Lithologic unit mapping based on OMEGA/Mars Express data

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1. Introduction

Existing Martian geologic map and its geologic units were based on their geomorphology, crater features and density, albedo, multi-spectral properties, and thermal characteristics[1]. It was the best geologic map though it was no way to tell really what minerals and lithologies for each unit. However, OMEGA/Mars Express imagery can be used to map not only individual minerals, but also corresponding lithologic units. The result will provide better information on the Marian crustal composition and evolution.

The purpose of this study is to develop a procedure that can be used to delineate the lithologic units based on the OMEGA imagery. Two study areas, Meridiani Planum and Ophir-Candor Chasma, were chosen to test our methods, since many previous works based on TES, THEMIS, OMEGA, or Opportunity Rover have been carried out in these two areas.

2. Dataset

OMEGA onboard Mars Express provides unprecedented mineral and lithologic information in 352 bands with a spatial resolution of 300 m/pixel to 4 km/pixel and spectral resolution of 7 nm in the visible and near-infrared range of 0.364 – 1.070 µm, 13 nm in infrared range of 0.926-2.695 µm, and 20 nm in infrared range of 2.527-5.089 µm[2]. The spectral range and resolution allow the identification of major surface and atmospheric species by their diagnostic spectral absorption feature. The OMEGA data (ORB0529_3 and ORB548_3) for the two areas (Meridiani Planum and Ophir-Candor Chasma) were downloaded from ESA's Planetary Science Archive. In this study, we mainly examined the spectral range between 0.926 to 2.55 µm (114 bands), which includes the diagnostic spectral absorption feature of minerals and lithologies. The data was pre-processed using a modified IDL program initially provided by ESA to a relative reflectance image (I/F).

3. Mapping procedure

3.1 Atmospheric correction

The existing atmospheric correction method to removed atmospheric absorptions is to use empirical transmission functions based on the ratio of two spectra acquired at the top and base of the Olympus Mons scaled to the CO_2 absorption depth at 2 µm[3] [4]. However, the detailed algorithm for the rescaling procedure is not available in literature. In order to apply the data, a new method called LLEE model was developed to carry out the atmospheric correction[5].

3.2 Minimum Noise Fraction

The atmospherically corrected image was then further processed using a called minimum noise fraction (MNF) transformation method. It is found that the MNF band 1 (accounting for ~50% of total information from 114 bands) is mostly correlated (positively or negatively) to the albedo (correlation coefficient r up to 0.83-0.98) of the OMEGA imagery, while the MNF bands 2, 3, and 4 contained almost lithologies information for making an informative and useful geologic unit map. A false color image of MNF bands 2, 3, 4 could then be produced to represent major geological information for the delineation of lithologic units.

3.3 Lithologic unit delineation

Based on the false color image generated from above method, the lithologic units could be delineated and compared with existing Martian “geologic units” based on geomorphology, crater features and density, albedo, multi-spectral properties, and thermal characteristics[1] [6].

3.4. Spectral matching

Representative spectrum (a spectral average of a typical area) of these units was then processed to match with various mineral and rock standard spectral libraries from USGS, John Hopkins University, and Brown University. Two spectral matching methods, spectral angle mapper (SAM) and spectral feature fitting (SFF), were applied based on both spectra and/or continuum removed spectra for scoring each individual minerals and lithologies from libraries with individual representative spectrum of each unit. The highest scores of matched minerals and lithologies were then recorded for each unit.

4. Experiment results

The false color image of MNF bands 4, 3, and 2 composition, showing four major geologic units in the Maridiani Planum area. Visually comparing the geologic units mapped by the OMEGA false-color image and the geologic unit map based on morphology, topography, and hematite index from Arvidson et al. (2003), it is clear that they matched very well. It is also found that the Ophir-Candor Chasmas area can be divided into 3 geologic units based on false-color image of MNF band 4, 3, and 2 of ORB548_3, and it can be used to update the USGS “geologic” unit map, in which 9 different units were mapped[1].

5. Conclusion

This paper developed a 4-step procedure to delineate the geologic unit map using the ESA’s OMGEA/Mars Express data and proved the method to be efficient. Two areas (Meridiani Planum and Ophir-Candor Chasma) were chosen to test the methods, some good results have been achieved by compared with previously well-known rock and mineral compositions derived from TES, THEMIS, and Opportunity Rover as well as the USGS “geologic” unit map. The minimum noise fraction (MNF) method is an efficient method to derive noise-free principle components that can be used to delineate the Martian geologic units. It is found that the MNF band 1 is mostly related (positively or negatively) to the albedo (r up to 0.83-0.98) of the hyperspectral imagery, while the MNF bands 2, 3, and 4 contained almost all lithologies information for making an informative and useful geologic unit map.

References

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