

SPECTROSCOPY OF LUNAR METEORITES FOR EXPANDED SAMPLE COLLECTION DIVERSITY: INITIAL RESULTS OF COMPONENT ANALYSES P. J. Isaacson¹, T. Hiroi², C. M. Pieters², Y. Liu³, A. Patchen³, and L. A. Taylor³ ¹Hawaii Institute of Geophysics and Planetology, University of Hawaii, Manoa, Honolulu, HI, 96822, ²Dept. of Geological Sciences, Brown University, Providence, RI, 02912, ³Planetary Geosciences Institute, Dept. of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN, 37996, [isaacson@higp.hawaii.edu].

Introduction: Returned lunar samples from the Apollo and Luna programs have provided the major data-base upon which our present-day knowledge of lunar science is based, yet several unsolved questions remain [1-3]. However, due to the limited sampling of the lunar surface (~6-8 %) by manned exploration, the discovery of numerous lunar meteorites has provided “new-sample science” and expanded the areas of the Moon from which we have samples. These meteorite collections have inherent limitations in that their provenances have been speculated on but are largely unknown. However, unlike much of the Apollo and Luna collections, several of these meteorite samples have evidence of originating from outside the anomalous geochemical region from which the returned samples were collected [2-4].

Most lunar meteorite samples are complex polymict breccias made up of a number of different lithologic components, the result of the weathering of the regolith. Bulk measurements of such polymict breccias present only high-level “averages” of the distinct components that form the rocks. Whereas pristine rocks can provide clear indications to formational processes and petrologic evolution [e.g., 5, 6], bulk measurements of complex breccias cannot reveal specifically the evidence provided by the individual lithologic components of the breccia.

Visible to near-infrared (VNIR) reflectance spectroscopy is a powerful tool for investigating the mineralogy of planetary materials, because the properties of absorptions in VNIR spectra are diagnostic of mineralogy and mineral composition [7]. With the advent of high-quality orbital VNIR datasets for the Moon, such absorption features can be analyzed globally. Interpretation of such VNIR data relies largely on ground truth from lunar samples and analogues in which information from laboratory investigations is used to interpret remote observations [e.g., 8-10].

We have previously presented bulk spectroscopic analyses of a suite of Antarctic lunar meteorites (ALHA81005, QUE93069, EET87521, EET96008, LAP02205, and MIL05035) [11]. Of these samples, four are breccias composed of distinct lithologic components, and 2 (LAP and MIL) are unbrecciated basaltic samples. Here, we present initial results of analyses designed to capture the VNIR signatures of the individual lithologic components (minerals and clasts) of

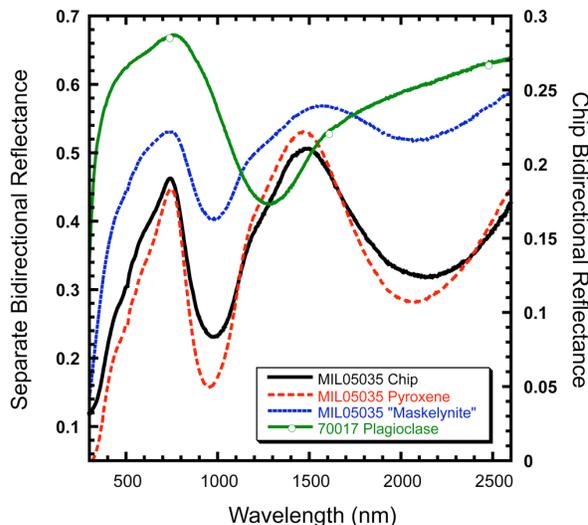


Fig. 1: VNIR reflectance spectra of mineral separates from lunar meteorite sample MIL05035 along with a lunar plagioclase separate from high-Ti basalt sample 70017 from Isaacson et al. [8]. The bulk MIL05035 measurement (black line) was collected from the chip surface, whereas the mineral separates were collected as particulates with grain sizes of <125 μm .

these rocks. These components contain signatures of the geologic processes that formed the minerals and rocks from which the clasts were sourced, and it is these parent rocks and minerals that will ultimately be investigated through orbital remote sensing (the clasts are assumed to represent small samples of larger outcrop-scale deposits). Studying the clasts in addition to the bulk samples with laboratory VNIR spectroscopy enables their use as ground truth for placing the clast parent rocks as well as the bulk breccia stones into proper geologic context with orbital data. Our sample suite includes breccias as well as unbrecciated samples. Here, we present results for an unbrecciated basalt (MIL), and anticipate presenting results for breccia samples at the conference.

Methods: As a first step, we used electron microprobe analysis of prepared thin sections and grain mounts to characterize the mineralogy, clast populations, and mineral chemistry of our samples [11]. We are processing the meteorite samples and conducting spectral reflectance analyses in a stepwise fashion. Prior to destructive analyses, the clasts visible on the surface are studied with laboratory spectroscopy following the approach of Hiroi et al. [12]. From the

bulk-rock chip samples, small subsets are being used to measure the bulk reflectance properties of the meteorite samples. The stones are then being separated into clast types for measurement of the clasts as particulates after crushing and sieving to standard grain sizes (e.g. $<125\ \mu\text{m}$, $<45\ \mu\text{m}$). The breccia samples are very resistant and texturally complex at all scales, and in most cases it is not possible to separate individual clasts; rather, a more general separation must be performed in which the clasts of interest dominate the separate but are mixed with some matrix materials.

Initial Results: As an unbrecciated basalt sample, the MIL chip sample does not contain “clasts” of distinct lithologic materials, as the entire sample is a single lithology (mare basalt). Bidirectional VNIR spectra of mineral separates from MIL05035 are presented in Fig. 1, along with a lunar plagioclase separate from Isaacson et al. [8] for comparison. Mid-infrared spectra for the same samples are presented in Fig. 2. All spectra were acquired in the RELAB at Brown University. In both cases, the separates were in particulate form, with a relatively coarse grain-size of $<125\ \mu\text{m}$. Mid-infrared spectra were acquired in reflectance using the RELAB FT-IR spectrometer. The “bulk” measurement (“Chip”) was collected from the chip surface rather than from a ground particulate sample. Note the compressed reflectance range and reduced spectral contrast (right axis) for the chip spectrum in both figures.

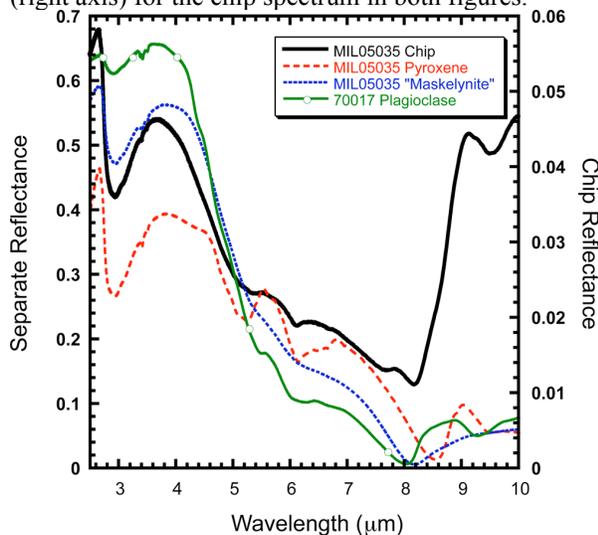


Fig. 2: Mid-infrared reflectance measurements of MIL05035 components (same samples as Fig. 1). Note the position of the Christiansen Feature (a compositionally diagnostic parameter) as a reflectance minimum in the $\sim 8\text{--}9\ \mu\text{m}$ region. For reference, $8\ \mu\text{m} = 1250\ \text{cm}^{-1}$.

Discussion: Despite the reduced spectral contrast of the bulk (“Chip”) spectrum (which results from its measurement as a chip surface rather than a particulate sample), the overall resemblance between the bulk sample and the pyroxene separate is readily apparent in

both wavelength ranges, particularly in the VNIR. Mineralogically, MIL05035 is relatively simple, being composed primarily of two minerals (pyroxene and plagioclase/maskelynite) [13]. Maskelynite is typically bright and featureless in the VNIR, as shock pressure has caused the plagioclase to lose its ordered crystal-line structure and thus its characteristic $1.25\ \mu\text{m}$ absorption feature [e.g., 14]. The maskelynite in MIL05035 has a relatively high FeO content ($\sim 0.4\text{--}0.5\ \text{wt.}\%$) [13], typical for plagioclase in mare basalts, but it lacks the diagnostic plagioclase absorption [e.g., 15]. For comparison, the 70017 plagioclase has comparable FeO content, but does exhibit a very clear $1.25\ \mu\text{m}$ feature. The spectrum labeled “Maskelynite” does exhibit clear evidence of pyroxene contamination (absorptions near $1\ \mu\text{m}$ and $2\ \mu\text{m}$). This separate was prepared by hand-picking, and is relatively pure by visual examination ($\sim 95\%$). This spectrum illustrates the dominant and highly nonlinear effect of minor pyroxene contamination in a transparent, non-absorbing phase. Pyroxene has strong crystal-field absorptions in the VNIR that dominate when it is mixed with a transparent, non-absorbing phase [16, 17]. The mid-infrared spectra illustrate the modal dominance of plagioclase/maskelynite in the maskelynite spectrum. While it lacks the vibrational feature near $4.2\ \mu\text{m}$ exhibited by the 70017 plagioclase [e.g., 8] due to the loss of crystallinity, the Christiansen Feature (CF, which is diagnostic of Si abundance) of the maskelynite is only slightly different from that of the 70017 plagioclase, indicating the relatively low modal abundance of the pyroxene contaminant [18, 19]. The CF position of the bulk (“Chip”) sample is intermediate between the pyroxene and maskelynite, reflecting this sample’s mixed composition of pyroxene and maskelynite.

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