A Study of Compositional Mapping of Lunar Surface using Chandrayaan-1 HYSI Sensor Data

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Abstract: The paper presents the study of compositional mapping of the lunar surface using Chandrayaan-1 Hyperspectral remote sensing data from hysi sensor for mineral abundance mapping. The paper covers the standard technique which provides an excellent opportunity for mineral exploration. Compositional mapping of the lunar surface is significant to understand the origin and evolution and different lithological units present on the surface of the moon. The Hyperspectral data offers a platform to discriminate the minerals on the lunar surface.

1. Introduction

The recent advancement in remote sensing is imaging spectroscopy or Hyperspectral remote sensing systems. It has considered as a useful approach for understanding the composition of the earth and planetary surface. The Recent Hyperspectral sensor which maps the lunar surface in many narrow contiguous bands from visible to near- infrared has allowed spatial and spectral characteristic features of minerals which helps in mineral abundance mapping of the lunar surface and hence leads to identify the rock types in the area. Moon minerals are distinguished in the visible to near-infrared reflectance spectra by different absorption bands caused by transitions of electrons in a the crystal field [2] The shape of the absorption ,the strength and the wavelength position across the spectrum are controlled by the crystal arrangement and composition of the mineral [3].The characteristic absorption features at different wavelengths across the electromagnetic spectrum is mainly because of electronic transitions and vibrational processes [1]. The presence of transition metal like Fe^{2+}, Mg^{2+}, in the atomic structure of minerals gives rise to electronic transitions in the near-infrared region from 700 nm to 2500 nm of the electromagnetic spectrum[1]. These electronic transitions vibrational process results in characteristic absorption features at specific wavelengths which are peculiar to composition of a mineral.

Many mission to acquire information from the moon including mariner in 1970 and Clementine mission of NASA was launched in 1994 on board UV-VIS imager was a multispectral imager captures the information in five bands at different crucial wavelengths and many more. The recent mission from ISRO’s Chandrayaan-1 spacecraft launched in October 2008 carrying total

11 payloads out of which five indian instruments and six were the guest instruments. it carries three Hyperspectral sensors specially designed for mineralogical studies Infrared (SIR-2) from Max-Planck Institute for Solar System Research, Germany, Moon mineralogy mapper of NASA, and Hyperspectral Imager (HySI) from ISRO. The guest instrument measured the reflected solar radiations in the spectral range from 430 nm -3000 nm with the spectral resolution of ~20 nm to ~40 nm [4].the Indian instrument Hyperspectral Imager HySI worked in push-broom mode and recorded the reflected solar radiation from the lunar surface in 64 contiguous bands in the spectral range 420 nm – 964 nm with the spectral resolution better than 15 nm [5].

2. Spectroscopy of the Lunar Surface

The common rock forming mineral on the lunar surface can be identified by examining the reflectance spectra [6].the iron bearing minerals like olivine and pyroxene which are the most abundant mafic minerals have electronic transition absorption band due to Ferrous ion at near infrared wavelengths [14]. The position of the absorption bands the shape and the strength indicates the crystal structure and the composition of the mineral and these are the diagnostic parameters for identifying the mineral abundance. Pyroxene have absorption band near 1000 and 2000 nm and olivine has three overlapping absorption bands near 1000 nm [7, 8]. The figure 1 shows the reflectance spectral of common mafic minerals superimposed with the five clementine UV-VIS bands.

The absorptions near 1000 nm and 2000 nm for pyroxene these characteristic absorption bands position vary across the spectrum with the pyroxene composition .the 1000 nm absorption shifts toward the longer wavelength with increase in abundance of Ca and Fe and towards the shorter wavelength with decreased abundance of Ca and Fe. typically the Band I centers for Pyroxenes are between 900–935 nm for low-Ca pyroxenes (LCP), 910–1070 nm for high-Ca pyroxenes (HCP) and Band II centers between 1780–1970 nm for low-Ca pyroxenes and _1970–2360 nm for high-Ca pyroxenes. This forms the basis for discriminating low-Ca pyroxene-rich noritic rocks from high-Ca pyroxene-rich gabbroic rocks. [9,10]. the olivine shows the broad absorptions near 1000 nm and it is composed of three overlapping absorption bands and generally lacks the 2000 nm absorption unless it has contaminations as in the figure it has absorption near 2000 nm because of the presence of spinel. The plagioclase is often bright across the spectrum and has a weak absorption feature near 1300 nm. These typical absorptions across the electromagnetic spectrum helps to discriminate among different mafic minerals which intern gives clues to identify different lithological units and studying the stratigraphy which helps to understand the history and the evolution of the lunar surface.

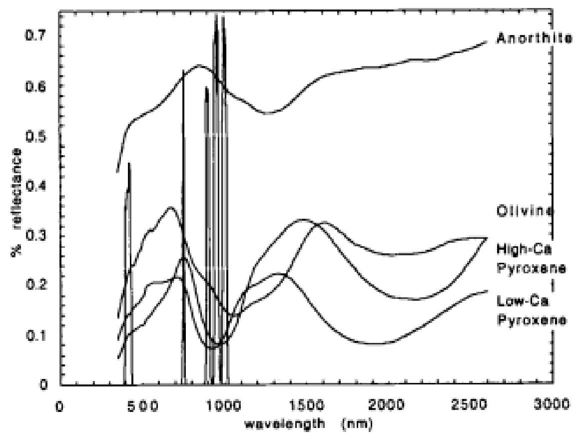

Figure: 1 Reflectance Spectra of Typical Lunar Minerals

2.2 Role of Space Weathering

Because of the Space weathering which is caused by the constant bombardment of the surface by micrometeorites and high energy particles causes the significant changes to the reflectance spectra which weakened the absorption features and decreased albedos. The effect of lunar type space weathering causes weak absorption features, reddened continuum slopes and decreased in the albedos [11]. The soil maturity is also considered as an important factor for accurate observation of absorption features using compositional mapping of remotely sensed data for reliable interpretation. There are many approaches which deal with maturity in order to interpret the results from compositional mapping [12].

3. Band Parameters

The band parameter mapped spectral and spatial variation more easily then the qualitative assessment .The use of different Spectral band parameters for Compositional mapping of lunar surface is a standard technique [13, 14, and 15]. there are three band parameters which was originally derived from UV-VIS data later extended and applied on the Hysi data by [10] for lithological mapping of the lunar surface for mare Mascovience and interpreted different lithological units containing different mafic minerals.

The band parameters are band strength; band curve and band tilt which is used primarily for mapping the mafic minerals on the lunar surface. The following section gives the detail about the band parameters.

3.1 Band Strength

The band strength parameter helps to estimate the abundance of the mafic minerals by the analyzing the strength of the 1000 nm absorption band. the band strength parameter derived for original clementine data by Tompkins and Pieter [18] which was originally derived for clementine data is given by the following equation and later due to the band limitation of hyperspectral imager sensor it was modified by [10].the band strength is directly related to the depth of the absorption band and it is indicative to the relative presence of the mafic minerals and insensitive to the type of minerals.

$$BS = R_{947.7}/R_{748.3} \text{ ----------- } (I)$$

3.2 Band Curve

The band curvature is indicative of the type of the mafic mineral present and it is specifically sensitive to pyroxene composition. This parameter can be derived using hysi bands by the following equation suggested by [10] that the curve decreases from low Ca pyroxene LCP bearing noritc rock to high Ca pyroxene HCP bearing gabbroic rock and it is further decreases for the olivine dominant rocks. The spectral Curve increase towards the longer wavelength as the wavelength of the absorption band moves towards the longer wavelengths.

$$BC=(R_{748.3}+R_{947.7})/R_{898.0} \text{---------} (II)$$

3.3 Band Tilt

The band tilt parameter is also the intensity ratio and it is complementary to the band curvature as shown in the expression. The high values of band tilt show the area which is abundance of Clinopyroxene and olivine. The parameter defined by [16] as difference in reflectance at crucial wavelengths and later modified by [14] as the ratio of 900 nm and 1000 nm. The formulation was implemented on the Hysi data by [10] and due to the band limitations of Hysi it is further modified as in given in the expression

$$BT = R_{898.0}/ R_{947.7} \text{-----------} (III)$$

4. Discussion

the band parameters is used to create the false color composites of the given area by assigning the band strength to blue, band curve to red and band tilt to green and the spatial variation results can be interpreted. the band strength values are high for rocks with low ferrous absorption such as anorthosites .the matured soil and anorthosites lacks the 1000 nm absorption feature so has high Bs values as compared to unweathered region which are rich in mafic minerals with strong 1000 nm absorption feature.

The band curvature as it is assigned to red, the high band curvature values at the shorter wavelength and low curvature value at the longer wavelength. the high band curvature values appears red to pink showing the abundance of low Ca pyroxene bearing noritic rock and the values decrease for high Ca pyroxene bearing gabbroic rock. The third parameter assigned to the green color and it reflects the area containing high Ca pyroxene and olivine will appear in shades of green to yellow.

Conclusion:

In the present article we did the study of mineral abundance mapping using hysi data. The standard technique using different band ratios at crucial wavelength to delineate mineralogy and extracting meaning full information was studied. However the limitation of the spectrum coverage of Hysi sensor will only suggest the local mineralogy trends and data at the longer wavelengths is required to confirm and discriminate between different mineralogy. The same techniques can be used for mineral abundance mapping for different parts of the lunar surface using Hysi data.

References:

1. Burns, R. G., Mineralogical Applications of Crystal Field Theory, Cambridge University Press, New York, 1970
2. Burns, R. G. (1993). Mineralogical applications of crystalfield theory (Vol. 5). Cambridge University Press
3. Kramer, G.Y. (2010). Characterizing bedrock lithologiesusing small crater rim and ejecta probing (SCREP). Advances in Space Research. 45 (10), 1257–1267.
4. Green, R. O. et al., 2011.The Moon Mineralogy Mapper (M3) imaging spectrometer for lunar science: instrumentation, calibration, and on-orbit measurement performance. J. Geophys. Res., 116, E00G19
5. Kumar, A. et al., Hyper spectral imager for lunar mineral mapping in visible and near infrared band. Curr. Sci., 2009, 96, 496.
6. McCORD T.B AND ADAMS J. B(1973) progress in remote optical analysis of lunar surface composition . The Moon 7,453-474
7. ADAMS J B (1974) visible and near infrared diffuse reflectance spectra of pyroxene as applied to remote sensing of solid objects in the solar system. j geophys. res 79,4829-4836
8. BURNS R.G. (1970) crystal field spectra and evidence of cation ordering in olivine minerals Am.mineral. 55 , 1608-1632
9. Cloutis, E.A., Gaffey, M.J., 1991. Pyroxene spectroscopy revisited: Spectralcompositional correlations and relationships to geothermometry. J. Geophys. Res. 96, 22809–22826.
10. Bhattacharya, S., Chauhan, P., Rajawat, A. S., Ajai and Kiran Kumar, A. S., Lithological mapping of central part of Mare Moscoviense using Chandrayaan-1 Hyperspectral Imager (HySI) data. Icarus, 2011, 212, 470–479.
11. Hapke, B., 2001. Space weathering from Mercury to the asteroid belt. J. Geophys. Res. 106, 10039–10074. doi:10.1029/2000JE001338
12. Pieters, C., Shkuratov, Y., Kaydash, V., Stankevich, D., Taylor, L., 2006. Lunar soil characterization consortium analyses: Pyroxene and maturity estimates derived from Clementine image data. Icarus 184, 83–101. doi:10.1016/j.icarus.2006.04.013.
13. Tompkins, S., Pieters, C.M., 1999. Mineralogy of the lunar crust: Results fromClementine. Meteor. Planet. Sci. 34, 25–41.
14. Dhingra, D., 2008. Exploring links between crater floor mineralogy and layeredlunar crust. Adv. Space Res. 42 (2), 275–280. doi:10.1016/j.asr.2007.10.024
15. Isaacson, P.J., Pieters, C.M., 2009. Northern Imbrium Noritic Anomaly. J. Geophys.Res. 114, E09007. doi:10.1029/2008JE003293
16. Pieters, C.M., Gaddis, L., Jolliff, B., Duke, M., 2001. Rock types of South Pole-Aitken basin and extent of basaltic volcanism.J.Geophys. Res. 106,28001-28022.doi:10.1029/2000JE001414.