DETECTION POSSIBILITY OF MANTLE MATERIALS BY MULTI-BAND IMAGER. N. Asada[1], K. Kimura[1], T. Hodokuma[1], H. Demura[1], N. Hirata[1], M. Ohtake[2], J. Haruyama[2] and T. Matsunaga[3], [1] The University of Aizu (Tsuruga, Ikki-machi, Aizu-Wakamatsu city, Fukushima pref., 965-8580, JAPAN, asada@u-aizu.ac.jp), [2]Japan Aerospace Exploration Agency, Institute of Space and Astronomical Science (3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, JAPAN), [3]National Institute for Environmental Studies, Center for Global Environmental Research (16-2 Onogawa, Tsukuba, Ibaraki 305-8506, JAPAN).

Introduction: Clementine was launched over 10 years ago and surveyed whole the lunar surface. The observed wavelengths of visible camera on Clementine mission were 5 bands (0.415, 0.75, 0.90, 0.95 and 1.00 μm), and there spatial resolutions were originally 100 to 200 m, but, effectively about 500m.

After Clementine exploration contents of Ca poor pyroxene, Ca rich augite, olivine and plagioclase were estimated and rock types were identified from only 4 visible bands, i.e., too poor information to give enough analysis.

In addition, stirring phenomena of different mineral species should occur at cratering processes, which are very common on the whole lunar surface. It is well known that reflection spectra of mixture minerals might be very resembled to that of the other mineral, where the reflection spectrum of olivine and Ca poor pyroxene mixture is easy to confuse that of Ca rich augite.

Here, the possibility of distinguishing the lava flow and the mantle materials on the crater walls or on the crater central peaks is described from both high spatial resolutions and effective observational wavelengths of Multi-band Imager, hereafter called MI, on SELENE mission.

Geologic structure of the lunar ocean: It is well known that lunar basins are covered by thick strata which consist of mainly basaltic lava and impact ejecta, while whole the lunar surface is covered with regoliths which consist of mixture of rocks crushed by micro-impacts and impact ejecta [1].

In addition, viscosity of basaltic lava flow at the time of the spout is low enough to flow over several hundred km with only a few tenth m in thickness.

It is quite important and meaningful to know geologic strata information compared to the depth by considering impact craters as natural boring holes.

Space weathering process: The lunar surface materials are damaged by the space weathering process in general. The reflectance becomes gloomy depending on degree of space weathering and the reflection spectrum of the continuum tends to rise at longer wavelength side, while after the continuum spectrum around 1 μm band is approximated by a line, the original spectrum is estimated by dividing with the line spectrum in general.

Although this method is useful for estimating the original spectrum of damaged minerals, it is very difficult to identify the rock types of the lunar surface materials with strong space weathering.

Multi-band Imager on SELENE mission: MI is one of remote sensing instruments loaded on the SELENE mission, in which there are 5 visible bands with 10 bits data at 415, 750, 900, 950, 1,000 nm in wavelength and 4 NIR bands with 12 bits data at 1000, 1050, 1250, 1,550 nm in wavelength, where the nominal spatial resolution is 20m/pixel in the visible bands and 62m/pixel in the NIR bands.

Characteristics of MI are as follows. (1) The 900 ~ 950 nm pyroxene absorption band can be separated. (2) The olivine absorption band near 1.05 μm and the shoulder absorption feature near 1.25 μm can be detected. (3) The plagioclase absorption band near 1.25 μm can be detected and shock degree of plagioclase can be estimated. (4) The effect of space weathering can be removed by deciding the continuum curve around 1 μm band from observations up to 1.55 μm.

In addition, observed data both from TC, Terrain Camera, and from SP, Spectral Profiler, which belong to the same LISM/SELENE team, can be utilized in analysis of MI data. In case of identification and classification of minerals and rock types, the detailed SP spectrum is very useful, while the reflectance can be corrected not only for the phase angle but also for the incidence angle and for the emission angle from DTM, Digital Terrain Model, made from TC data.

Classification of minerals by ratio operation: SELENE takes the polar orbit for whole the lunar surface scanning, in which the phase angle of lunar surface decided by the solar altitude depends on both the lunar latitude and observed lunar time. However, both the incidence angle on the moon and the emission angle from the moon depend on the inclination of observed lunar surface, while the phase angle is easily decided from the sun altitude because of the right under apparent of MI.

The ratio operation pictures among the pictures with different wavelength after correction of the phase angle from the sun altitude could apparently show difference of the lunar surface materials, if the lunar surfaces were totally flat.

However, it is well known that results of simple ratio operations show not differences of minerals but existence of crater walls or central peaks, if geographical inclination is too large such as the crater wall or the crater central peak.

Hapke model: Many scientists derived theories or experimental formulae of light scattering by particles including Mie theory as a representation. Hapke model is the most generally used for the scattering function of accumulated many powder particles such as the lunar surface in spite of its too simplified model.

$$R(\theta_i,\theta_e,w)=\{w/4(\mu_i+\mu_e)\}\{P(g,w)+H(\mu_i,w)H(\mu_e,w)-1\}$$

$$\mu_i = \cos\theta_i,\ \mu_e = \cos\theta_e,\ g = \theta_e - \theta_i$$

$$H(\mu,w)=[1-\{1-(1-w)^{1/2}\}\mu\{r_0+(1-r_0/2-r_0\mu)\ln(1+\mu^{-1})\}]^{-1}$$

$$r_0 = 2/\{1 + (1-w)^{1/2}\} - 1$$

where, $R(\theta_i,\theta_e,w)$ denotes reflectivity with the incidence angle θ_i and the emission angle θ_e to the scattered material on the isotropic scattering plane i.e., Lambert plane, w is the single particle albedo, P(g,w) is the phase function which denotes the ratio scattered to the phase angle g, and the H function denotes contribution of multiple scattering [3]. The single particle albedo for compounded materials is given by the following expressions.

$$w = \langle Q_S\rangle/\langle Q_E\rangle$$

$$\langle Q_S\rangle = \Sigma\sigma_i Q_{Si},\ \langle Q_E\rangle = \Sigma\sigma_i Q_{Ei}$$

where, Q_S and Q_E are scattering efficiency and extinction efficiency, respectively and σ_i is the total scattering cross section ratio of component minerals.

Correction of geographical influence: Digital terrain model of the moon, hereafter called DTM, with spatial resolution of 10 m/pixel will be obtained after analyzing TC data. More advanced analysis becomes possible after considering not only the phase angle correction but also the incidence angle and the emission angle correction if this geographical model of the moon is taken into account.

The outcrop of the mantle substance, which is in the lower stratum of the moon, is possible to be formed at the time of a crater formation larger than 100 km in the diameter, although whole lunar surface is covered by regoliths. MI has enough spatial resolution to separate or to detect the outcrop of the mantle substance at the crater walls or the crater central peaks.

The reflection spectrum after simultaneous correction of the phase angle, the incidence angle and the emission angle by using topographical inclination data may be able to distinguish the ejecta materials, the lava flow materials and the mantle materials, and furthermore has the possibility to analyze some physical properties of the minerals.

Conclusive remarks: A part of above-mentioned analysis can be done early after the launch of SELENE, and can be fed back from the result of the analysis to the exploration plan of other areas. An early analysis is intended to contribute on the success of the whole SELENE project.

References:

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