REVISITING PLAGIOCLASE OPTICAL PROPERTIES FOR LUNAR EXPLORATION. L. C. Cheek[1], C. M. Pieters[1], M. D. Dyar[2], K.A. Milam[3], [1]Dept. of Geological Sciences, Brown University, Providence RI 02912, Leah_Cheek@brown.edu, Carle_Pieters@brown.edu, [2]Department of Astronomy, Mount Holyoke College, 50 College St., South Hadley, MA 01075, mdyar@mtholyoke.edu, [3] Department of Geological Sciences, Ohio University, 316 Clippinger Laboratories, Athens, OH 45701, milamk@ohio.edu.

Introduction: Plagioclase feldspar is the most abundant mineral of the lunar crust, yet the spectral characteristics of plagioclase in the near-infrared remain incompletely understood. Iron-bearing crystalline plagioclase exhibits a broad absorption band at ~1.3 μm due to electronic transitions of Fe^{2+} in a poorly characterized site (Fig.1). Laboratory studies of this feature [1-3] have suggested that its characteristics may be composition-dependent, with band depth varying according to Fe content and band center position varying with %An.

Remote identification of plagioclase feldspar using the near-infrared has proven challenging for several reasons: 1) the diagnostic 1.3 μm plagioclase absorption feature is only present if trace amounts of Fe^{2+} (0.1-0.5%) has been incorporated into the mineral structure, 2) this feature disappears if plagioclase has been shocked above ~25-30 GPa [4, 5], 3) terrestrial feldspars used as laboratory analogs ubiquitously include sub-microscopic-scale oxide exsolution that can only be detected through careful magnetic or Mössbauer studies, 4) feldspars break down easily to form clay minerals in terrestrial environments, but the alteration may initially occur at scales that can only be detected with careful TEM, SEM, or EMPA study, and 5) both olivine and pyroxene have strong absorption bands near 1 μm that dominate the near-infrared spectra. As a result, remote studies of the lunar surface have typically identified areas of pure plagioclase based on spectra that lack a 1 μm Fe^{2+} band and have a high albedo, rather than by direct observation of the diagnostic 1.3 μm plagioclase absorption [6, 7].

However, the newest near-infrared orbital data have sufficient spatial and spectral resolution to permit the unequivocal identification of plagioclase for the first time. The Spectral Profiler of the Japanese SELENE mission recently detected anorthosite in the central peak of Jackson crater and others on the lunar farside [8], and Pieters et al. [9] have identified crystalline plagioclase in various slopes of the Orientale Basin with the Moon Mineralogy Mapper (M^3) of Chandrayaan-1. In order to extract valuable information about the occurrence and composition of plagioclase on the lunar surface using these powerful new datasets, it is necessary to understand various controls on its spectral characteristics.

In this study, we present preliminary laboratory measurements of a diverse suite of terrestrial plagioclase samples. The results highlight the importance of a detailed investigation in order to 1) constrain the compositional controls on spectral features sufficiently to permit accurate modeling of the 1.3 μm band, and 2) address the importance of trace contaminants and mixtures of plagioclase and other components of lunar surface material in remote analyses.
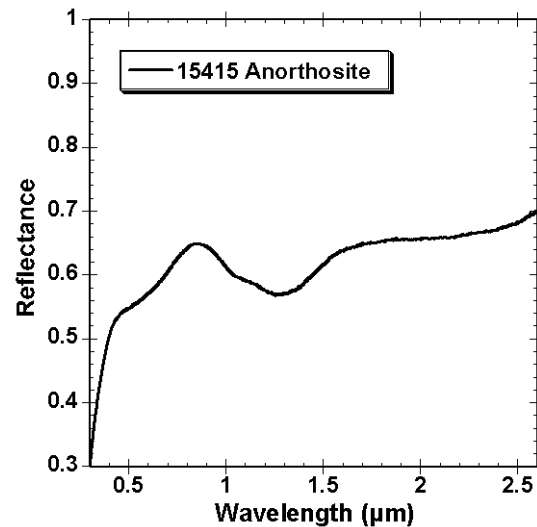

Fig. 1. Laboratory reflectance spectra of lunar anorthosite 15415 (0-500 μm), with diagnostic plagioclase absorption at ~1.3 μm. Trace amounts of other phases may cause weak features at other wavelengths.

Approach: The plagioclase samples studied here originate from various geologic settings, including the Bushveld layered intrusion and several volcanic provinces [10, 11]. Mössbauer and hysteresis data are available for roughly half the samples and work is in progress to characterize the others. The samples were crushed and sieved to 45-125 μm to allow cross-comparisons. Although we manually removed visible contaminants (primarily opaques, pyroxene, and hydrous minerals), some contaminants remain, either as individual grains or inclusions within plagioclase. Spectra were acquired as diffuse reflectance in the near-infrared (0.3-2.6 μm) in the RELAB.

Preliminary Results: Most of the samples analyzed exhibit an absorption band at ~1.3 μm (Fig. 2). The band positions and depths of these features are variable, suggesting different amounts of Fe^{2+} in the crystal structure, variations in %An, and/or contamination by impurities. The presence of minor amounts of hydrated minerals is indicated by the 1.9 μm feature in several of these spectra. Additional clay or carbonate contami-

nants are often observed near 2.2 and 2.3 µm and at longer infrared wavelengths (Fig. 2, 3).
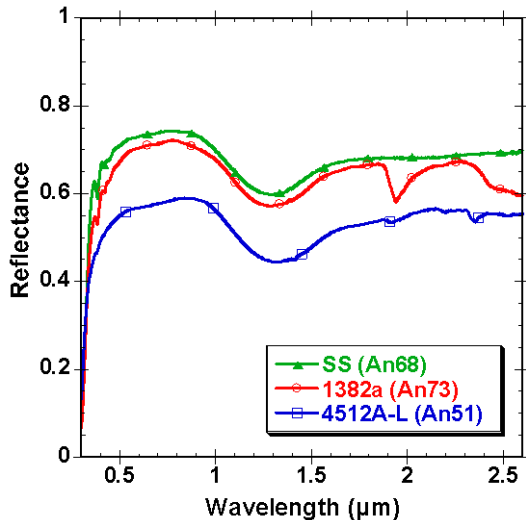

Fig. 2. Laboratory reflectance spectra of plagioclase mineral separates (45-125 µm) with prominent absorption at ~1.3 µm. All three samples are volcanic. Anorthite content shown in labels.
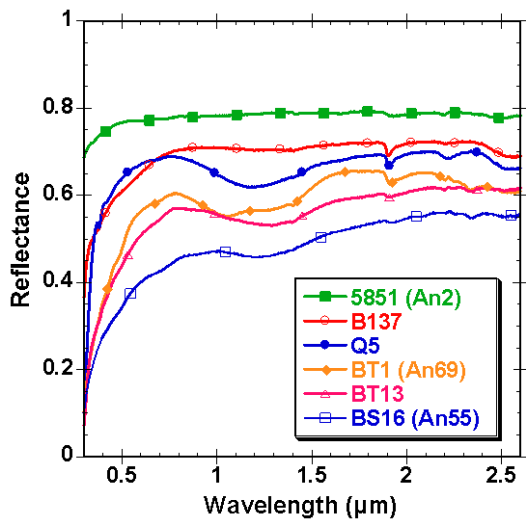

Fig. 3. Laboratory reflectance spectra of plagioclase mineral separates (45-125 µm) with obvious contamination features. Samples 5851 and Q5 are volcanic; BT1, BT13, and BS16 are from the Bushveld intrusion. Measured %An shown in labels.

Plagioclase is normally a relatively transparent mineral and small amounts of absorbing species present as trace amounts of contaminants have a disproportionately strong effect. While most spectra have retained a 1.3 µm band, many also show indications of weathering or the presence of other phases (Fig. 3). The spectrum of BT1 has a feature near 1 µm and an absorption across the visible (also evident in B137, BT13, and BS16) that suggests terrestrial weathering. The spectrum of 5851 (An_2) has a relatively flat slope and shows no absorption features other than a small water band at ~1.9 µm.

The lack of Fe absorption in this sample is consistent with previous observations that the diagnostic plagioclase feature is rare among albites [3], probably because substitution of Fe^{2+} for Ca^{2+} is more easily accommodated in the plagioclase structure than Fe^{2+} for Na^{1+}. The spectrum of Q5 has a steep slope into the UV, similar to that seen in Figure 2. This strong UV absorption (<0.5 µm) is also characteristic of most lunar plagioclase [12].

Future work: In addition to obtaining other pure plagioclase samples, a detailed compositional assessment is required for the samples presented here. Comparisons with the Mössbauer and hysteresis data are needed to confirm previous conclusions [3] that the strength of the 1.3 µm feature is correlated with Fe content of the feldspars rather than Fe in the impurities. Those results will allow us to address the causes of absorptions in BT1 and the red slope of BS16. Better models for the effects of minor absorbing components in a transparent medium are also needed.

Major element chemistry is necessary to constrain the degree to which anorthite content controls the substitution of Fe^{2+} and the resultant position of the plagioclase absorption band. In conjunction with the Mössbauer results, these will enable us to determine the concentration and speciation of iron in the plagioclase structure, and potentially to relate the lack of an iron band in samples 5851 and B137 to their compositions.

Summary: These data provide the beginning of a constrained database for plagioclase spectra, but considerable additional work is needed. A thorough understanding of the compositional controls on plagioclase spectra is essential for remote sensing analyses of the lunar surface, particularly as SELENE's Spectral Profiler and Chandrayaan's M^3 provide new data that resolve a crystalline plagioclase absorption band.

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