

CHARACTERIZING PLAGIOCLASE FOR LUNAR ANALOGUE SHOCK EXPERIMENTS. K. A. Shirley¹, S. J. Jaret², K. L. Donaldson Hanna³, C. J. Cline⁴, M. Cintala⁴, K. D. Burgess⁵, M E Gemma⁶, ¹University of Oxford, Oxford UK, (katherine.shirley@physics.ox.ac.uk), ²Kingsborough Community College, City University of New York, NY, USA. ³University of Central Florida, Orlando, FL, USA, ⁴NASA JSC, Houston, TX, USA, ⁵U.S. Naval Research Laboratory, Washington, D.C., USA, ⁶Stony Brook University, Stony Brook, NY, USA.

Introduction: The lunar landscape has been completely transformed due to space weathering, encompassing both irradiation and impacts. It can be difficult to disentangle these comingled processes, however, understanding the contribution from impacts is important throughout the Solar System. The effect of impacts has been studied in several cases [e.g. 1,2], but they have not fully characterized the effects of shock on both the VNIR and MIR on highly calcic plagioclase. Here we will examine the effects of shock on an anorthosite sample from the Stillwater Igneous Complex (Montana, USA), often used as a lunar analogue.

To specifically investigate the effects of impacts, we will carry out a series of shock experiments on both rock slices and powdered samples. We will characterize the anorthosite slices and powders before and after shock experiments to see how spectral features are affected with increasing degrees of shock. While we will be unable to reconstruct the original position and orientations of the pre-shock sample mineralogy, we will be able to compare each sample to its pre-shock counterpart. These in-depth analyses will allow us to draw general information about the transformations undergone during shock in a true rock sample with multiple crystals with boundaries and various orientations as we would expect in a lunar rock.

In this abstract we will outline our pre-shock analysis of the samples to show the amount of variability within the mineralogy of each sample, and the variability within the spectra for the same minerals.

Methods: The Stillwater Complex, Montana, anorthosite is a medium grained (~2-6 mm) anorthosite comprised of highly calcic plagioclase grains (An₉₂) [3,4]. Samples were cut into circular slices roughly 4 mm in radius and ~1 mm thick to comply with the experimental set-up. The powders are roughly on the order of 30 µm particle size.

The slices were imaged using Back Scatter Electron (BSE; Fig1a) as well as under visible and infrared microscopy. Infrared microscopy on the slices was carried out using a Bruker Vertex v70 spectrometer connected to a Hyperion 2000 microscope at the Planetary Spectroscopy Facility at University of Oxford. Images were taken through a 15x Schwartzchild Objective using a cooled MCT detector with wide-range beamsplitter and calibrated to the internal gold standard to measure over 0.8-25 µm at 4 cm⁻¹ resolution. Spectral maps of 8x8 grids were

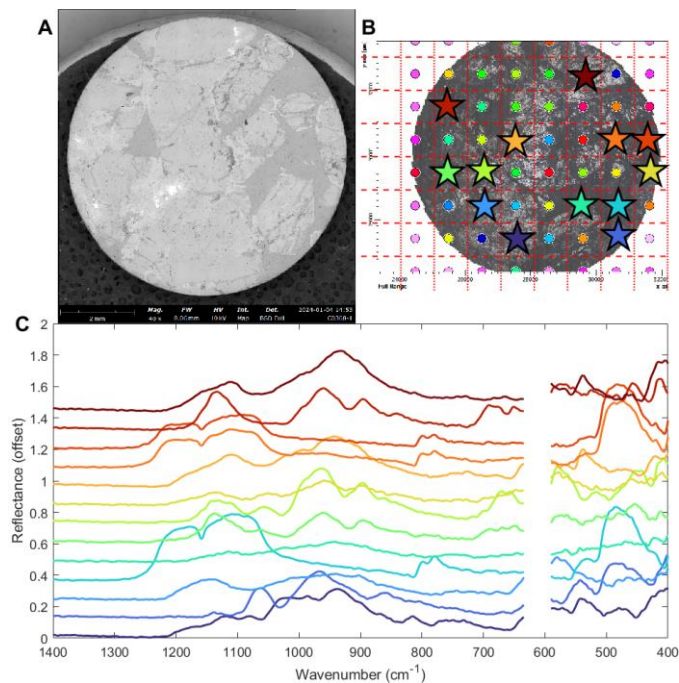


Figure 1. BSE (A) of slice, Visible image with map of IR spectral sampling spots (B, circles show all sampling spots, stars correlate to spectra color), and a sampling of the spectral variation in the mid-infrared seen in this slice (C). Spectra show evidence of quartz, anorthite and pyroxene with variations possibly due to mixing within spot size or mineral orientation.

measured over each side of the slice to capture mineral variation within the sample.

The powders were measured within the sample compartment of the same Bruker spectrometer in a diffuse reflectance set-up. To cover the same wavelength range, we used an InGaAs detector with a Quartz/VIS beamsplitter for the near-infrared and a RT-DLaTGS detector and wide-range beamsplitter for the mid-infrared, both calibrated to a diffuse gold standard. Samples were poured into the sample cups, but not compressed. They were measured 3 times and turned between measurements to capture any spectral variation with orientation of the sample cup.

Additionally, there is a 1.4 µm feature within the samples that is associated with water. To determine its effect, the powdered samples were heated over a period (1 day and 2 months) at 110 °C, but no changes to this feature were observed (Fig2). It is therefore likely that this is a feature inherent to its

formation conditions. A similar feature was noted to change with levels of shock in experiments on albite [5] and will have to be accounted for when treating the sample as a lunar analogue.

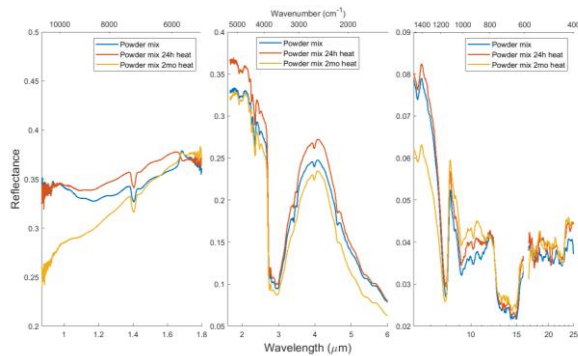


Figure 2. Powdered samples measured after heating for up to two months. Note little change in spectra.

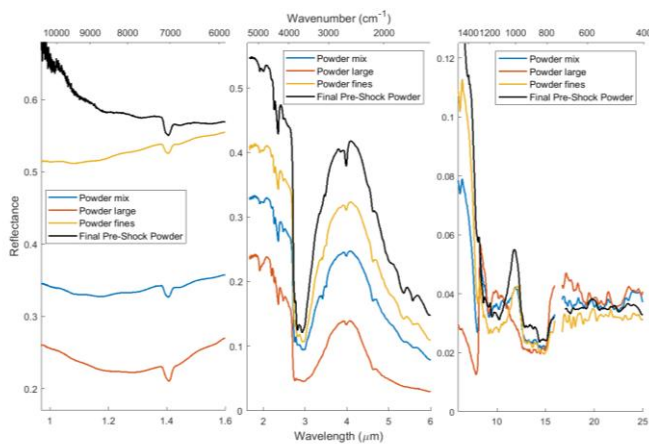


Figure 3. Powdered spectra comparing the effect of particle size.

Results: The slices were all taken from the same starting section, and yet they each have their own unique mineralogy. The Stillwater anorthosite is comprised mostly of anorthite (~92%), the rest includes amphibole, interstitial glass, and minor alteration phases, so we did not expect to see so much of these non-plagioclase phases in our samples. While anorthite is the major phase, we identify quartz, pyroxene, and likely iron sulphide within the slices (Fig1). We also see a lot of spectral variability due to mineral orientation. Analysis is ongoing to attempt to quantify the mineralogy from the BSE imagery as compared to the variation measured by the infrared maps.

The powders show less spectral variation, ~2.5% between all samples overall decreasing to ~1% from 6-25 μm , and a strong overall anorthite signature (Fig 3). In our analysis of the effects of heating, we also noted the effect of particle size and the resulting changes to transparency features, most obvious in the peak near 12 μm increasing with decreasing particle size, the prepared pre-shock sample being the

finest (Fig 3). While the final powdered samples to be shocked will be of uniform size, the resulting post-shock samples will likely be a range of sizes, so attention to these features will be important, as well as grinding the post shock materials to their starting particle size fraction.

Summary: This careful characterization of the variations in our samples prior to subjecting them to shock experiments will provide an excellent basis for correlating any shock-induced spectral changes. While this effort will likely not support one-to-one comparison of grains/particulates, we are confident we will be able to identify changes as a function of shock level by comparing the pre-shock and post-shock versions of each sample. We have also remarked on the variability between samples from the same rock, and will tailor our experiments to minimize the effects due to properties like grain boundaries at critical pressures.

These analyses will help disentangle the effects of space weathering due to shock versus those due to irradiation, and allow better interpretation of remote sensing data like that from M3, Diviner, and Lunar Trailblazer.

References: [1] Johnson et al., (2002) *JGR* 107, 5037 [2] Pernet-Fisher et al., (2016) *Sci Reports* 7 [3] McCallum, I. S., Raedeke, I. D., & Mathez, E. A. (1980) *AJS* 280A, 59-87 [4] Czamanske, M. L. & Zientek, G. K., (1985) *Montana Bureau of Mines and Geology Special Publication* 92 [5] Johnson & Horz, (2003) *JGR-Planets*.