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REGOLITH THERMOPHYSICAL FEATURES OF MARE SMYTHII IN VERTICAL DIRECTION REVEALED BY CE-2 MRM DATA

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ABSTRACT

Mare Smythii is a special basin, which is one of the oldest mare basins with the considerably young mare basalts and the high density of floor-fractured craters. In this paper, the Chang'E-2 (CE) lunar microwave radiometer (MRM) data was used to evaluate the thermophysical features of the floor deposits in mare Smythii. Based on the theoretical simulation and the previous geological results, several special findings are noted as follows. (1) The substrate temperature in mare Smythii is likely fairly high. (2) The regolith thermophysical parameters change greatly with depth in the northeast unit, and there probably exists a special material in the shallow layer of the lunar regolith with strong thermal absorption ability. These special findings will be of fundamental significance to improve understanding the thermal evolution of the Moon.

Index Terms— microwave propagation, remote sensing, Mare Smythii, thermal anomaly, high substrate temperature

1. INTRODUCTION

Mare Smythii, centered at 2° S and 87° W, is one of the most ancient regular impact basins with multiple ring structures (Fig.1). It is located at the eastern limb of the lunar nearside, which extends from the main mare regions in the west part (nearside) to the highlands in the east part (farside). Mare Smythii contains valuable information about the primary and secondary crustal formation processes on the Moon [1][2][3]. Therefore, the study on mare Smythii can provide fundamental information about the thermal evolution of the Moon.

Until now, mare Smythii has been thoroughly studied with the Lunar Orbiter, Apollo photographs, Apollo X-ray data, Clementine ultraviolet-visible (UV/VIS), gravity, and topography data [1][2][3][4]. It is one of the most geologically diverse areas, which has the rather old basin floor deposit in the southwest interior and fairly young mare deposit in the northeast interior of the basin [2][5] (Fig.1).

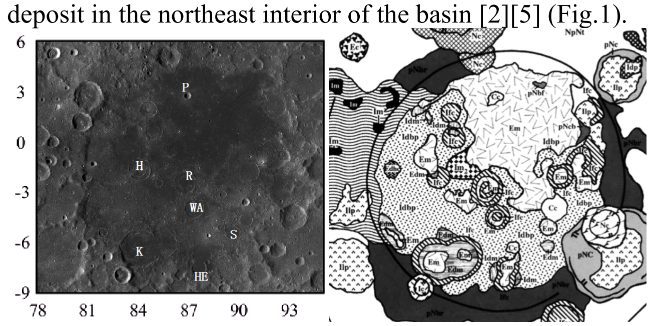


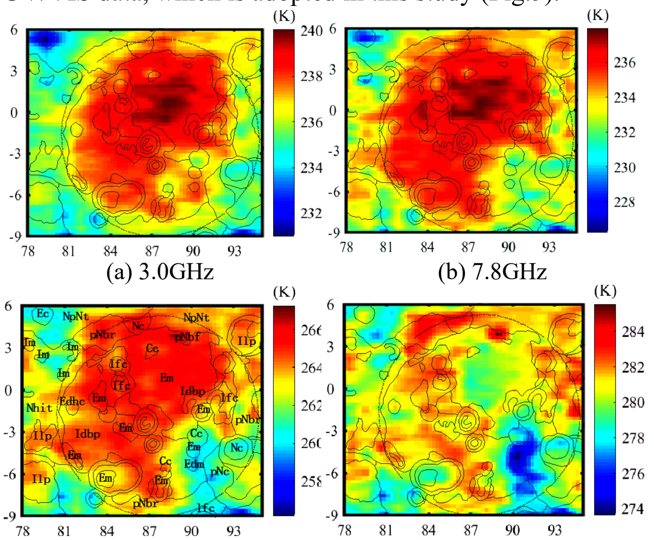
Fig. 1. (a) A mosaic of optical images from LROC showing the geography of Smythii Basin: Haldane (H); Kiess (K); Peek (P); Runge (R); Swasey (S); Warner (WA) (The unit used for the geological coordinate system is given in decimal degree.) and (b) Geological map of Smythii [2][6]. Solid line indicates the crest of basin ring.

2. CE-2 MRM DATA PROCESSING

To obtain the TB maps of mare Smythii, the first step is to ascribe the TB points into 24 time intervals, one hour in one time interval, using the hour angle method [7]. According to the range of mare Smythii, the study area is defined from 9° S to 6° N along the latitude and 78° E to 95° E along the longitude. Through the comparisons of the scatter plots of the selected TB points in the 24 time intervals, the MRM data in the time intervals from 12:00 to 13:00 and from 21:00 to 22:00 are the best candidates to represent the TB at daytime and nighttime, respectively. Moreover, compared to the apparent change of the TB with the latitude, the change of the TB with the longitude is small. Thus, the linear interpolation scheme was properly used to generate daytime TB (Fig.2) and nighttime TB maps (Fig.3) with a spatial resolution of 0.25° × 0.25°.

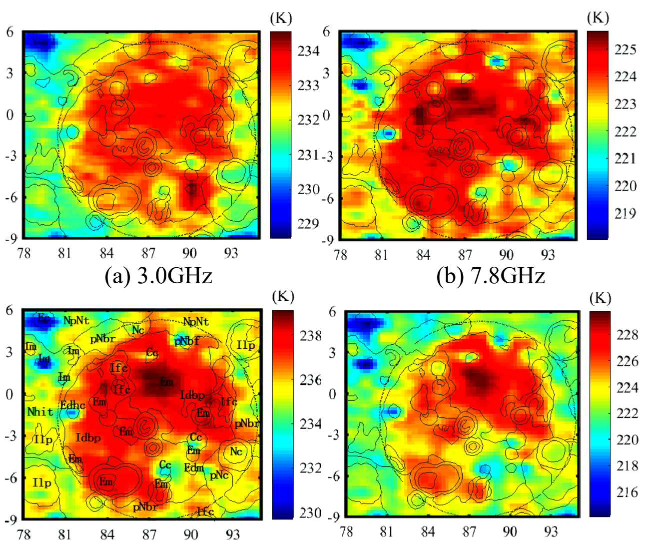
The TBD, defined as the difference between the daytime and nighttime TB values of the same frequency, is proposed to be directly related to the regolith thermophysical parameters within the penetration depth of the corresponding microwave [8][9]. Therefore, the TBD maps were also generated with the interpolated daytime and nighttime TB data in this study

The (FeO + TiO_2) abundance (FTA) is the decisive factors for the TB performances of the mare units [10]. Additionally, the methods developed [11] are widely used to retrieve the FeO and TiO_2 abundances with Clementine UV/VIS data, which is adopted in this study (Fig.5).



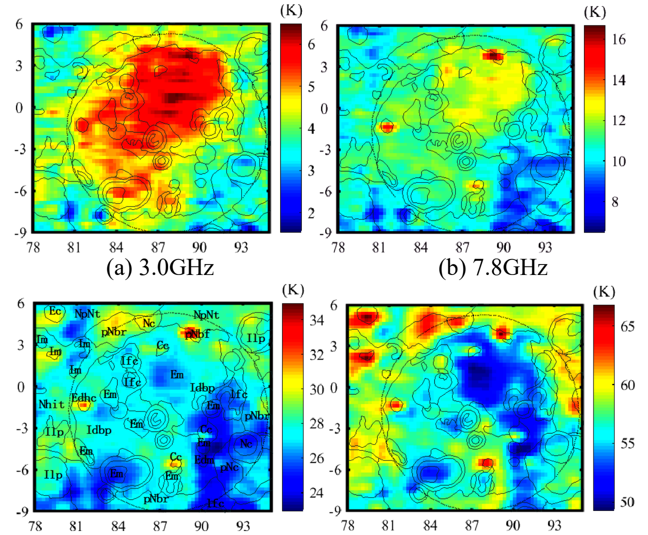
(a) 3.0GHz (b) 7.8GHz
(c)19.35GHz (d) 37.0GHz

Fig. 2. TB maps of mare Smythii at daytime: (a) 3.0 GHz, (b) 7.8 GHz, (c) 19.35 GHz, and (d) 37 GHz.



(a) 3.0GHz (b) 7.8GHz
(c)19.35GHz (d) 37.0GHz

Fig. 3. TB maps of Mare Smythii at nighttime: (a) 3.0 GHz, (b) 7.8 GHz, (c) 19.35 GHz, and (d) 37 GHz.



(a) 3.0GHz (b) 7.8GHz
(c)19.35GHz (d) 37.0GHz

Fig. 4. TBD maps of Mare Smythii: (a) 3.0 GHz, (b) 7.8 GHz, (c) 19.35 GHz, and (d) 37 GHz.

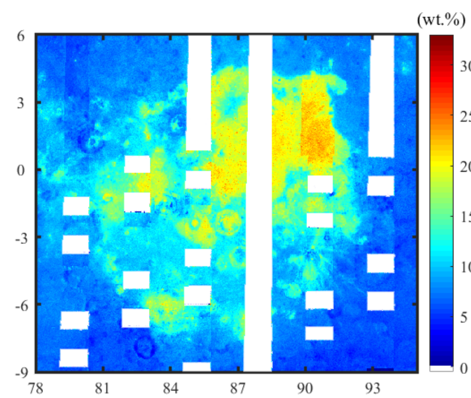


Fig. 5. FTA map of Mare Smythii. White regions represent no data.

3. RESULTS AND DISCUSSIONS

3.1. TB Anomaly in basin floor

Figs.2 and 3 show that the TB in Em unit with elevated FTA is higher than that in Idbp unit with moderate FTA, which is rational according to the simulation results. But the daytime TB at 37 GHz in Em unit is lower than that in Idsp unit, which is not rational. Particularly, the FTA in Smythii floor is clearly higher than the nearby highland NpNt unit, while the TB in the former is higher than the latter no matter at daytime and nighttime.

Similar findings also occur in maria Nubium, Moscoviense and Orientale [12][13][14]. Combined with the theoretical simulation, Meng et al. [13] thought that there were four possible explanations to the abnormally high TB both at daytime and at nighttime, including the FTA, surface slope, rock abundance, and the substrate temperature. The FTA is eliminated because the observed nighttime TB is just opposite to the theoretical simulation. The surface slope can also be omitted because the region with TB anomaly is just located near the lunar equator with almost the subsolar illumination at daytime. Also, the rock abundance is excluded for the study [15] suggested the relatively lower nighttime TB in the regions with abundant rocks, opposite to the observations in this study.

Therefore, the only left parameter is the substrate temperature, that is, the higher substrate temperature brings about the warmer TB at nighttime. Thus, the substrate temperature of the lunar regolith in mare Smythii is likely much higher than what we know.

However, this hypothesis does not support the finding about the daytime TB at 37 GHz, which is lower in Em unit than that in the nearby Idbp unit and even the highland NpNt unit. Fortunately, this validates the rationality of the hypothesis. Considering penetration depth of the used microwave, a temperature structure can be constructed in Smythii

3.2. Change of regolith thermophysical features with depth

The change of regolith thermophysical features with depth has not been reported by other studies with the remote sensing techniques. To better understand the issue, we first hypothesize that the thermophysical parameters of the regolith are constant with depth, if the TBD of the deposits does not change with frequency compared to its nearby regions. Thus, if the TBD of one region clearly changes with frequency compared to its nearby regions, it is likely brought by the change of the regolith thermophysical parameters with depth.

Since the regolith in mare Smythii is rich in ilmenite content, the microwave signal can only penetrate the regolith to about 10 times the wavelength [8]. That is, the penetration depth is about 1 m at 3.0 GHz, 38.5 cm at 7.8 GHz, 16.5 cm at 19.35 GHz, and 8.1 cm at 37 GHz. Therefore, Fig.4 shows a good description of the change of the regolith thermophysical features with depth in lateral and vertical directions combined with Figs. 2 and 3, which is expressed as follows.

In the northeast Em unit, the TBD is highest at 3.0 and 7.8 GHz, however, it becomes relatively lower at 19.35 GHz in the central part, and it becomes nearly the lowest at 37 GHz in the majority of the unit. According to the simulation results, this means that the FTA is rich in the substrate layer represented by the 3.0 and 7.8 GHz microwave. However, it is hard to accept that the FTA is absent in the shallow layer represented by the 19.35 and 37 GHz microwave, for the outmost layer of the regolith is also rich in FTA indicated by the optical results in Fig.5.

The probable cause of these findings is the existence of a special material in the shallow layer of the lunar regolith in Em unit, which is strong in the thermal absorption ability. This hypothesis can be verified by the relatively lower 37-GHz TB during the daytime and the highest 7.8-, 19.35-, and 37-GHz TB at nighttime.

4. CONCLUSION

In this paper, the CE-2 MRM data was used to study the thermophysical features of the floor deposits in mare Smythii. Based on the theoretical simulation and the geological results by Gillis and Spudis [2], several special findings about the thermophysical features of the floor materials are proposed.

First, The nighttime TB in Em unit with the highest FTA is highest at nighttime compared to the regions with lower FTA. Thus, we hypothesized and validated that the substrate temperature in Em unit of mare Smythii should be much higher than the nearby regions.

Second, the four-channel TB and TBD maps indicate the great change of the regolith thermophysical parameters with depth in Em unit. Moreover, the comparatively lower daytime TB and TBD at 37 GHz hints that there exists a special material in the shallow layer of the lunar regolith in Em unit, which has a strong thermal absorption ability.

However, the MRM data does not have the ability to pursue the special material existed in the shallow layer of Em unit. More work deserved to be done to further explore the geological applications of the MRM data.

5. ACKNOWLEDGMENTS

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