**CLEMENTINE UV-VIS MULTISPECTRAL DATA AND THE APOLLO 17 LANDING SITE: WHAT CAN WE TELL AND HOW WELL?**

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The 1994 Clementine mission acquired global-coverage digital images of the Moon using ultraviolet-visible (UV-VIS) and near-infrared (NIR) cameras [1]. The UV-VIS data cover much of the Moon in five wavelengths at a resolution of ~125m per pixel, potentially providing a wealth of information on soil composition, maturity, and mineralogy at a fine scale. While much information can, in principle, be inferred from these data based on laboratory studies of lunar samples and their spectral properties, we can test conclusions drawn from these data using what is known from the returned lunar samples and the geology of the landing sites. This abstract reports preliminary findings of a study of the Apollo 17 landing site, where I have correlated sample data with the spectral properties of individual 125m pixels to which the sample stations correspond. Summaries of FeO and $TiO_2$ mapping using Clementine data correlated to Apollo landing-site sample stations are given in [2,3]. In this abstract, I investigate some of the uncertainties associated with the data and with processing of Clementine UV-VIS images for the specific purpose of extracting compositional or petrographic information. I have used the Integrated Software for Imaging Spectrometers (ISIS) programs developed by the U. S. Geological Survey, using routines designed, in some cases, specifically for Clementine UV-VIS images. I have followed the same procedures as detailed by [2], but without a normalization to the Apollo 16 telescopic site [2] using 62231 [4].

Uncertainties: Two tests. During systematic mapping, the UV-VIS camera took two exposures of each scene for each bandpass, a long and a short exposure. Also, there is considerable overlap between adjacent scenes for each bandpass. It is therefore possible, using the two exposures and using regions of overlap in adjacent scenes, to test the reproducibility of brightness values, pixel for pixel.

For a given scene, if the long exposure for a given bandpass contains saturated pixels, it can be merged with the short exposure, normalized to the same exposure duration. This is one of the routine steps generally taken during processing with ISIS. While this produces good-looking images, it appears that small but systematic variations may exist between long and short exposures, and this is of concern if the merged data are used for high-resolution compositional mapping. Corresponding pixels for coregistered long and short exposures using calibrated 750nm filter images show a mean deviation of the difference between short and long exposure brightness values of 3.22% of the brightness value, and the slope of the correlation line is $0.983 \pm 0.009$. One of the ISIS routines for automated calibration checks long and short exposures for saturated pixels and makes decisions about whether to merge the two exposures. If a merge is done, then a histogram match first adjusts brightness values in the exposure used to fill in saturated pixels in the "primary" image. Typically the primary image would be the long exposure, which has the greatest contrast. After a histogram match, the mean deviation of the short exposure brightness values for the image of the Apollo 17 site is 1.33% of the brightness value (much improved) and the slope of the correlation line is $0.993 \pm 0.009$, which is an excellent match and is probably as good as can be expected, given uncertainties in the coregistration. However, it is important when constructing large mosaics for compositional mapping to ensure that if exposures are merged, the long exposure is the primary image.

The second test involves two adjacent scenes, the one containing the Apollo 17 landing site and the next one to the south. This is a test of our ability to coregister the two scenes as well as a test of the reproducibility of brightness values. Again using the 750nm images, corresponding pixels in the region of overlap have a mean deviation of only 1.05% of the brightness value, an excellent reproducibility, as good as that between long and short exposures, and an indication that the coregistration is adequate for compositional mapping. However, the correlation line has a slope of $0.995 \pm 0.001$. This may be improved by continued work on the photometric function. Histogram matching during coregistration has no effect on the mean deviation and slightly overcorrects the slope.

FeO calibration. Compositional data for individual sampling stations at the Apollo landing sites have been used to refine (calibrate) the method for determining the FeO concentration of lunar surface areas using Clementine UV-VIS data [1,2]. Here I show only data for the Apollo 17 landing site (Fig. 1), using the method of [5] and parameters from [2]. The correlation between measured FeO of Apollo 17 soils, compiled mainly from [6] and the spectral parameter $\theta$ is good, as is the correlation between soil $TiO_2$ and the "$TiO_2$ parameter" for the Apollo 17 data, shown by [3]. The good quality of the correlations at the A17 site can be understood in part as a result of what is to first order a two-component mixing trend between high-Ti mare-basaltic soils and noritic highland soils (Fig. 2). Inspection of Fig. 2 shows that the highland component is more complex, with some soils (South Massif and light mantle) richer in basin-formed impact-melt-breccia components and others (North Massif) richer in anorthositic, prebasin highland crustal materials. Figure 2 combines high-Ti basalt, very-low-Ti basalt, and orange pyroclastic glass as mare components. Likewise, the highland "prebasin" component combines several distinct lithologic components, including granulitic breccias, noritic and troctolitic anorthosites, norite, and gabbronorite.

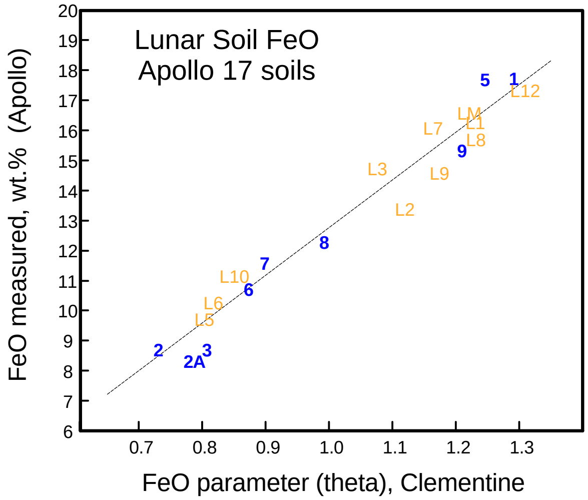


Figure 1. Average measured concentrations of FeO in Apollo 17 surface soils from sampling stations (**1, 2, 2A, 3, 5, 6, 7, 8, 9**), lunar roving vehicle (Ln) stops, and the landing module (LM). The values of theta are offset slightly from those of [2] because spectral data used here were not normalized to the values of reference spectrum of 62231. Line fit by linear regression, correlation coefficient: 0.954.

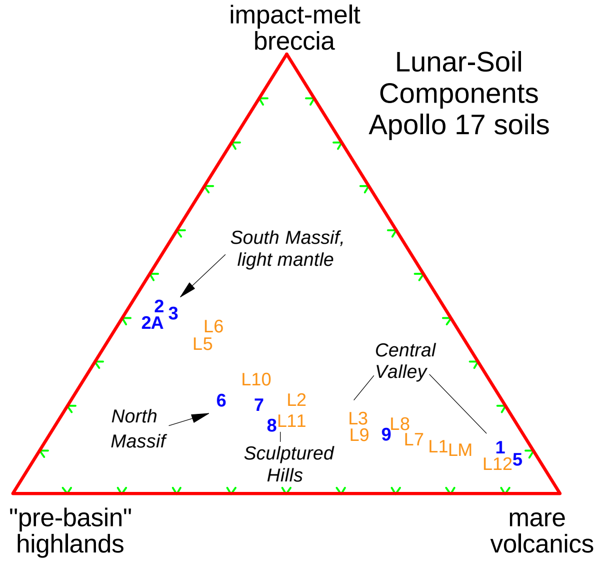


Figure 2. Lithologic components of Apollo 17 surface soils based on compositional mixing analysis of [6] for each sample station and LRV stop. IMB represents average noritic impact-melt breccia.

Maturity. A method to estimate of maturity of non-mare soils from Clementine UV-VIS data was developed by [7,8] based on a relationship between the values of 750nm/950nm (as a measure of the strength of the $Fe^{2+}$ absorption feature) of reference lunar soils and their measured $I_S$/FeO. This method could prove useful for normalizing Clementine data to a common state of maturity (space weathering) [8], which appears to be the first order process affecting spectral variability of Clementine UV-VIS data. This would, in principle, enable more accurate extraction of other parameters such as FeO based on the ~1μm $Fe^{2+}$ absorption feature. However, using the Apollo 17 landing site data, the $I_S$/FeO values (from [9]) of soils that best represent individual sampling stations do not correlate well with 750/950 values. There are three reasons why this may be so. First, many Apollo 17 soils are mare soils, and even highland soils contain substantial proportions of mare basalt and pyroclastics. Second, the observed variations of $I_S$/FeO values for different soils from a given sampling station are substantial. At the Apollo 17 site, especially near the central-crater cluster, it is unlikely that we can extrapolate specific $I_S$/FeO values measured from individual soils to areas as large as 125 x 125 meters (assuming we can locate the exact appropriate pixel in the image, which is not trivial) nearly as well as we can extrapolate the FeO values to larger areas. Third, most of the soils are relatively mature, having Is/FeO values >50, where the relationship between the $Fe^{2+}$ absorption feature and $I_S$/FeO is not very sensitive.

Preliminary results. We can now begin to extend what we know about the Apollo 17 landing site to other unsampled features in the area. (1) From point spectra sampled from the tops of the North and South Massifs, FeO concentrations there appear to be mainly in the range of 8-9 wt.%. The prominent impact-melt breccia (IMB) components from massif samples have FeO concentrations ranging from 8-10 wt.%, but the more anorthositic, pre-basin highland crustal materials have lower FeO, generally <5-6 wt.% [10]. The high FeO values atop the massifs, where mare contamination is not expected, suggest enrichment in impact-melt breccia, as deduced from the light mantle deposits [10]. However, patches of lower FeO concentrations atop the massifs (e.g., 6 wt.%) suggest an IMB-dominated chaotic mixture or that small craters and mass wasting have exposed underlying more anorthositic, pre-basin crustal material. (2) The Sculptured Hills, away from Central Valley mare contamination, are similar to the North and South Massifs both in relatively high surface FeO concentrations and in the range of FeO. (3) Selected spot FeO concentrations from Mons Vitruvius, the large massif east of Taurus Littrow Valley, are considerably lower than those of North and South Massifs, e.g., 6-9 wt.%, suggesting that surface soils there may be less dominated by mafic IMB. (4) Family Mountain and Bear Mountain, two prominences rising above the Taurus-Littrow Valley floor, both appear to have substantially higher FeO concentrations (10-13%) than either the Massifs or the Sculptured Hills, suggesting that they both have substantial mare contamination even in their central heights, or that they contain an unusually mafic highland component.

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