EPSC Abstracts
Vol. 8, EPSC2013-374, 2013
European Planetary Science Congress 2013

Mapping lunar TiO_2 and FeO with M3 data

W. Zhang and N. E. Bowles
(1) University of Oxford, Department of Physics, Clarendon Laboratory, Parks Road, Oxford, OX1 3PU, United Kingdom (zhangw@physics.ox.ac.uk)

Abstract

Lunar Fe (Iron) and Ti (titanium) are two important elements distributed on the Moon. The study of lunar Fe and Ti characterization contributes to revealing the origin and development of the moon and determining lunar surface chemistry and mineralogy. In the current study, visible to near-infrared reflectance data acquired by the Moon Mineralogy Mapper (M3) on Chandrayaan-1 are used to investigate the mineralogy of lunar surface.

1. Introduction

The motivation of this study is to apply previous methods derived from the Clementine mission to a new data set.. The M3, a high resolution, high precision imaging spectrometer, flew on board India's Chandrayaan-1 Mission from October 2008 through August 2009. Compared with Clementine data, M3 data is new and contains wider spectral range, and is well calibrated too. At present some researchers have used M3 data to detect OH/Water on the lunar surface [1–2]. But there is little research on determining bulk Fe and Ti abundance of the lunar surface using M3 data [3]. M3 acquired visible to infrared reflectance data at spatial and spectral resolutions capable of measuring discrete basaltic flows within the lunar maria. Despite an abbreviated mission, M3 was able to cover more than 95% of the Moon in its global mode of operations [4,8].

2. Methods

After acquiring the data from the NASA PDS, we then decided on using mapping methods on the basis of previous models. FeO and TiO_2 mapping methods were developed using Clementine and Galileo multispectral data. A series of empirical models have been developed to predict the FeO and TiO_2 content from Clementine UVVIS images [4-5]. Among these models, Lucey's model has been one of the most popular and has undergone a series of refinements [4-5]. Lucey et al. [6,7] used the predictions of the Hapke model[11] to quantify the spectral variations that accompany compositional changes. The effect of maturity on ferrous ion spectra of lunar soil, can be summarized in three points from the description of the spectral characteristics: first, at the 750 nm band, the reflectance R750 nm decreases with the increase of lunar soil maturity; on the contrary, R950 nm/R750 nm just increases while the lunar soil maturity increases; when the iron ion concentration increases, both R750nm and R950nm/R750nm decreases. Based on the above characteristics, Lucey et al developed the spectral characteristic angle parameters method [4-7] for FeO and TiO2 content retrieval while mapping Clementine UVVIS data. The method takes into account the parameters of the two spectral features, separated spectral features of FeO and TiO2 with the effect of maturity. The formula to calculate FeO content is therefore provided,

$$\theta_{Fe} = -\arctan\left(\frac{R_{950}/R_{750} - 1.26}{0.01}\right) \quad \text{......(1)}$$

$$FeO\% = 17.83 \times \theta_{Fe} - 6.82 \quad \text{......(2)}$$

The design and principle of the TiO_2 inversion method is much more simple. For TiO_2 content retrieval, Lucey's method introduces a simple relation between the UV/VIS ratio (415 nm/750 nm) and TiO_2 content in soil of a mature mare to a titanium-sensitive parameter, an angular measure of the TiO_2 content of soils taken from landing sites and sample stations in the plot of UV/VIS versus visible reflectance, to suppress the effect of maturity. In this paper, however, because M3 doesn't include the 415nm frequency (Clementine choose the different R415nm, while M3 data does not cover the band, and first few bands are noisy), we use Shukuratov [9] model instead. Using correlation diagram FeO–TiO_2 for the lunar nearside, Shukuratov [9] has studied the relationship for FeO and TiO_2. It shows the correlation to be rather high with the correlation coefficient 0.81. The regression equation is:

log(TiO2[%])= 0.06 (FeO[%]) - 0.54……(3)

3. Results

According to formula (1-2), we analyzed the FeO content based on M3 data, and show that lunar FeO content varies from 0 wt.% to 20 wt.%. See Figure 1. As expected, we notice from above that the iron distribution is much higher in mare regions than in highland. The iron content map indicates some similarity with geography. See Figure 2. According to formula (3), we analyzed the TiO_2 content based on M3 data, and show that TiO_2 content also varies from 0 wt.% to 7 wt.% (Figure 3). In [10], we also made a comparison with soils from the "Apollo," "Luna," and "Surveyor" Landing Sites[9], Except the titanium abundance from two extremely high samples (Surveyor 5 and Apollo 11), all the other landing sites' M3 data matches with return sample data with a deviation less than 15%.

Figure 1: FeO content retrieval result from M3.

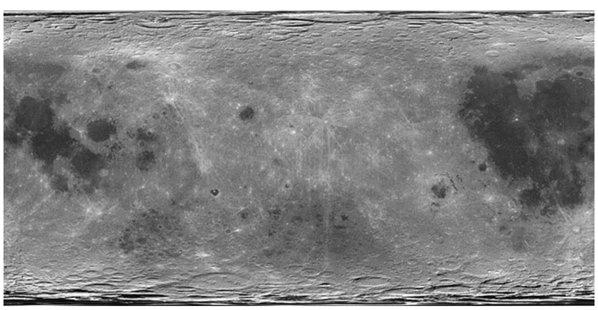

Figure 2: Lunar albedo map.

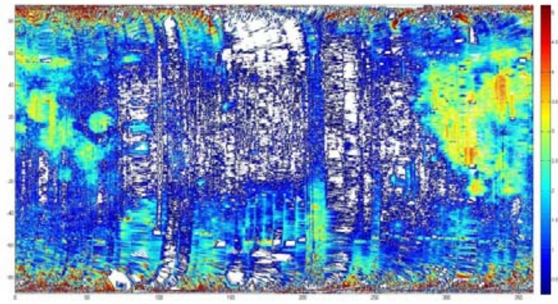

Figure 3: TiO2 content retrieval result from M3.

4. Conclusion

M3 provides the FeO and TiO2 valid contents which fit with "ground truth" from returned samples. Owing to its high spatial resolution (140 m/pixel) and spectral resolution (85 channels), M3 data is applicable to determine the chemical and mineral composition of the lunar surface.

References

[1] Clark R, Pieters C M, Green R O, et al.: Water and hydroxyl on the moon as seen by the Moon Mineralogy Mapper. In: 41st Lunar Planet Sci Conf, 2010, 1533: 2302. [2] Pieters C M, Goswami J N, Clark R N, et al. Science, 2009, 326(5952): 568–572. [3] Dhingra D, Pieters C M, Isaacson P, et al.: Spectroscopic signature of the high titanium basalts at Mare Tranquillitatis from Moon Mineralogy Mapper (M3). In: 41st Lunar Planet Sci Conf, 2010, 1533: 2494. [4] Lucey P G, Blewett D T, Hawke B R.: Mapping the FeO and TiO2 content of the lunar surface multispectral imagery. J Geophys Res, 1998, 103: 3679–3699. [5] Lucey P G, Blewett D T, Jolliff B L.: Lunar iron and titanium abundance algorithms based on final processing of Clementine ultraviolet-visible images. J Geophys Res, 2000, 105: 20297–20305. [6] Lucey,P . G., G. J. Taylor, and E. Malaret: Abundance and distribution of iron on the Moon, Science, 1995, 268: 1150-1153. [7] Lucey, P. G., D. T. Blewett, J. R. Johnson G., J. Taylor, and B. R. Hawke: Lunar titanium content from UV-VIS measurements(abstract), Lunar Planet Sci., 1996 XXVII, 781-782. [8] Boardman et al.: Measuring moonlight: An overview of the spatial properties,lunar coverage, selenolocation, and related Level 1B products of the Moon Mineralogy Mapper. Journal of Geophysical Reasearch, 2011, 116: E00G14. [9] Shkuratov Y G., Kaydash V G., Opanasenko N V.: Iron and Titanium Abundance and Maturity Degree Distribution on the Lunar Nearside, Icarus, 1999, 137: 222–234. [10] Zhang W., Bowles N E.: Mapping Lunar TiO2 and FeO with Chandrayaan-1 M^3 Data, LPSC abstract, 2013, 1212. [11] Hapke, B. W. (1981), Bidirectional reflectance spectroscopy. Theory, J. Geophys. Res. 86:3039-3054.