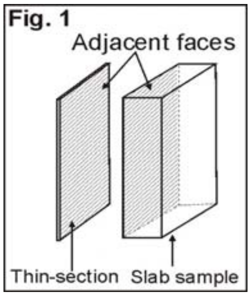
LUNAR ROCKS AND MINERALS CHARACTERIZATION CONSORTIUM: MINERAL CHEMISTRY, AND MINERAL SEPARATIONS FOR REFLECTANCE SPECTRAL ANALYSIS.

A. Basu Sarbadhikari[1], Y. Liu[1], L. A. Taylor[1], P. J. Isaacson[2], R. L. Klima[2] and C. M. Pieters[2]; [1]Planetary Geosciences Institute, Dept. of Earth & Planetary Sciences, Univ. of Tennessee, Knoxville, TN 37996 (abasusar@utk.edu), [2]Department of Geological Sciences, Brown University, Providence, Rhode Island 02912.

Introduction: Reflectance spectroscopy of the Moon provides compositional information at the highest spatial resolution obtained remotely for lunar science. Prominent diagnostic absorption bands occur in spectra of freshly exposed lithologies, while space weathering products (nanophase Fe) gradually weaken these features as soils form and mature. We have learned a great deal about the weathering process and now know how to better interpret the products. Although complex, mature lunar soils contain a plethora of valuable information. Equally important, we can recognize the vast amount of immature exposures across the Moon that provide excellent insight into lunar composition and science issues.

In order to bridge the range of features observed, it is imperative that one uses the best library of standards. The Lunar Rock and Mineral Characterization Consortium (LRMCC) [1] was formed to support science objectives of the Moon Mineralogy Mapper (M3), a spectral instrument on the soon-to-fly Chandrayaan-1 lunar orbiter by India. LRMCC will provide this exacting set of minerals, directly correlated with their presence in lunar rocks, and their spectral properties. This LRMCC integrated analysis addresses the unweathered components of exposed lunar materials and complements the previous LSCC analyses of soils. This will provide the foundation necessary to reliably link remote spectral measurements to compositional properties of the coarse and fine portions of the regolith. It should be mentioned that the Lunar Sample Curator and CAPTEM have been instrumental in facilitating this endeavor.

Fig. 1



Lunar mare basalts, chosen for their representative nature to an Apollo landing site, were cut such that a thin-section could be prepared directly opposite the bulk portion of the rock (Fig. 1). The opposing rock slab was used for preparation of clean mineral separates. This arrangement of thin-section and chip was used to aid in the correspondence of the mineralogies. The chemistry of the minerals was fully characterized in both the thin-sections and the mineral separates.

In this study, four (4) contrasting mare basalts were selected with low-Ti and high-Ti contents, from Apollo 15, 15058 & 15555, and Apollo 17, 70017 & 70035, resp. Detailed petrography, mineral compositions, and crystallization trends have been revisited for these basalts.

Methodology: The chemical compositions of different mineral phases were determined in thin sections using an electron microprobe. The modal mineralogy (vol %) was obtained using the *Feature Scan Phase Distribution* software package of an Oxford instrument energy dispersive spectrometer interfaced to the microprobe [2]. Based on modal data, major mineral phases were separated dry by crushing the slab samples. The ground sample was separated to >250, 125-250, and <125 μm fractions. Major mineral phases were picked, based on their differences in color, from the 125-250 μm fraction and visually checked for purity. Less-pure grains were ground to finer fractions to remove the impurities. The finer grains are approximately <125 μm. Several grains from each mineral separate were mounted in epoxy and microprobed in order to estimate the separate's compositional range and purity.

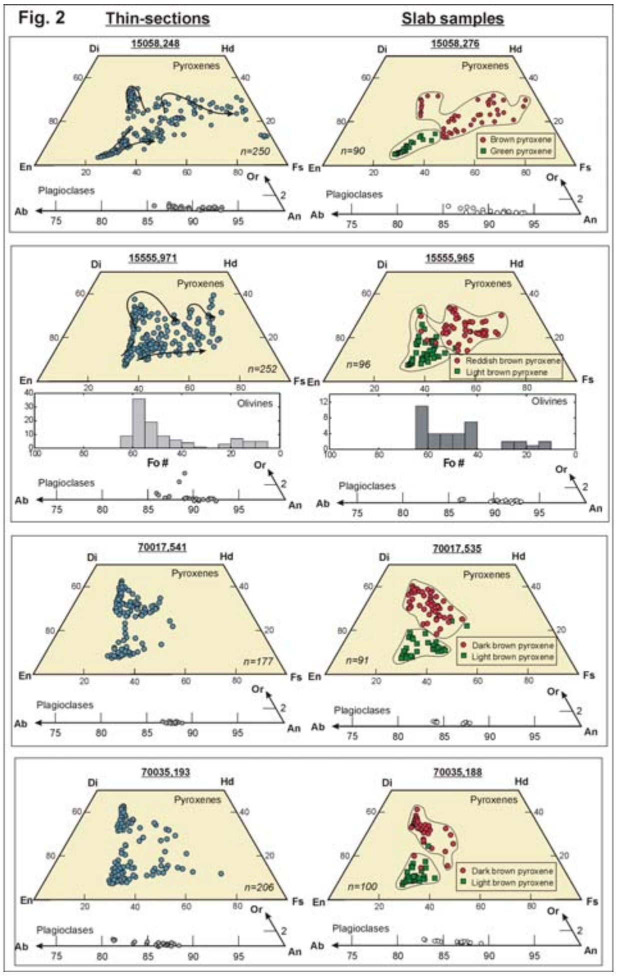
Petrography and Mineralogy of the Thin-Sections: ***15058,248:*** This is a coarse-grained subophitic low-Ti basalt, consisting of phenocrysts of pyroxene (1-1.5 cm long) and plagioclase. Pyroxenes and plagioclase are the most abundant mineral phases. Pyroxene compositions occur over a wide range (Fig. 2), similar to those reported by [3] and [4]. However, in this study, we also analyzed orthopyroxenes and several pyroxferroites. High-Mg orthopyroxene to pigeonite cores become Ca-rich or alternatively follow the low-Ca trend towards Fe-enrichment, with the appearance of pyroxferroite in several grains (Fig. 2). Plagioclase is anorthitic (An_{93-85}) (Fig. 2). Ilmenite, chromite, and ulvöspinel occur as inclusions within the pyroxene and plagioclse phenocrysts.

15555,971: This is a medium-grained, low-Ti basalt. Plagioclase poikilitically encloses the olivine, pyroxenes, and accessory phases. Olivines show a bimodal distribution in Fo-content (Fig. 2). Pyroxene compositions occur over a wide range (Fig. 2), similar to those reported by [3] and [4]. Pigeonite cores become augites or alternatively follow the low-Ca trend (Fig. 2), with the appearance of ferro-augite at the high-Ca trend. Plagioclase is anorthitic (An_{92-86}) (Fig. 2), compared to the range of An_{94-78} of [5]. Ilmenite occurs as single grains and as exsolution within ulvöspinel, whereas ulvöspinel appears as individual grains or as inclusions. Chromites, sometimes rimed by ulvöspinels, occur as inclusions within olivine and pyroxene.

70017,541: This is a coarse-grained crystalline granular high-Ti basalt. Olivine (Fo_{55}-$_{78}$) is generally enclosed in plagioclase and pyroxene. Coarse pyroxene grains are zoned from augite core to Mg-pigeonite rim (Fig. 2), similar to [6]. Plagioclase is anorthitic with a composition in a restricted range (An_{89}-$_{86}$) (Fig. 2). Euhedral to subhedral ilmenites occur in abundance, with exsolution lamellae of rutile. Minor amounts of chromite and armalcolite were found as inclusions within olivine and pyroxene.

70035,193**:** This is a coarse-grained crystalline granular high-Ti basalt. Olivine ($Fo_{58\text{-}70}$) is commonly enclosed within plagioclase & pyroxenes. Compositions of pyroxenes (Fig. 2) agree with the previous study [6]. Individual pyroxene grains display variation from an augite core to pigeonite and then to a Fe-rich pigeonite rim (Fig. 2). Plagioclase is $An_{88\text{-}81}$. Euhedral to subhedral ilmenites occur in abundance, with exsolution lamella of rutile & chromite. Cr-ulvöspinel & armalcolite are commonly associated with ilmenite.

Fig. 2



Mineral Separates and their Chemistry: The composition of pyroxenes and other minerals (Fig. 2) of the different particle-size separates indicates a representative sampling of the total range found in the polished thin section.

15058,276**:** The dominant mineral phases are green pyroxene, brown pyroxene, and plagioclase. The brown pyroxenes are mainly augites, consisting of both the Mg-clinopyroxene and Fe-clinopyroxene types of [7] (Fig. 2). The green pyroxenes are orthopyroxenes and pigeonites, with high Mg-content. Plots of plagioclase compositions (Fig. 2) for the polished thin-section, 15058,248, and the slab sample, 15058,276, are almost identical.

15555,965: Major phases are green olivine, reddish-brown pyroxene, light-brown pyroxene, and plagioclase. Compositional ranges of the pyroxene separates, as a whole, are representative of the polished thin section, 15555,971 (Fig. 2). The mean composition of reddish-brown pyroxene is Mg-poor augite, and that of the light-brown pyroxene is Mg-rich subcalcic augite. The compositions of olivine and plagioclase separates (Fig. 2) are almost identical to those of the polished thin section (Fig. 2), although fayalitic grains ($Fo_{5\text{-}10}$) are missing in the separates.

70017,535: Major mineral phases are light-brown pyroxene, dark-brown pyroxene, transparent to white plagioclase, and opaque oxides. Dark-brown pyroxenes are mainly augites, while the light-brown pyroxenes are mainly pigeonites (Fig. 2). Compositional ranges of the plagioclase separates (Fig. 2) are representative with those of the polished thin section, 70017,541.

70035,188: The dominant mineral phases are light-brown pyroxene, dark-brown pyroxene, transparent plagioclase, and opaque oxides. Dark-brown pyroxenes are mainly augites, while the light-brown pyroxenes are mainly pigeonites (Fig. 2). Compared to the compositional range of pyroxenes in the polished thin section, 70035,193, our pyroxene separates have Mg#> 50, which is the majority of pyroxenes. Plots of plagioclase compositions (Fig. 2) for the polished thin-section and the slab sample are practically identical.

Summary: This study has prepared the mineral separates and samples of the powdered rock, along with their detailed petrology and chemistry. This information forms the basis for the spectral reflectance data presented in an accompanying abstract by Pieters et al. [1], with the coordinated spectroscopic analyses of mineral and bulk particle-size separates. Future work will concentrate on expanding coordinated analyses with well characterized mineral separates.

References: [1] Pieters et al. (2008), this vol.; [2] Taylor et al. (1996) *Icarus* 124; [3] Bence & Papike (1972) PLSC 3; [4] Ryder (1985) *Catalog of Apollo 15 Rocks*, JSC 20787; [5] Longhi et al. (1972) In: *Apollo 15 Lunar Samples;* [6] Papike et al. (1974) PLSC 5; [7] Taylor et al. (2001) *JGR* 106.