equipped with 532 nm Nd YAG laser with 50 mW nominal power at the sample surface. Each spectrum was acquired through a 50X (0.85 NA) objective, and consisted of 50 acqusitions each with a 2 second integration time.

Sample Description: LC-09-253 was collected from an outcrop of heavily altered melt-bearing breccia among the lowest pre-impact basalt flows [8]. Only basalt clasts (no melt) were considered for this study. The clasts are dominated by 100-300 μm laths of labradorite, <200 μm augite, hematite, and nanophase iron oxides. Minor minerals include zeolite and coesite.

Optical Characteristics: Optically, LC-09-253 is a Class 2 basalt (Figure 1). Under cross-polarized light, labradorite remains at extinction through full rotation of the microscope stage. The grains retain original grain boundaries, are only minorly cracked, and show no textural evidence of flow. All 13 grains are optically identical, each exhibiting characteristics of maskelynite.

Micro-FTIR results: Ten of the 13 grains selected for detailed study appear amorphous with 1 broad peak spanning from 798 to 1226 cm^{-1}, centered at 982 cm^{-1}, and a CF position of 1245 cm^{-1}. The other 3 gains, appear to retain some crystallinity as indicated by peaks at 966 cm^{-1} and 1077 cm^{-1}. For comparison, the labradorite in the non-Lonar Deccan basalt shows 2 narrow peaks, centered at 1122 and 1003 cm^{-1}. The position of the Christiansen feature is at 1262 cm^{-1} (Figure 2).



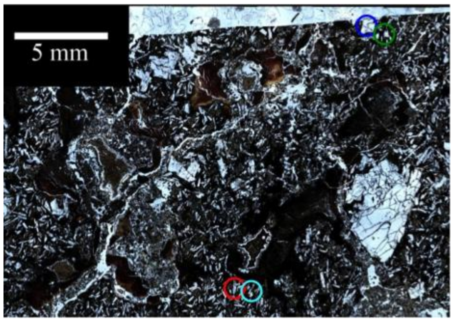


Figure 1: A) Plane-polarized light mosaic of section LC-09-253. B) Region of LC-09-253 showing the locations of selected grains. Colors denote grains, where D=blue, E=green, H=red, and I=teal.

Micro-Raman results: Unshocked Deccan labradorite shows narrow characteristic peaks at 173, 281, 504, and a broad peak centered at 1039 cm^{-1}, providing a high quality match to a standard labradorite in the CrystalSleuth library database [9]. All 13 grains from sample LC-09-253 studied in detail show only 2 broad peaks, centered at 496 and 1010 cm^{-1}. None show the strong 504 peak seen in unshocked labradorite (Figure 3). Two of the grains ("E" and "H") show slightly higher spectral contrast than the others, with peak intensity / floursecent background ratios (I_{496} / FB) of 1.22, compared to 1.15 for the other amorphous grains. Unshocked labradorite, on the other hand, has an I_{496} / FB of 2.96.

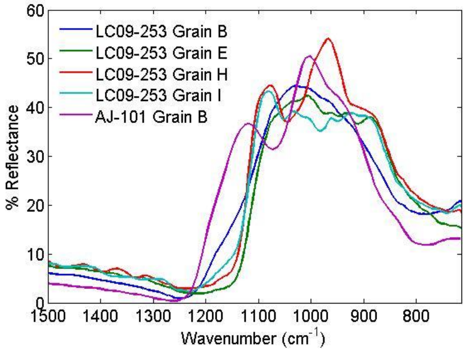


Figure 2: Micro-FTIR spectra of selected grains. D is a representative spectrum of the majority of the grains. One borad peak centered at 982 is typical of maskelynite. E, H, and I are grains which appear slighytly more crystalline. For reference, unaffected labroadorite is also plotted (AJ-101 grain B)

Discussion: Within a sample that is optically similar (e.g., Class 2, all feldspar grains are complety isotropic) individual differences in crystallinity of grains can be detected spectrally. Specifically, the micro-FTIR spectrum of grain "H" is similar to unshocked labradorite. Peak positions, however, are slightly shifted towards lower wavenumbers, suggesting a minor degree of disordering. Shifts in peak position can occur due to the orientation of the grain, but such shifts are generally smaller than what is observed here.

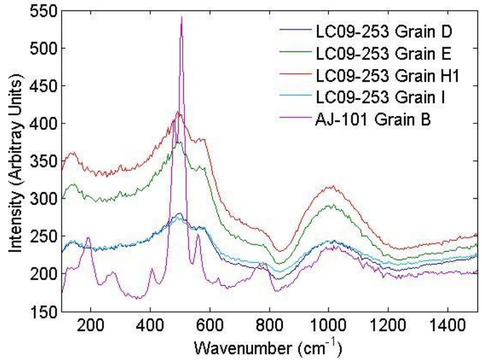


Figure 3. Raman spectra of selected grains. Note that grain I, which had a microFTIR spectra suggesting it is slightly crystalline, appears amorphouse with Raman.

Micro-Raman data is consistent with previously analyzed maskelynite [10]. The coalescence of narrow labradorite peaks into broad peaks centered 496 cm^{-1} is consistent with shock pressures of approximetaly 40 GPa [10]. Similarlly, I_{496} / FB values of 1.15 is consistent with maskelynite measured in meteorites.

Spatially, the two of the crystalline grains are located near a large fracture adjacent to the coesite, suggesting the variation in shock level within this sample is due to heterogeneity in the shock process and/or target properties, as these rocks were heavily altered prior to shock.

Conclusions: In samples that are all optically isotropic, micro-Raman and micro-FTIR techniques reveal differeing degrees of crystallinity. This is more pronounced in micro-FTIR data. While 10 of the 13 grains appear amorphous in micro-FTIR data, 11 appear amorphous in micro-Raman data. Additionally, differenes in micro-Raman spectra are defined by changes in spectral contrast and peak intesnity, whereas with micro-FTIR analysis, more crystalline grains retain characteristic peaks.

References: [1] Velde and Boyer (1985), JGR, 90, 3675-3682; [2] Ostertag (1983), JGR, 88, B364-376; [3] Johnson et al. (2002), JGR, 107 E10, 5073; [4] Johnson et al. (2003), Am Min. 88, 1575-1582; [5] Stöffler (1971), JGR, 76, 5541-5551; [6] Kieffer et al. (1976), Lunar Sci Conf., 1391-1412. [7] Wright et al. (2011), JGR, 116 E09006; [8] Wright (2012). LPSC abstract 1659; [9] Downs R T (2006)Program and Abstracts of the Int. Min. Ass. [10] Fritz et al. (2005), Ant. Met. Res. 18, 96-116;