

STUDY OF THE APOLLO 16 LANDING SITE: AS A STANDARD SITE FOR THE SELENE MULTIBAND IMAGER.

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Introduction: It is our ultimate goal in our future lunar exploration mission to obtain data of modal abundances of minerals and chemical compositions of the lunar surface. Global multi-spectral data of Multiband Imager (MI) for the SELENE mission is going to derive that information by combined with hyper-spectral data of Spectral Profiler (SP). To understand mineral abundance and mineral compositional distribution of the lunar surface from the remote sensing data using MI and SP data we need precise correction and calibration procedure. One of the most important procedures for the precise correction and calibration of remote sensing data is a selection and understanding of a suitable optical standard site.

Purposes: MI will take images of the whole surface of the moon during one year SELENE mission [1] [2]. We are planning to take several images of the same standard area under different phase angle condition throughout the mission period. During conversion process of radiance to reflectance data accuracy of used reflectance value for the standard site is important. Matured, homogeneous and low reflectance rectangle area near the Apollo 16 landing site was selected as an optical standard area for the Clementine UV/VIS camera based on the intense studies [3][4]. This area is also used in the many previous lunar observation study.

We need high quality calibration procedure to maximize scientific returns from the MI's hardware advantages such as high radiance and special resolution. MI can have standard area for MI own in spite of the successful calibration of the Clementine UV/VIS camera. Purpose of this study is to re-evaluate optical properties of Apollo 16 landing site and selected laboratory standard by studying correlation between their mineralogy and reflectance spectra and select a best standard area for the MI. To check capability of our spectral analyses algorithm [5] using MGM [6] [7] is also the aim of this study.

Samples and Methods: We measured bidirectional reflectance spectra of five Apollo 16 regolith samples (from 400 to 2500 nm at $i=30$ and $e=0$) by MIRAI (Mineralogical Reflectance Analyses Instrument) at JAXA. These 5 samples (listed in Table 1) were selected as representatives of 5 different geological units of this area, including a regolith 62231 used for

Clementine standard. To understand the effect of compaction rate and surface roughness to the obtained reflectance value, we measured reflectance of Apollo samples under different compaction and surface roughness conditions. Obtained spectra were compared to the spectra of sampling spots pixels in the Clementine PDS mosaic data [5]. Curve fitting calculation using Modified Gaussian Model (MGM) [6] were applied to the derived sample spectra to understand the relation between the reflectance spectra

Table 1 Description of studied Apollo samples.

Sample No.	Description
60501	Soil at LM landing site.
62231	Soil at Station 2 Buster crater rim.
63501	Soil at Station 13 rich in North Ray crater ejecta.
67601	Soil at North Ray crater, highland component mixtures.
66041	Soil at Station 6 white ray material.

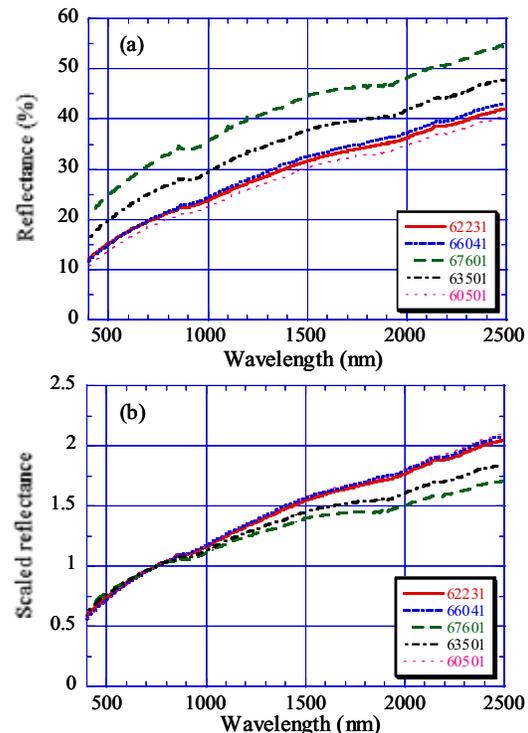


Figure 1. Reflectance spectra of (a) 5 Apollo 16 samples and (b) scaled reflectance at 750 nm under the condition of $i=30$ and $e=0$ degree. Individual spectrum shows averaged value of several measurements. Sample 62231, 66041 and 60501 show lower and "redder" reflectance.

and the mineralogy of the samples. Three polished thin sections (PTSs) 62231,43, 66041,129, and 67601,88 are prepared and provided by the NASA Johnson Space Center (JSC). We selected these 3 PTSs to study modal mineralogy and mineral composition by Electron Microprobe because 66041 has most resembled spectra to 62231 and 67601 has most bright and distinct spectra. Chemical compositions of minerals were studied by a JEOL 733 electron probe microanalyzer (EPMA) and elemental distribution X-ray map by JEOL EPMA (8900 Super Probe) at the Ocean Research Institute, the University of Tokyo.

Results: All sample spectra (Figure 1-a) indicate weak pyroxene absorption signatures at around 1000 and 2000 nm. Absolute value of the obtained reflectance is higher in the order of sample 67601, 63501, 66041, 62231 and 60501. Reflectances at 750 nm are 32.0, 26.0, 20.8, 20.5 and 19.3 % (given in the order of sample numbers). Reflectance variation of 62231 between 3 different compaction and surface roughness conditions, maximum density difference of 15%, is up to 25 % of the reflectance value. And this variation is larger than that of the terrestrial olivine and pyroxene analogous samples.

Our laboratory reflectance and the correspondent reflectances in the Clementine mosaic data are very consistent with each other in the order of reflectance. Scaled reflectance (Figure 1-b) indicates that sample 67601 and 63501 seem to be less matured than other samples. Real variation of reflectance less than special resolution of the Clementine UV/VIS camera have not known but in the Clementine mosaic data higher reflectance area show higher special variation of reflectance. Variation of reflectance for each sample in the order of higher reflectance is 28.2-25.7, 23.8-22.6, 21.6-20.3, 21.5-20.8 and 20.8-20.0 % within 3×3 pixels around sampling spots.

Three calculated parameters, wavelength, depth and width of absorption peak center, of MGM analyses show that 67601 has largest absorption peak depth while 62231, 60501 and 66041 have similar smallest depth. And there is variation among samples of absorption peak center as indication of mineral composition of samples. Variation of the wavelength of the calculated peak center around 2000 nm is about 90 nm among 5 samples. Modal (vol. %) abundances of mafic minerals (pyroxene+olivine) analyzed in the PTS for particles with the 100-800 μm size fraction of 62231, 66041 and 67601 are 5.6, 3.2 and 7.6 respectively. These mafic mineral abundance shows consistency with the ratio of calculated absorption peak depth around 1000 nm which is 2.0: 1.0: 2.2. Representative mineral compositions are listed in Table 2. Correlation between the calculated wavelength of absorption peak center and the

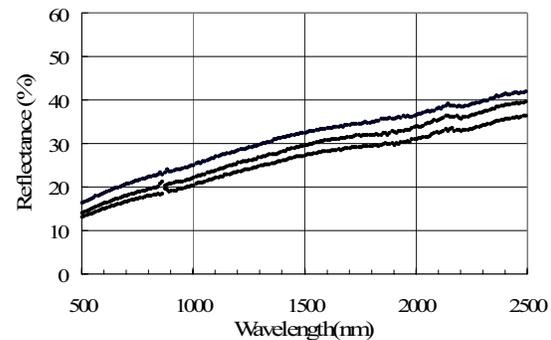


Figure 2. Reflectance spectra of 62231 under 3 different compaction and surface roughness conditions. Denser sample show higher reflectance. Density for each condition is 0.163, 0.157 and 0.141 and the density difference between 3 conditions is up to 15%.

Table 2. Mineral compositions of representative mineral fragments.

	Plagioclase	Pyroxene (co-existing high-Ca & low-Ca pyroxene)	Olivine
66231	An=94-98	Fe#=23, Wo42 Fs13 En44 (high-Ca) Fe#=29, Wo 3 Fs29 En69 (low-Ca)	Fe#=86
66041	An=93-98, 58	Fe#=14, Wo45 Fs 7 En47 (high-Ca) Fe#=18, Wo 24 Fs13 En62 (low-Ca)	-
67601	An=91-98	Fe#=26, Wo43 Fs15 En42 (high-Ca px1) Fe#=36, Wo 3 Fs35 En62 (low-Ca px1) Fe#=23, Wo39 Fs14 En47 (high-Ca px2) Fe#=26, Wo 4 Fs24 En71 (low-Ca px2)	Fe#=81-83

An=Ca/(Ca+Na), Fe#=Fe/(Fe+Mg), Wo=Ca/(Ca+Fe+Mg), Fs=Fe/(Ca+Fe+Mg), En=Mg/(Ca+Fe+Mg)

measured mineral composition within 3 PTSs indicate relative consistency but further studies are required to estimate absolute accuracy.

Discussion: From our result that 62231 is not the lowest reflectance samples and also there are samples of similar degree of maturity there can be better laboratory standard for MI. For example sampling spot of 60501 has homogeneous property and also it has similar degree of maturity therefore this sample could be the reflectance standard for MI same as sample 62231.

Parameters of absorption peak depth calculated by our MGM algorithm show that it detects 2% difference of mafic mineral abundance of the 100-800 μm size fraction within lunar samples.

Measured large reflectance variation of lunar samples with compaction and surface roughness may explain part of the reason of the reflectance gap between earth-based observation and Clementine measurements.

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References: [1] Ohtake M. *et al.* (2002) *LPS XXXIII*, #1528. [2] Ohtake M. *et al.* (2002) *ISTS*, k-27p. [3] Pieters C. M. *et al.* (1992) *LPS XXIII*, 1069-1070. [4] Pieters C. M. (1999) *New Views of the Moon*, 8025-8026. [5] Ohtake M. *et al.* (2001) *LPS XXXII*, #1512. [6] McEwen (1996) *LPS XXVII*, # 841. [7] Sunshine J. *et al.* (1990) *J. Geophys. Res.*, 95, B5, 6955-6966.