MICRO-THERMAL INFRARED IMAGING SPECTROSCOPY OF EXPERIMENTALLY SHOCKED PLAGIOCLASE FEDLSPARS.

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Introduction: During the impact process, pressures at the front of a propagating shock wave can vary greatly at microscopic scales within an individual grain, among nearby grains, or along grain boundaries. To examine the spectral effects of shock pressures at microscopic scales we acquired micro-hyperspectral thermal infrared images on thin sections of experimentally shocked (~16 to ~56 GPa) bytownite (An_{79}), andesine (An_{36-46}), and albite (An_{02}). Our previous macroscopic work [1-3] on these samples demonstrated significant spectral changes with increasing pressure, specifically a loss of features associated with Si-O stretch and bending vibrations in silica tetrahedra during the pressure-induced transition to amorphous glass. At the highest shock pressures feldspars lost all but two major spectral features, a deep band near 440-460 cm-1 (caused by bending vibrations in the Si-O-Al structures) and broad Si-O stretch bands that varied from ~960 cm^{-1} (bytownite) to ~1010 cm^{-1} (andesine), to ~1040 cm^{-1} (albite).

Methods: Samples were shocked at the Johnson Space Center's Flat Plate Accelerator [1], from which relatively large chips (2-10 mm) were recovered at 10-13 pressure intervals from ~16-56 GPa. We acquired micro-Fourier Transform Infrared (FTIR) biconical reflectance on thin sections of the shocked and unshocked samples using a Nicolet iN10MX FTIR microscope equipped with a liquid nitrogen-cooled MCT array detector capable of acquiring 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. We also acquired point spectra of 50-400 µm/pixel spots on the thin sections using both MCT and DTGS point detectors (4000 and 400 cm^{-1}) (not shown here).

Results: Figure 1 shows unshocked (0 GPa) and 56 GPa image products for each of the three plagioclase samples. False-color images and band depth maps at specific frequencies demonstrate that the unshocked albite sample is relatively homogeneous compared to the andesine and bytownite samples. At 56 GPa bytownite still exhibits some residual heterogeneity, although the other two are quite homogeneous, suggesting evenly distributed peak shock pressures at microscopic scales. The numbered white ovals on the false-color images in Fig.1 denote the areas from which spectra were extracted (Figure 2).

Unshocked spectra (0 GPa). The unshocked albite spectra show some variability in reflectance peaks between 1150-1200 cm^{-1} and in absorption bands between 1070-1130 cm^{-1} (Figure 2). This may be caused by crystal orientation effects related to the Si–O antisymmetric stretch motions. However, the peak positions from 1000-1050 cm^{-1} are more consistent. Similarly, unshocked andesine spectra show variations in the 1070-1200 cm^{-1} region, compared to more consistent features near ~1000 cm^{-1}. The heterogeneity of the unshocked bytownite sample is evidenced by the large variation in spectra of different units. Areas 3 and 4 (Orange and Dark Green areas in false color images, respectively) comprise the majority of the sample. Spectral unmixing models suggest that these areas represent mixtures of different types of plagioclase. For comparison, the 1 (Red) areas are a mixture of quartz and plagioclase, the 2 (lighter Green) areas include amphibole, and other regions include pyroxenes. This is all consistent with the petrography of the original Stillwater Complex bytownite sample [1,5].

Shocked spectra (56 GPa). Peak reflectance positions vary in the 56 GPa samples from ~958 cm^{-1} in bytownite to ~1020 cm^{-1} in andesine to ~1041 cm^{-1} in albite. These positions and variance with Ca content are consistent with earlier studies [1-3], and result from the greater number of weaker Al–O bonds compared to Si–O bonds in bytownite relative to andesine and albite [4]. The lack of complete homogeneity in the 56 GPa bytownite sample results from its greater original complexity compared to the other samples. We note the spectrum 2 in the 56 GPa bytownite sample is similar to the area 2 (lighter Green) unshocked spectrum, and both are modeled using amphiboles.

Future work. Raman spectra collected of these samples [6] are being compared to ongoing static pressure experiments using diamond anvil cells [7]. Similar thermal infrared and Raman analyses are underway for experimentally shocked basaltic samples [8] and naturally shocked samples from Lonar and Ries craters.

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References: [1] Johnson et al., 2002. JGR 107(E10) 5073; [2] Johnson et al., 2003. Am. Min., 88, 1575-1582; [3] Johnson, 2012. Icarus 221 359–364; [4] Fritz, J. et al., LPSC 42, abs. #1196, 2011; [5] Haskin, L., and Salpas, P, Geochim. Cosmochim. Acta, 56, 1187– 1212, 1992; [6] Jaret et al., LPSC, #2056, 2015; #1530, 2016; [7] Jaret et al., GSA abstract, 267947, 2015; [8] Johnson et al., *American Mineralogist*, 92, 1148-1157, 2007.

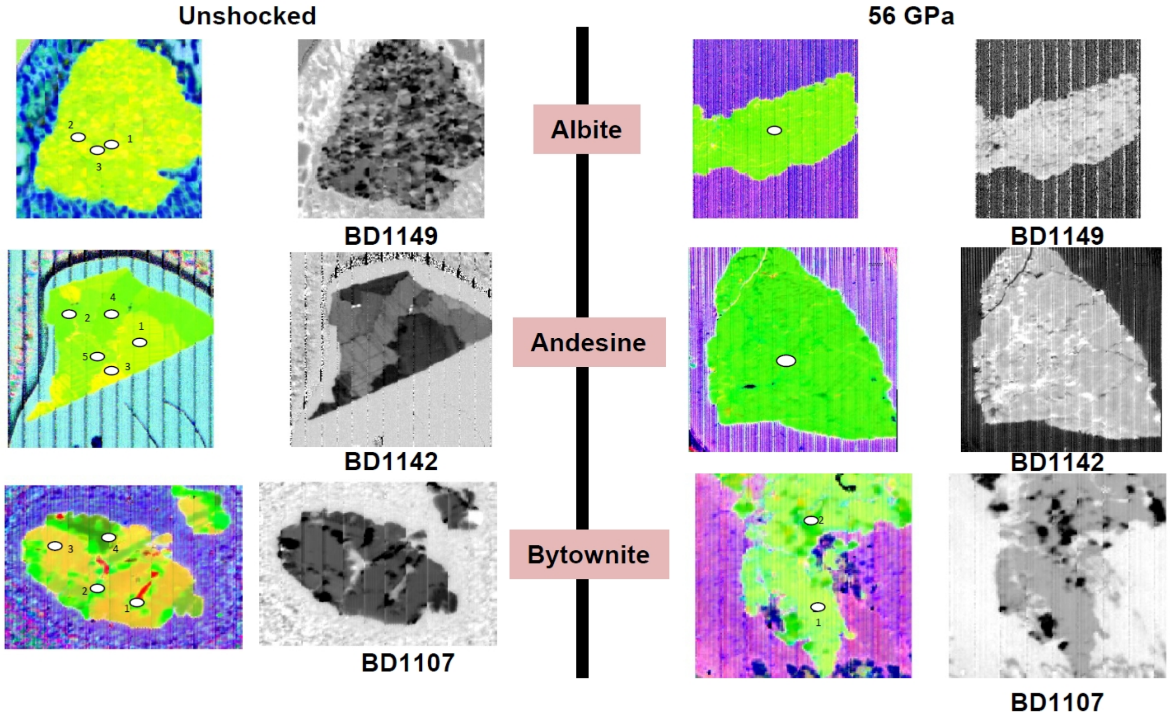
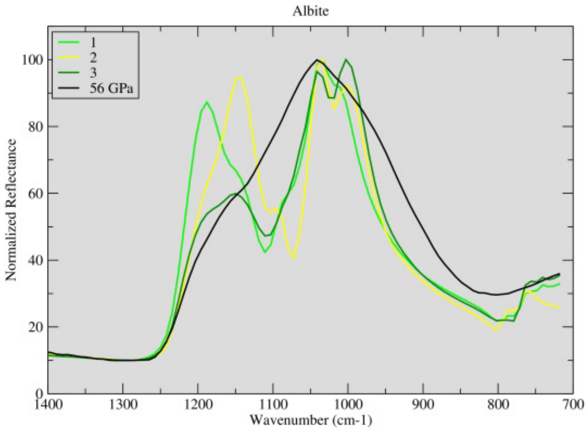
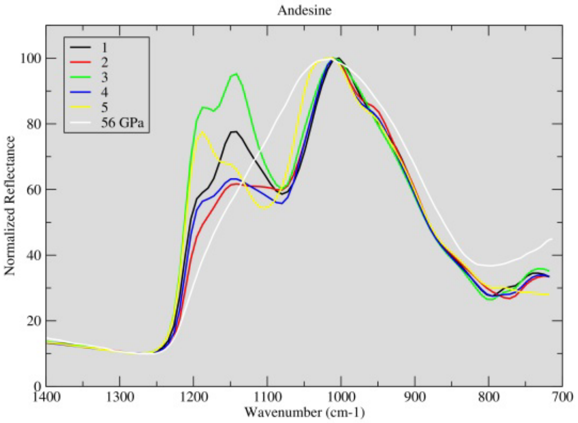


Figure 1. Spectral parameter maps for the three plagioclase samples at unshocked and 56 GPa shock pressure. False-color RGB images in 1st and 3rd column (albite: 1149, 1034, 802 cm^{-1}; andesine: 1142, 1011, 802 cm^{-1}; bytownite: 1107, 964, 752 cm^{-1}). Band depth (BD) maps at designated wavenumber in 2nd and 4th columns.





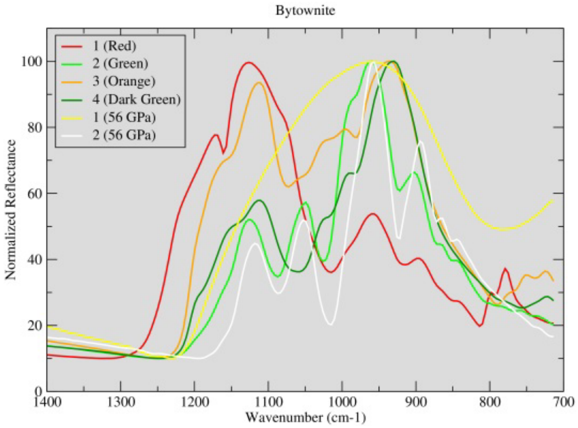


Figure 2. Spectra extracted from unshocked (0 GPa) and 56 GPa samples. Numbers in legends correspond to numbered white ovals in Figure 1. All spectra normalized to 100% at maximum reflectance wavelength.