

Estimation of Lunar Elemental Abundances Using Clementine UVVIS+NIR Data

C. Wöhler (1,2), A. Berezhnoy (3) and R. Evans (1,4) – (1) Geologic Lunar Research (GLR) group

(2) Daimler AG, Group Research, P. O. Box 2360, 89013 Ulm, Germany, christian.woehler@daimler.com

(3) Sternberg Astronomical Institute, Moscow State Univ., Universitetskij pr., 13, Moscow, Russia, ber@sai.msu.ru

(4) 114 Simonds St., Fitchburg, MA 01420, USA, revans_01420@yahoo.com

Introduction

Many attempts have been made to derive elemental abundances of the lunar surface from multispectral images. A method to predict Fe abundance based on Clementine UVVIS data is presented in [1]. A refined method which also addresses the TiO_2 abundance is provided in [2], demonstrating that in spite of issues posed by soil maturity, grain size, mineral content, topographic shading, and glass content, elemental abundances can be predicted at an accuracy of about 1 wt%. The gamma ray spectrometer on board the Lunar Prospector spacecraft (LP GRS) provided the first “direct” global measurements of lunar elemental abundances including Fe, Th (15 km surface resolution), Ti, K, Sm (60 km), Al, O, Si, Mg, Ca, and U (150 km).

Correlation of LP GRS and UVVIS+NIR data

Previous studies comparing elemental abundances predicted by Clementine spectral data to abundances inferred from LP GRS data utilise calibrated Clementine UVVIS spectral reflectance data obtained at 415, 750, 900, 950, and 1000 nm. In [3], a linear regression approach between LP GRS and Clementine UVVIS data is proposed which relies on the 750 nm albedo and several spectral ratios. The LP GRS data are used as “ground truth” to establish a linear relationship between the two data sets. Our present study is related to the work described in [3], however, it takes advantage of the relatively recent calibration of the Clementine NIR Global Mosaic at 1100, 1250, 1500, and 2000 nm [4, 5] to utilise a calibrated UVVIS+NIR dataset in place of the five band UVVIS dataset. Our approach is based on modelling the wt% abundances of Ca, Al, Fe, Mg, Ti, and O as weighted sums of spectral features based on a least-squares regression. The algorithm is based on eight spectral parameters [6]:

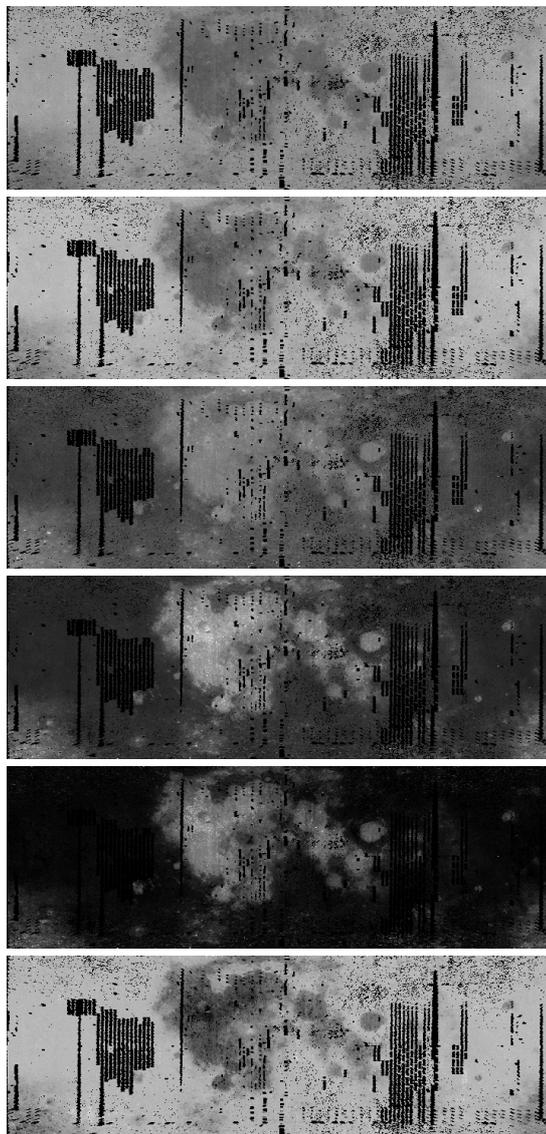


Figure 1: Abundances of (top to bottom) Ca (grey value range 2–18 wt%), Al (0–20 wt%), Fe (0–25 wt%), Mg (0–16 wt%), Ti (0–6 wt%), and O (40–47 wt%), estimated based on the described 44 UVVIS+NIR spectral features. Spatial resolution is 0.5° (15 km).

- Spectral slope of the continuum (albedo difference between 750 and 1500 nm)
- FWHM of the ferrous absorption trough near 1000 nm (after continuum division)
- Two absorption wavelengths between 890 and 1150 nm (after continuum division; identical values for a single absorption)
- Two relative absorption depths of the absorption minima (after continuum division; identical values for a single absorption)
- Wavelength and absorption depth of an olivine inflection feature between 1000 and 1150 nm (set to the values of the principal absorption trough if no inflection feature is present)

The number of features is increased by adding the 36 pairwise products of the eight original features, resulting in a total of 44 features [7]. The coefficients that perform the linear mapping of these 44 features to the corresponding six LP GRS elemental abundances for each Clementine pixel are determined in the least-squares sense using standard linear algebra techniques.

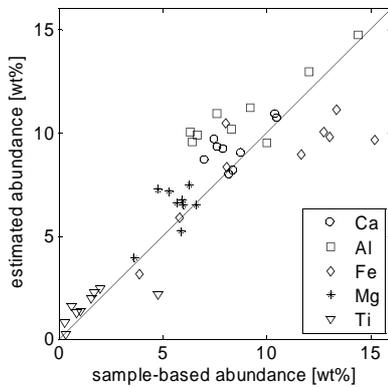


Figure 2: Estimated vs. sample-based abundances.

Results

The elemental abundances obtained based on our regression analysis and their root-mean-square (RMS) deviations from the LP GRS data are shown in Fig. 1 and Table 1. We also determined the (RMS) deviations between the abundances estimated with our approach for the Apollo and Luna landing sites using UVVIS+NIR data of 150 m/pixel resolution and those directly measured for the returned lunar samples [8] (cf. Fig. 2). The correlation coefficients are comparable to those reported in [3], but our abundance maps are much

less sensitive to surface albedo and, thus, soil maturity. This favourable behaviour is especially evident in the Tycho region. For all elements, the RMS deviations are lower than or comparable to those between LP GRS and sample-based abundances [9].

	<i>Ca</i>	<i>Al</i>	<i>Fe</i>	<i>Mg</i>	<i>Ti</i>	<i>O</i>
C_{GRS}	0.63	0.73	0.89	0.72	0.83	0.75
E_{GRS} [wt%]	1.65	1.86	1.65	1.41	0.53	0.79
E_s [wt%]	1.16	2.45	2.73	1.21	1.00	1.03

Table 1: Correlation coefficients C_{GRS} and RMS deviations E_{GRS} between estimated and LP GRS elemental abundances, RMS deviations E_s between estimated and sample-based abundances.

Conclusion

The described technique allows to examine the elemental composition of the lunar surface at high spatial resolution, up to 100 m. The abundance maps of the main elements agree well with the study of returned lunar samples. The estimated Ca, Al, and Mg abundances tend to be systematically higher by $\sim 1-2$ wt% than the sample-based abundances. The estimated Fe abundances are lower by ~ 2 wt% for high Fe contents, while for Ti they are higher by 0.3–1 wt% except for the high-Ti Apollo 11 soil. Qualitatively, these relations are similar to those established in [9] between LP GRS data and sample-based abundances. For O, no systematic deviations occur.

References

- [1] Lucey, P. G. et al. (1998) *JGR*, 103(E2), 3679-3699.
- [2] Lucey, P. G. et al. (1995), *Science*, 268, 1150-1153.
- [3] Shkuratov, U. G. et al. (2005) *Planet. Space Sci.*, 53, 1287-1301.
- [4] Lucey, P. G. et al. (1998) *LPSC XXXI*, 1576.
- [5] Cahill, J. T. et al. (2004) *LPSC XXXV*, 1469.
- [6] Evans, R. et al. (2009) *LPSC XL*, 1093.
- [7] Schürmann, J. (1996) “Pattern Classification”, Wiley-Interscience.
- [8] Elphic et al. (2000) *JGR*, 105, 20333-20345.
- [9] Berezhnoy et al. (2006) *ASR*, 37, 45-49.