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Research Article

DISCOVERY OF LUNAR OLIVINE WITH OH/H_2O BAND AT MOSCOVIENSE BASIN USING HYPERSPECTRAL IMAGING SPECTROMETER DATA (M^3)

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ABSTRACT
Hyper spectral imaging spectrometer data (M^3) has allowed identifying olivine mineral with OH/H_2O band in Moscoviense basin on the Moon surface. Moon Mineralogy Mapper (M^3) sensor records the reflected radiance between 0.46 and 2.97 μm in 85 contiguous spectral bands, between 20 – 40 nm spectral sampling with 140 m/pixel spatial resolution from the Moon's surface in push broom mode. A spectral reflectance profile was collected (average of 3 pixels) and modeled and continuum was removed. Automatic straight-line approximations continuum-removal method was used for removing background continuum. A strong absorption band near 1000 nm and moderate absorption band near 2800 nm wavelength regions have been observed due to presence of olivine mineral with OH/H_2O band. The olivine sample with OH/H_2O band indicates that magmatic water could be present in the lunar olivine. Presence of olivine along with OH/H_2O band could be of endogenic origin. One paragraph only (Maximum 200 words).

Keywords: *Hyperspectral, Olivine, OH/H_2O Band, Moon, Moscoviense Basin, Moon Mineralogy Mapper*

INTRODUCTION
Identifying mineral distributions on the lunar surface provides clue to know the origin, crustal evolution, geological history and stratigraphy of the Moon. Olivine is a useful mineral to evaluate the geologic evolution of igneous planetary bodies such as the Moon (Isaacson *et al.,* 2011). Olivine represents the exposure of the lunar mantle, but could also represent differentiated plutons resulting from secondary magmatic intrusions into the lunar crust (Yamamoto *et al.,* 2010). At the present time, imaging spectroscopy provides finest information about the planetary surface to discriminate various minerals across the spectrum. The M^3 onboard Chandryaan-1 provides hyperspectral data of lunar surface to study about the Moon. In this paper, olivine with OH/H_2O band mineral is investigated using M^3 data in the part of Moscoviense basin.

Visible to near-infrared reflectance imaging spectroscopic data is helpful for identifying minerals on the Moon surface due to analytical absorption bands as a result of transitions of electrons in a crystal field (Burns, 1993). The spectral (spectra) characteristics such as shape and absorption centers are useful for identifying various minerals. Many literatures are provides insight into detection of minerals on the lunar surface based on minerls absorption characteristics (Anbazhagan and Arivazhagan, 2010; Sivakumar and Neelakantan, 2014; Anbazhagan and Arivazhagan, 2010; Klima *et al.,* 2011; Adams, 1974). The olivine and OH/H_2O minerals can be identified based on absorption characteristic near 1000 nm and 2800 nm wavelength regions (Isaacson *et al.,* 2011; Bhattacharya *et al.,* 2014; Clark, 2009; Pieters *et al.,* 2009; Saal *et al.,* 2008).

Regional Setting
Moscoviense basin is a multiringed impact basin located in the far side of the Moon at 27°N, 148°E (Figure 1). A recent study suggested that the Moscoviense Basin is actually the thinnest on the entire Moon (Ishihara *et al.,* 2009) using data from the Japanese Mission, Kaguya. The basin was first identified as a large region of dark mare in Luna 3 spacecraft images, launched in 1959 by the USSR. Moscoviense basin has been filled by mare basalts of varying compositions (Craddock *et al.,* 1997; Kramer *et al.,*

2008). The unique geologic setting of the Moscoviense basin may be helpful for understanding the Moon lower crustal materials and series of magmatic intrusions.

MATERIALS AND METHODS

Data Used

M^3 data was used for identifying olivine with OH/H_2O band in the Mare Muscovine basin of the Moon. M^3 sensor was a guest instrument from NASA, which was on the Chandrayaan-1, the Indian Space Research Organization's (ISRO) first mission to the Moon (Goswami and Annadurai, 2009). M^3 sensor records the reflected radiance from the Moon's surface in pushbroom mode between 0.46 and 2.97 μm in 85 contiguous spectral bands, between 20 – 40 nm spectral sampling with 140 m/pixel spatial resolution (Pieters *et al.*, 2009). Photometrically calibrated and pixel-located reflectance image (Level-2) was downloaded from http://ode.rsl.wustl.edu/moon/. Optical period-2 coverage was used for identifying mineral.

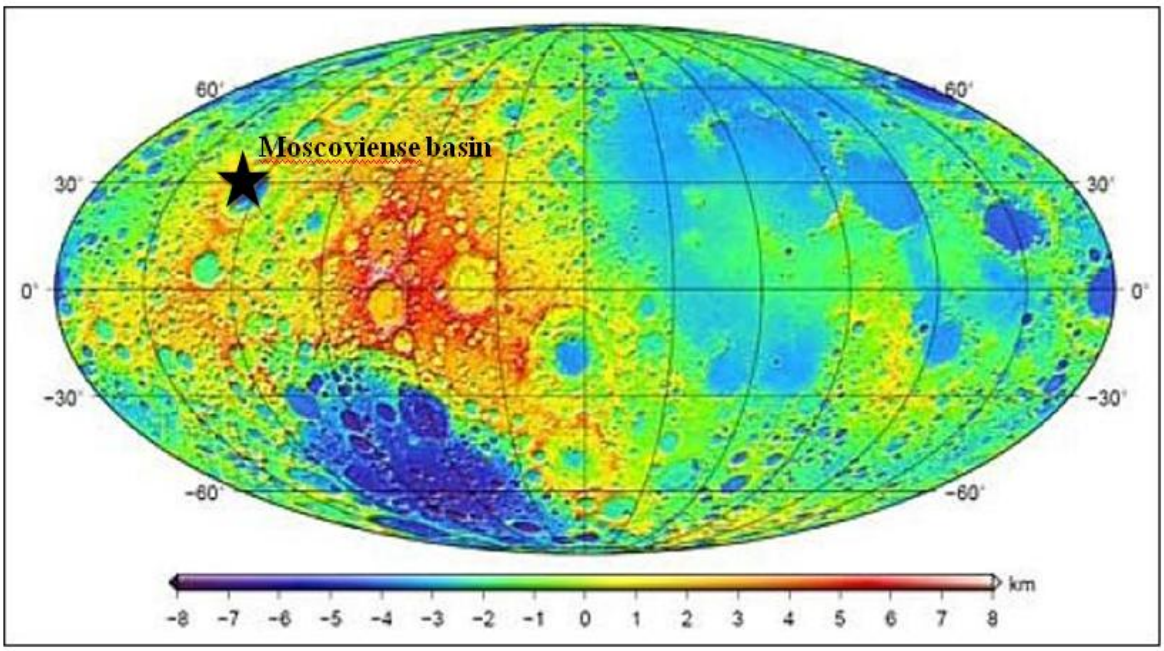

Figure 1: Black color star mark shows study area location on the topography of the Moon from the Chang'E-1 laser altimeter data (Image CREDIT: SHAO/CAS, Wuhan University). Approximate geographic location of the spectral sample is 22°38'3. 08"N and 147°52'37. 32"E.

Methodology

ENVI image processing software was used for collecting, modeling and analyzing mineral spectra. M^3 data was clipped for analyzing mineral in the basin region. Spectral reflectance profile was collected (average of 3 pixels) and modeled and continuum was removed for the reflectance spectra for better understanding of absorption parameters. Automatic straight-line approximations continuum-removal method was used for removing background continuum (Clark *et al.*, 1987).

RESULTS AND DISCUSSION

Results

Figure 2 and Figure 3 shows the reflectance and continuum removed spectra of olivine with OH/H_2O band, respectively. A location of the sample spectra is shown in the Figure 1. Olivine rich area located in the southern edge of the inner ring of the basin. Olivine rich spectra shows strong absorption band near

1000 nm (Isaacson *et al.*, 2011). The spectra shows typical absorption bands near 2800 nm wavelength regions due to OH/H_2O content in the sample (Bhattacharya *et al.*, 2014; Clark, 2009; Pieters *et al.*, 2009). Theses specific absorption indicates the presences of olivine mineral with OH/H_2O band.

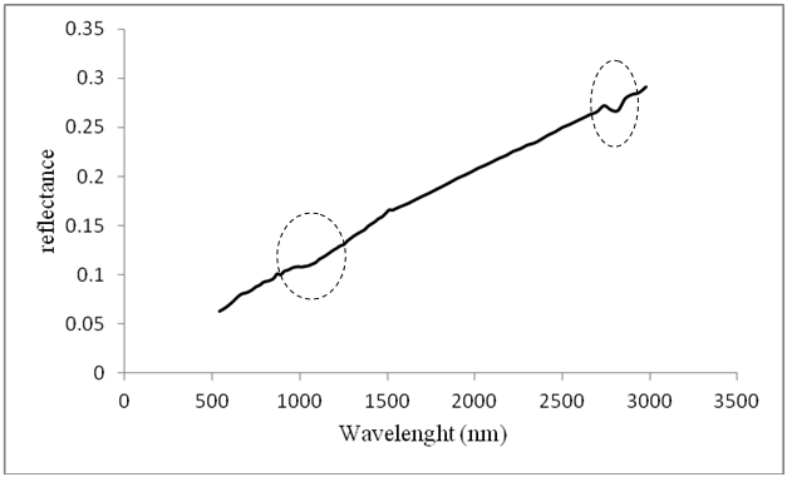

Figure 2: Reflectance spectra of olivine with OH/H_2O band. Sample location is shown on the Figure 1. Absorption near 1000 nm shows presence of olivine and near 2800 absorption indicates OH/H_2O band. Doted circle shows absorption region of the sample spectra.

Figure 3: Continuum removed reflectance spectra olivine with OH/H_2O band. Sample location is on the Figure 1. Absorption near 1000 nm shows presence of olivine and near 2800 absorption indicates OH/H_2O band. Doted circle shows absorption region of the sample spectra.

Conclusions

Hyperspectral imaging spectrometer data has allowed identifying lunar olivine with OH/H_2O band. Olivine rich spectra shows strong absorption band near 1000 nm and also near 2800 nm wavelength region due to presence of OH/H_2O band in the sample. The sample contains OH/H_2O band, it indicates that magmatic water could be present in the lunar olivine. Presence of olivine along with OH/H_2O band could be of endogenic origin. This study put forward that hyperspectral imaging spectrometer data is extremely suitable for mapping and identifying the minerals on the Moon surface. Further scope of the

study would be identifying similar spectra at different locations with thermal corrected different optical period data.

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