A MICRO-SPECTROSCOPIC COMPARISON OF EXPERIMENTALLY SHOCKED BASALTS.

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Introduction: As part of an ongoing infrared and Raman micro-spectroscopy study to characterize and assess shock effects in plagioclase [1-3] we are currently focusing on plagioclase in experimentally shocked basalts. Plagioclase is a major mineral on the surfaces of planetary bodies such as Mars, the Moon, and asteroids. These objects are heavily cratered and both remote sensing studies and future sample return missions will undoubtedly encounter shocked rocks. Therefore, it is critical that we understand how shock affects the whole rock spectra so that we can correctly interpret spectra of planetary surfaces [4-7].

In plagioclase, the major effect of shock metamorphism is the transition to diaplectic glass (also referred to as "maskelynite") which occurs at approximately 28-30 GPa. However, this transition is complex; exact transformation pressures decrease with increased Ca content, increased temperature, or increased strain rate [8-11].

The majority of studies using experimentally shocked samples have focused on single crystals or mineralogically pure samples [5-8]. Relatively few studies [10,14] have considered polymineralic rock samples as starting materials.

While pure samples or single crystals are necessary starting points for understanding shock effects, there are some potentially important differences between pure sample and naturally shocked rocks that may complicate interpretations of planetary surfaces. Shock effects are orientation dependent, and the amorphization transformation conditions may be biased if only a single orientation is considered

Secondly, shock effects in a particular mineral grain are also affected by crystal structure and density. Thus, the shockwave velocity can change as it passes between minerals of different densities [12].

Samples and Methods: We have analyzed experimentally shocked basalts from two locations in Arizona: a basalt from Grand Falls and a basaltic andesite from SP Flow. Samples were experimentally shocked at the NASA Flat Plate Accelerator (Johnson et al. 2007) to pressures between 17 and 63 GPa. Both are fine-grained basalts dominated by plagioclase (~An_{45}), pyroxene, and up to 10% olivine phenocrysts. Grand Falls is slightly coarser grained with plagioclase phenocrysts up to 350 µm. The SP flow samples are cryptocrystalline and contain ~30% volcanic glass in the unshocked material, compared to ~10% in Grand Falls samples (Fig. 1).

All spectra were collected in the Center for Planetary Exploration at Stony Brook University. Micro-FTIR 2D maps were acquired using a Nicolet iN10MX FTIR microscope, equipped with a liquid nitrogen-cooled HgCdTe (MCT) detector, generating hyperspectral image cubes between 7000 and 715 cm^{-1} (1.4-14.0 µm) at 25 µm/pixel and 8 cm^{-1} spectral sampling. Spectra were normalized to 100% maximum reflectance for ease of comparison.

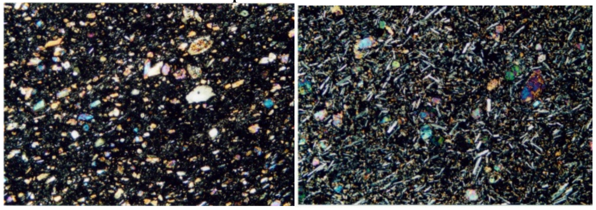

Fig 1. Cross-polar thin sections of Grand Falls (left) and SP Flow (right) samples. Field of view is 2.6 mm.

Micro-Raman spectra were acquired using a WiTec alpha300R confocal imaging system equipped with 532 nm Nd YAG laser with 2.24 mW nominal power at the sample surface, and a 50X (NA=0.8) objective (spot size of 763 nm). 2D maps were collected using an integration time of 0.5 sec.

Results: Plagioclase in the shocked SP basalt becomes dominantly amorphous by 17 GPa, as indicated by micro-FTIR spectra having only one broad peak centered near 1010 cm^{-1}. The shocked Grand Falls sample, however, remains crystalline beyond 24 GPa, and the micro-FTIR spectra show weak features near 1090 and 1140 cm^{-1} (Figure 2). The Grand Galls sample shocked to 17 GPa show a slightly broadened Raman peak at 512 Δcm^{-1} and a weak peak at 484 Δcm^{-1} consistent with partially disordered crystal lattice in plagioclase (Figure 3).

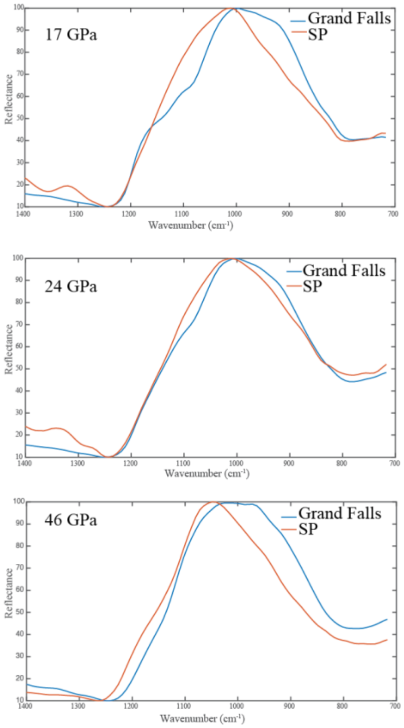

Figure 2: Preliminary micro-FTIR spectra of the Grand Galls and SP plagioclase shocked to 17, 24, and 46 GPa. At 17 GPa, the Grand Falls sample shows weak but characteristic spectral features of plagioclase, whereas SP exhibits only one peak indicative of a dominantly amorphous material. There is also an offset in position of the primary peak between these two samples, but this is likely due to either difference in orientation of the individual grains being measured or slight differences in plagioclase composition between the two basaltic samples.

Discussion: The SP Flow and Grand Falls basalts do not appear to behave similarly under comparable shock conditions. At both 17 and 24 GPa, Grand Falls plagioclase retains some crystallinity, whereas SP plagioclase is amorphous at these same pressures. The amorphous plagioclase in the SP sample at 17 GP is surprising and lower than other reports of shocked basalt and pure plagioclase samples. This difference could be due to grain size, starting composition, or porosity. The SP sample is significantly finer grained than the Grand Falls sample. Smaller grains therefore may be more easily deformed during shock. The SP sample also contains a significant amount of volcanic glass prior to shock. Perhaps the additional glass phase changes the shock impedance allowing for the plagioclase to be more readily transformed. Porosity is also known to cause lower amorphization pressures in basalts [14].

Ongoing micro-FTIR and Raman work will compare higher pressures from each sample.

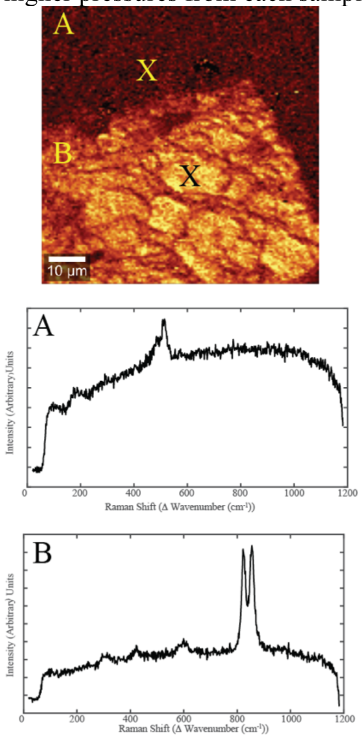

Figure 3: Micro-Raman map and spectra of a the Grand Falls sample shocked to 17 GPa. Spectra for both phases A and B were extracted from the locations X. The color map is displaying intensity (yellow = higher intensity) of the primary olivine peak at 856 Δcm^{-1}. Plagioclase (spectrum and position A) is crystalline, but disordered compared to an unshocked andesine, as noted by the shoulder at 484 cm^{-1} rather than a discreet peak and an overall low peak intensity relative to the fluorescent background. Olivine (spectrum B) appears unaffected by the shock event at 17 GPa.

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