ULTRAVIOLET CHARACTERIZATION OF PLAGIOCLASE SERIES SAMPLES AS ANALOGS FOR THE LUNAR SURFACE.

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Introduction: The lunar highlands are dominated by anorthosite, a rock containing >90% Ca-rich plagioclase end member named anorthite. Anorthite has an An# of 90-100, indicating that 90-100% of the cation sites are filled with Ca^{2+} (rather than Na^{2+} or K^{2+}). One particular subset of lunar anorthosites, called ferroan anorthosites (FANs), contains Ca-rich anorthite (An# 94-98) that is also Fe-rich.

Since plagioclase is a major component of many terrestrial bodies, understanding the spectral signature of plagioclase is vital to deconvolving spectra of planetary surfaces. Indeed, plagioclase spectra have been studied extensively in the visible (Vis), near-infrared (NIR), and thermal infrared (TIR) (e.g., [1], [2], [3]). The work of [1] sought to advance upon the work of [2, 3] for lunar applications by studying anorthite from the Miyake-jima volcano in Japan. These samples are derived from anorthite megacrysts that are better analogs to FANs than most other terrestrial anorthosites.

Although the Miyake-jima anorthite was studied extensively in the NIR [1], it has not been previously studied in the ultraviolet. This work will present UV spectra of the Miyaki-jima anorthite as well as a complementary set of plagioclase series that span the full compositional range.

This is all critical for accurately interpreting lunar surface composition but until recently has not been explored at ultraviolet wavelengths in a similar manner to the Vis-NIR. The Lunar Reconnaissance Orbiter (LRO) features two ultraviolet instruments: the Lyman Alpha Mapping Project (LAMP) and the Lunar Reconnaissance Orbiter Camera Wide-Angle Camera (WAC). In order to examine the LRO ultraviolet data sets more effectively, we are collecting UV-NIR spectroscopy measurements as lunar analogs to improve our understanding and interpretation of these LRO data sets.

Methods: Spectra were collected in the APL **L**aboratory for **S**pectroscopy under **P**lanetary **E**nvironmental **C**onditions (**LabSPEC**). Spectra of the standard and sample are collected under high vacuum conditions (10^{-6} to 10^{-7} Torr). UV data were collected using a McPherson monochromator (150-570 nm) using MgF_2 as the calibration standard and a scintillating material in front of a photomultiplier tube attached to chamber. Visible Near Infrared (Vis-NIR) data are collected using a Spectra Vista Corporation (SVC) HR-1024i point spectrometer (350-2500 nm) using MgF_2 as the standard. Mid-infrared (MIR) data are collected with a Bruker Vertex 70 lab FTIR (1.8-8 μm) using diffuse Au used as the standard. Both use a halogen light source with beam splitters (Quartz, KBr) and both spectrometers are mounted outside the chamber at dedicated ports that are 60° from the light source (i = 15°, e = 45°). The SVC and FTIR detectors are mounted on a linear stage that allows us to toggle between the two spectrometers. A full spectrum, from UV (~150 nm) out to MIR (~8 μm) is generated by combining three spectral ranges, scaled to the SVC Vis spectrum. For this work, we are displaying a combined spectrum in the UV to visible portion of the spectrum (150 – 600 nm).

Samples: This study utilizes the UCLA Plagioclase series studied in the TIR previously by [1] and [2]. This series represents a range of plagioclase compositions from An# from 1 to 76 (Table 1) and currently include two particle size splits (<64 um and 64-100 um). The plagioclase also varies in the iron content, from 0 to 0.5 wt.% FeO (Table 1). All spectra included in this presentation are from the <64 um grain size split.

We also include a sample dubbed 'An100', which was derived from anorthitic megacrysts collected from Miyake-jima Volcano in Japan. Related samples were previously characterized by [1] to have An# of 97 (Table 1). The An100 anorthite sample also contains 0.5 wt.% FeO and thus provides an excellent analogue to plagioclase present in lunar ferroan anorthosites (FANs) [1]. This sample was previously separated from surrounding basaltic coatings, crushed, and sieved. Our sample consists of a particle size split of <32 um.

Table 1: Information for available plagioclase samples. (Samples listed in gray have not been studied yet; others colors are coded to Fig. 1.)

Plagioclase End Member (An #)	An# (molar)*	FeO (wt. %)*
Anorthite (90-100)	97	0.5
Bytownite (70-90)	76	0.5
Labradorite (50-70)	62	0.5
Andesine (30-50)	59	0.4
Oligoclase (10-30)	18	0.0
Albite (0-10)	01	0.0

*Compositional information (An# and wt. % FeO) from [3], except for Anorthite from [1].

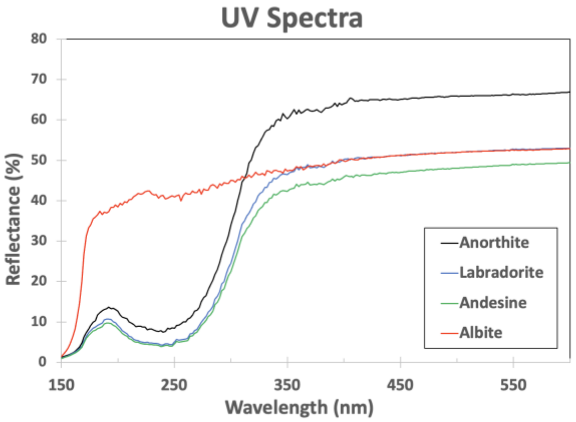

Figure 1: UV Spectra of four plagioclase samples spanning the full range of compositions (An_{97} – An_1).

Results: UV spectra were collected for four of the plagioclase samples representing the full compositional range (Fig. 1), from An_1 to An_{97}. The spectra for albite, andesine and labradorite are very similar for wavelengths >350 nm, with only minor differences in overall reflectance. Anorthite, on the other hand, has much higher reflectance overall in that spectral region, but has very similar shape. Moving into the UV (<350 nm), the albite (An_1) spectrum has fairly flat reflectance well into the near-UV before the reflectance drops off in the far-UV (<200 nm). By contrast, the andesine (An_{59}), labradorite (An_{62}), and anorthite (An_{100}) spectra have steep drops in the near-UV at ~300 nm (Fig. 1).

Discussion: The drop in reflectance in the UV for andesine, labradorite, and anorthite is due to the oxygen-metal charge transfer (OMCT) absorption due to the presence of Fe in these plagioclase samples. This band is extremely sensitive to low abundance of iron in a sample, so even the low abundances of 0.4-0.5 wt.% FeO that are present in the andesine, labradorite, and anorthite samples create a strong OMCT absorption band (Fig. 1). The albite, which contains no FeO, lacks the OMCT band altogether (Fig. 1). We plan to collect additional spectra of oligoclase (An_{18}, 0 wt. % FeO) and bytownite (An_{76}, 0.5% FeO) to confirm these observations.

Despite a large variation in the An number of these samples (from An_{59} to An_{97}), the location of the OMCT band is constant. This suggests that the location of the OMCT does not shift due to variations in the ratios of Ca:Na:K of the plagioclase. Rather, the constant location of the OMCT band is only dependent upon the presence of FeO. In fact, when all spectra are scaled to the same reflectance at 350 nm, the location and depth of this band is very similar (Fig. 2).

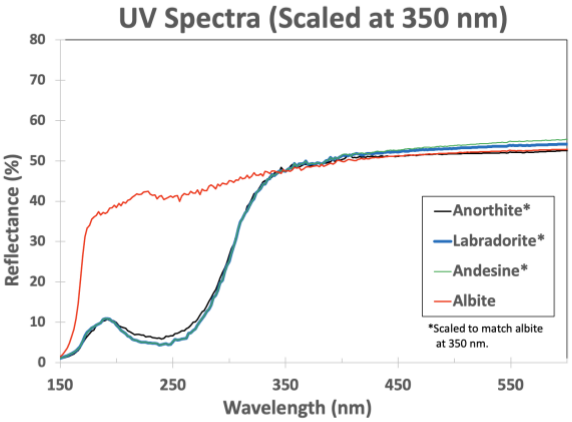

Figure 2: Normalized UV Spectra scaled to match the ~50% reflectance of albite at 350 nm.

Implications: The result of this study demonstrates the sensitivity of the UV to the presence of iron, even at low abundances found in ferroan anorthosites. This may also prove useful for distinguishing ferroan anorthositic rocks from other lithologies. With this information in hand, the UV albedo for the Moon observed in LAMP data (Fig. 3) can be combined with Vis observations to better constrain the compositions present on the Moon.

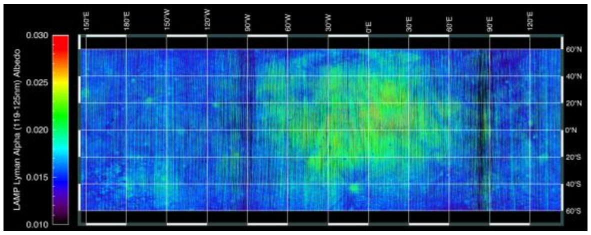

Figure 3: LAMP Lyman-α 121-nm map of the Moon, showing the higher reflectance of the mare (greens) relative to the highlands (blues).

Future and Ongoing Work: We are working to collect additional UV spectra of all plagioclase samples and will also collect UV spectra of the larger grain size splits (64-100 um) when available. This will allow us to more fully understand the spectral influence of plagioclase composition and grain size differences as it applies to spectra of the Moon. Such measurements will be good for context and interpretation of more diverse and petrologically evolved (e.g., silicic compositions) regions of the lunar surface (e.g., Aristarchus or Gruithuisen Domes).

References: [1] Brydges et al. (2015) *LPS XLVI, Abstract #1251.* [2] Greenhagen (2009), PhD dissertation. [3] Donaldson Hanna et al. (2012) *JGR, 117,* 2012JE004184.