SPECTROSCOPY OF LUNAR METEORITES AS CONSTRAINTS FOR GROUND TRUTH: EXPANDED SAMPLE COLLECTION DIVERSITY. P. J. Isaacson[1], Y. Liu[2], A. D. Patchen[2], C. M. Pieters[1], and L. A. Taylor[2], [1]Dept. of Geological Sciences, Brown University, Providence, RI, 02912, [2]Planetary Geosciences Institute, Dept. of Earth & Planetary Sciences, University of Tennessee, Knoxville, TN, 37996, [Peter_Isaacson@Brown.edu].

Introduction: The Apollo and Luna samples are vital to our evolving understanding of the Moon, but they present an incomplete picture of the Moon's geology [1-6]. First, the full geologic evolution of any body is difficult to infer regardless of the number of samples collected, so it is easy to see that a few samples, no matter how well chosen, will be limited in the degree to which they can record the full view of lunar geology. Additionally, while impossible to know at the time the samples were collected, more recent data suggest that the samples were collected from a unique geochemical region characterized by elevated abundance of Th and other incompatible elements [3-5]. This region has been termed the Procellarum KREEP Terrane [7-10]. However, the collection of lunar meteorites [2, 11] likely represents a more diverse, global sampling of the lunar surface and crust, assuming that the impact process is largely stochastic. However, the more diverse view of lunar geology these samples provide is limited by the lack of geologic context for the samples, as their source regions are largely unkown beyond broad generalizations.

Several spacecraft have been recently or are currently in operation in lunar orbit. The scientific payloads of these orbiters include a number of instruments intended to map the surface chemistry and mineralogy of the Moon. Most of these instruments rely on ground truth provided by lunar samples to calibrate or constrain their measurements. Because the lunar meteorites include materials not sampled by the Apollo and Luna programs, they represent a valuable expansion to the collection of materials useable as ground truth. With sufficient study and careful measurement, the lunar meteorite samples should provide a more diverse dataset that can be used both for calibration and for constraints on science analyses.

Compositional data with the highest spatial resolution will be provided by optical instruments, which are sensitive largely to surface mineralogy. Optical instruments are not sensitive to geochemical properties like bulk chemistry or trace element abundance, which are often used to differentiate suites of materials. However, optical instruments, particularly reflectance spectrometers, are sensitive to mineralogy and major element mineral composition, which also vary between suites of lunar samples [1, 2, 4, 6, 12-17]. Thus, reflectance spectroscopy has the potential to constrain the source region of the meteorite samples and thus to begin to provide the geologic context of these valuable samples [e.g., 18]. Obtaining this geologic context will enhance the value of the meteorite samples enormously, as the data they provide can be used on par with the data from Apollo and Luna samples for which precise source locations and geologic contexts are known. Our current sample suite includes two feldspathic breccias (ALHA81005, QUE93069), two unbrecciated basalts (LAP02205, MIL05035), and two basaltic breccias which are likely to represent paired samples (EET87521, EET96008) [19-21]. We continue to analyze this suite of lunar meteorite samples to provide the groundwork needed to investigate the source regions of these important samples with remote sensing, following the efforts of [22].

Mineralogy/Petrography: Because mineral abundance and composition can vary significantly within individual stones, we conducted detailed mineralogy/petrography analyses to aid interpretation of reflectance spectroscopy results. We have conducted such analyses of LAP02205, ALHA81005, QUE93069, and MIL05035, and found them to be consistent with previous studies [22 and references therein.

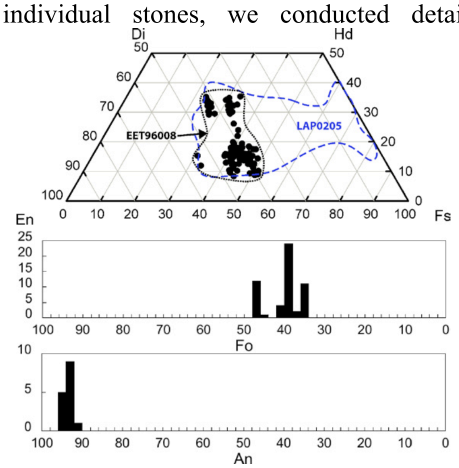

Fig. 1: Composition of pyroxene, olivine, and plagioclase in EET96008. Compositional range of pyroxene in LAP02205 is provided for comparison (blue dashed line).

Here we present similar petrographic analyses of EET96008. Fig. 1 shows the compositions of the major mineral phases found in EET96008. Compared to basaltic meteorites studied by [22], represented by the blue dashed line in Fig. 1, pyroxenes cover a limited compositional range. Olivine compositions (Fo_{50}-Fo_{30}) are more Fe-rich than some of those in LAP02205, which exhibits a largely bimodal olivine composition (Fo_{64}-Fo_{46}, Fo_{13}-Fo_0) [23]. Plagioclase compositions (>An_{90})

are more Ca-rich than those in LAP02205 and MIL05035 (most <An_{90}). The compositional data for EET96008 as well as the diverse lithologies it contains are consistent with a significant feldspathic highland component, which is logical for a polymict basaltic breccia [19]. Our results are consistent with previous analyses of the paired stones EET96008 and EET87521 [19-21, 24-29].

Reflectance Spectroscopy: The basaltic breccia chip samples have been analyzed in bidirectional reflectance (BDR) from .28 – 2.6 µm, and with biconical reflectance by FT-IR to ~50 µm. All reflectance measurements were performed in the RELAB at Brown University. BDR spectra for the two chip samples are presented in Fig. 2. Measuring the samples as chips rather than as particulates leads to a pronounced negative ("blue") continuum slope. Despite the unfavorable measurement conditions and the brecciated and somewhat glassy nature of the samples, high-quality reflectance spectra were obtained.

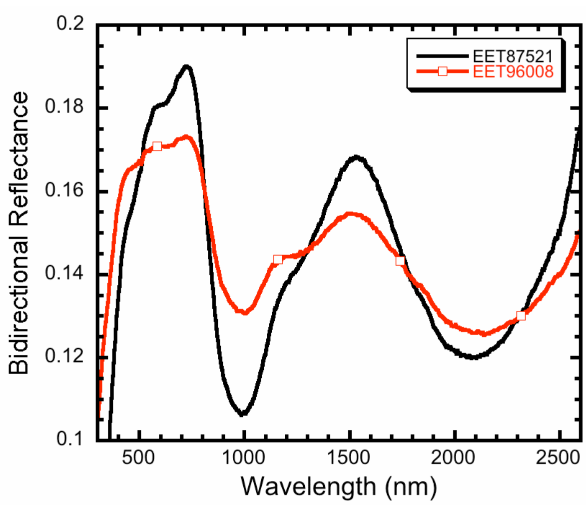

Fig. 2: BDR spectra for basaltic breccia chips EET87521 and EET96008. Both spectra exhibit prominent blue continuum slopes due to measurement as chip samples. Note the prominent absorption near 1.3 µm for EET96008.

Both breccia samples exhibit prominent 1 and 2 µm pyroxene absorption features. The position of these features is consistent with high-Ca pyroxene [e.g., 14]. Both exhibit features near 1.2-1.3 µm, although the feature is much more prominent in EET96008. The strength of this feature is sufficient to suggest an absorption due to olivine, which has a strong absorption feature in this wavelength region [e.g., 15]. As these two samples are highly brecciated with diverse lithic clasts, modal mineralogy is difficult to quantify. Additionally, measurement as a chip sample introduces the possibility of a sample orientation bias. However, the BDR spectrum of EET96008 suggests reasonably abundant Fe-rich olivine [17], consistent with the mineralogy reported above and with several other studies that report a range of olivine compositions in these stones [19, 24, 25].

While it is difficult to deconvolve precisely the contributions of individual clasts to the bulk reflectance spectra of the chips, these chip spectra clearly illustrate the spectral diversity of the meteorite collection and its potential for expanding our library of well-characterized lunar materials for ground truth. Additionally, we intend to separate physically the chip samples into the various component clasts that comprise the bulk samples wherever practical. Where possible, the reflectance spectra acquired will be deconvolved quantitatively with the Modified Gaussian Model (MGM) [16].

Summary: Following the initial results described by [22], we present new integrated analyses of a suite of lunar meteorite samples that demonstrate and expand the diversity of the sample collection. Initial mineralogy/petrography is presented for EET96008, along with visible to near-infrared reflectance spectra of chips of EET87521 and EET96008. Such data represent the type of coordinated analyses needed to include the lunar meteorite samples in our collection of well-characterized lunar samples available as ground truth for remote sensing measurements. Additionally, these measurements and focused analyses of the specific components of the meteorite samples will provide the groundwork necessary to place these samples in their proper geologic context with remote sensing, which will increase their value to the lunar science community still further.

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