
Introduction: Minerals subjected to high shock pressures exhibit structural changes with increasing pressure (e.g., fractures, deformations, formation of diaplectic glass, and complete melting [1-6]). Petrologic and thermal infrared spectroscopic studies have shown that diaplectic glass (maskelynite) formation in feldspars occurs between ~25-45 GPa, while significant melting occurs above ~45 GPa [7-12]. Past studies of visible/near-infrared spectra of shocked plagioclase feldspars demonstrated few variations in spectral features with pressure except for a decrease in the absorption feature near 1250 nm and an overall decrease in albedo [13-17]. We report new visible/near-infrared spectra of albitite- and anorthite-rich rocks experimentally shocked from 17-56 GPa.

Methods. We used polycrystalline and essentially monomineralic rocks in this work to avoid possible bias of crystal-lattice orientation relative to the propagating shock on the type and degree of shock deformation. This required target rocks of millimeter-sized crystals of random orientations. Two samples that fulfilled these criteria were an anorthosite (80-90% An₃₀-₃₅; 10-15% clays/clinozoisite [20]) from the Stillwater Complex [18], and an albitite (97-99% Ab₉₈) from Szklary (Lower Silesia), Poland [19]. The shock recovery experiments were performed at the Johnson Space Center using a powder propellant gun and provided peak pressures from 17-56 GPa for both samples [e.g., 18]. For each experiment both centimeter-sized chips and finer-grained particles were recovered. Large chips were separated and the remaining particulates were ground to a powder with relatively constant grain size (~20-30 µm) [18]. Bidirectional reflectance (320-2550 nm) of the powders was acquired at a standard observing geometry (i=30, e=0) by the RELAB facility.

Results. Figures 1 and 2 show the anorthosite and albitite spectra, plotted with and without offsets. The anorthosite spectra show differences in the strengths of the broad absorption band at 1250 nm (Fe²⁺ in feldspars) and an absorption longward of 1000 nm (Fe³⁺ in clays or clinozoisite). A band near 2370 nm shallows with increasing pressure and is associated with Al-OH bonds in clinozoisite and/or Mg-OH bonds in clays. Overall, the 1250 nm band is only apparent at pressures below 23 GPa and the 1000 nm band is more prevalent at higher pressures. However, compositional differences among the sample splits [20-21] may contribute to these observed spectral variations.

The albitite spectra show mainly water- and OH-related features near 1400 and 1900 nm that first shallow and then disappear at the highest shock pressures. No bands at 1250 nm are observed, which is indicative of a low iron content in this sample. Electron microprobe measurements of these samples [20-21] indeed show that the anorthosite contains < 0.5 wt% FeO and the albite contains < 0.1 wt% FeO.

The sample reflectances decrease overall with pressure, which was noted by [13] but considered by [15] to be due in part to the contamination of Fe from the sample holders used in the shock experiments. However, little variation in Fe content with shock pressure is observed in these samples [20-21]. We also observe reflectance increases between 20-25 GPa in the anorthosite and between 27-35 GPa in the albitite, followed by a continued decrease in reflectance in both samples. Figure 3 demonstrates this for an arbitrary high-reflectance wavelength (1700 nm), although similar trends are observed for the average spectral reflectance. The pressures at which these increases in reflectance occur coincide with the general onset of diaplectic glass formation in each feldspar. Thermal infrared spectra of these samples demonstrate that this onset occurs at lower pressures in anorthite than albrite [e.g., 10,22]. Other studies of shocked feldspars also documented increases in reflectance at intermediate pressures followed by decreased reflectance [13,17].

Conclusions. Variations in absorption band strengths related to water and OH-bonds of experimentally shocked plagioclase feldspars are correlated with pressure levels. Observed band variations at 1000 nm (Fe³⁺) and 1250 nm (Fe²⁺) in anorthites may be related more to compositional differences among samples. Changes in reflectance appear to be non-linear, with overall reflectance decreases interrupted by increases coinciding with the presence of diaplectic glass. Optical observations suggest that below pressures required for maskelynite formation fracturing and mosaicism in feldspars are prevalent, which could provide the internal scattering necessary to decrease reflectance. Conversely, diaplectic glasses have more homogeneous textures that could explain the reflectance increases. Finally, as true melts are generated at higher pressures, the presence of mixed phases and vesicles and may provide internal scatterers capable of resuming decreases in reflectance.

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Figure 1. RELAB spectra of anorthosite shown from unshocked to a peak shock level of 56 GPa; spectra offset in bottom plot.

Figure 2. RELAB spectra of albite shown from unshocked to a peak shock level of 56 GPa; spectra offset in bottom plot.

Figure 3. Comparison of 1700 nm reflectance values as a function of pressures for albite and anorthosite spectra. Linear fits to different portions of the data are used to emphasize the increase in reflectance at different pressures for the two feldspars, near where the onset of diaplectic glass formation occurs.