PLANING A LUNAR LONG-TERM RESEARCH STATION IN MARE SMYTHII

*Wenqing Chang[a], Yanxiang Shi [a, *], Zhiguo Meng[a,b, *], Xiaoping Zhang[b], Alexander Gusev[c]*

a. College of Geoexploration Science and Technology, Jilin University, Changchun 130026, China;
b. State Key Laboratory of Lunar and Planetary Sciences, Macau University of Science and Technology, Macau, China;
c. Institute of Geology, Kazan Federal University, Kazan 420008, Russia.
Tel (86-431)88502362, Fax (86-431)88524544, *shiyx@jlu.edu.cn, mengzg@jlu.edu.cn

ABSTRACT

Mare Smythii is located at the junction of the lunar farside and nearside, and it is rich in the geological diversities and scientific values. In this paper, combined with the SLDEM 2015 elevation data, Clementine UV/VIS data, Kaguya MI data, and Chang'e-2 microwave radiometer data, the geological significance, topography, material composition, and microwave thermal emission features of Mare Smythii are thoroughly analyzed. Then, the region centered at (88°E, 1°N) is proposed for constructing the long-term lunar research station with high priority from the perspectives of scientific research, resources, and energy. Finally, three routes are outlined according to the surface topography, and 14 candidate exploring sites are planned aiming to scientific studies and resource utilizations. This study is of essential significance for the construction of the long-term lunar research stations in future.

Index Terms— Long-term lunar research station, Mare Smythii, Geological importance, Topography, Brightness Temperature

1. INTRODUCTION

The moon is the neighbor of the earth. It can not only provide information about the evolution of the solar system, but also has abundant resources. With the development of the times, the purpose of lunar exploration has been transformed into the comprehensive utilization of lunar resources and the exploration of related scientific issues. For the site selection of lunar research station, predecessors have done a lot of work. Duke et al. [1] proposed three selections of lunar research stations for different scientific objectives. The site principle includes lunar science, resource utilization and lunar settlement. China's Space White paper "2021 China's Space" released in 2021, one of which is to build a lunar scientific research station with the goal of lunar science and resource development and utilization. Xiao et al. [2] combined with the hot lunar science issues of common concern to the international planetary science community, systematically analyzed the scientific issues worthy of attention for China's lunar landing exploration according to China's possible exploration capabilities in the next 15 years (2016-2030), and provided 18 alternative landing areas.

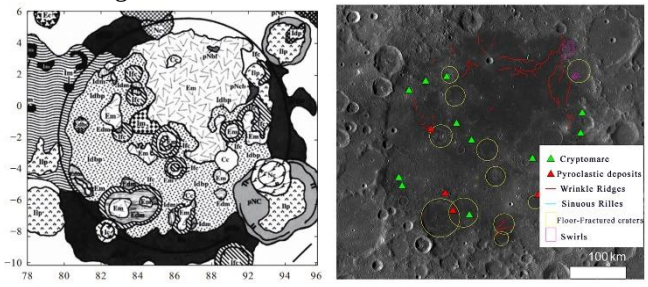
However, there is still a lack of research on the location of long-term stable and comprehensive lunar research stations in the middle and low latitudes. Mare Smythii has abundant geological features and scientific value [3][4]. Mare Smythii can provide observational support for the scientific objectives proposed by Duke et al. [1] and Xiao et al. [2]. Therefore, this paper intends to make a comprehensive description of the scientific basis for the construction of the Smith Sea long-term lunar research station by synthesizing the lunar history and the latest exploration results.

2. MARE SMYTHII FEATURE ANALYSIS

2.1. Geological and Geomorphic features

Mare Smythii (87°E, 1°N) is located at the eastern limb region of the Moon, was formed in the Pre-Nectarian Period [4], is one of the oldest regular impact basins [5].

Based on Clementine data, Gillis et al. [3] re-recognized the geological characteristics of Mare Smythii and provided new geological unit (Fig.1a). Fig.1b show that there are abundant geological characteristics and characteristics of landforms, mainly contain: sinuous rilles, pyroclastic deposits, floor-fractured craters, cryptomare, mare basalt, wrinkle ridges and swirls.



(a) Geological map (b) Geomorphological map

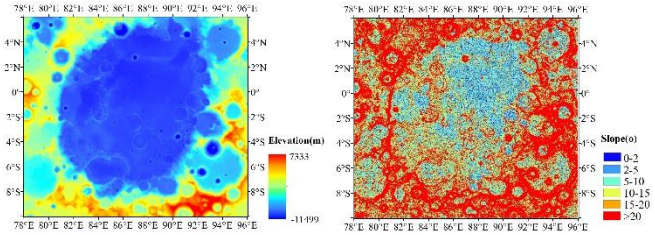
Fig. 1. Geologic feature of Mare Smythii

2.2. Topographic features

Terrain is one of the most important factors for selecting a lunar research station [6]. Based on SLDEM2015 elevation data, the topographic of Mare Smythii are systematically analyzed (Fig.2).

Mare Smythii is about 5 km lower than the northern lunar land and about 7 km lower than the southern highlands. The highest point in the interior is about −2275.4m, and the lowest point is about −5589.4 m. The mean elevation of the basin is about −2952.4 m. The Em unit in the northeast has an average elevation of about −3372.3 m and an average slope of 3.8 °. An Idbp unit with large topography and multiple large impact craters has an average elevation of about −2911.9 m and an average slope of 5.5 °.

The Em unit, the topography is small and the number of impact craters is small, which can fully meet the landing requirements of the landing, and is an ideal area for the construction of long-term scientific research stations on the moon.



(a) Elevation map (b) Slope map

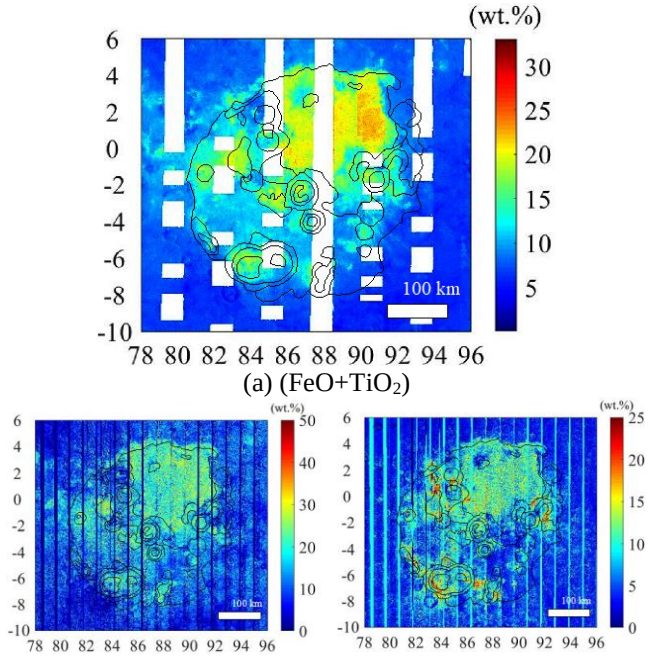
Fig. 2. Elevation and Slope map of Mare Smythii

2.3. Material composition characteristics

In this study, Clementine UV/VIS data and Kaguya MI data were used, and the methods of Lucey et al. [7] and Lemelin et al. [8] were used respectively to invert the composition of substances in the study area (Fig.3).

Fig.3 shows that the contents of FTA, CPX and OL in different geological units in Mare Smythii present an obvious uneven distribution. The contents of FTA, CPX and OL in Em units in northeast basin were the highest and distributed continuously in a large area. The highest value of FTA content in Em unit was about 33.1 wt.%, and the average value was about 19.1 wt.%. The maximum value of CPX was about 40.4 wt.%, and the average value was about 22.5 wt.%. The highest OL value was about 24.9 wt.%, and the average was about 9.3 wt.%.

In the Edm unit, the highest FTA content was found outside the Kiess crater, reaching 16.3 wt.%, the average CPX content was about 12.6 wt.%, and the average OL content was about 11 wt.%. In the floor-fractured craters Ifc unit, the highest FTA content occurs in the Runge crater, reaching 23.5 wt.%. The lowest FTA content was found in Swasey crater, reaching 11.4 wt.%



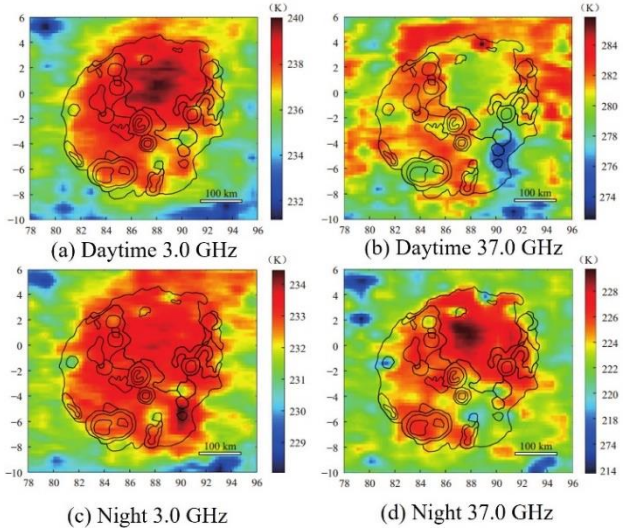
(a) ($FeO+TiO_2$)

(b) CPX (c) OL

Fig. 3. Composition maps of Mare Smythii (The black line is the geologic boundaries of Gillis et al [3])

2.4. Microwave thermal features of Mare Smythii

Based on the microwave radiometer data of the Chang 'e-2 satellite, the thermal and physical characteristics of the basin materials were analyzed. In this study, according to the method of Liu et al. [9], brightness temperature maps of Mare Smythii during the daytime and night were made (Fig.4).



(a) Daytime 3.0 GHz (b) Daytime 37.0 GHz

(c) Night 3.0 GHz (d) Night 37.0 GHz

Fig. 4. Brightness temperature maps of Mare Smythii (The black line is the geologic boundaries of Gillis et al [3])

Based on the brightness temperature performance, Liu et al. [9] combined numerical theoretical simulation and FTA, and made the following findings:

(1) The Em unit in northeast basin has higher substrate temperature. Possible presence of a special material in the Em

unit of the northeastern basin based on daytime and nighttime 37.0 GHz brightness temperature performance.

(2) Ishiyama et al. [10] discovered three ring structures that may represent the distribution of basalt at different depths based on LRS data. The three ring structures are in good agreement with the area of abnormally high brightness temperature.

3. SUGGESTED SITES FOR RESEARCH STATIONS AND PLANNING SCIENTIFIC EXPLORATION

Based on the research results of geology, composition and brightness temperature of Mare Smythii, it is suggested to take the 37GHz night high brightness temperature anomaly area inside Em unit as a reference.

We propose to build a long-term research station on the moon in the area (point A) centered on (88 ℃, 1 ℃) (Fig.5). We also planned the route according to the distribution of high-value scientific points and combined with Kaguya TC data.

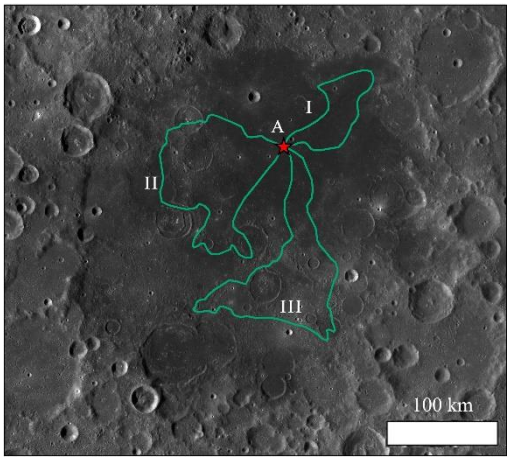


Fig. 5. Site selection and proposed routes of long-term lunar research station (the red star is the landing site suggested by this study; Green line is the route)

Route I can accomplish the following objectives: to investigate lunar swirls, wrinkle ridges, sinuous rilles, high brightness temperature anomaly, and carry out moon-based radio astronomy observations; Route II can complete the investigation of floor-fractured craters and pyroclastic deposits. Route III can complete the sampling of the cryptomare material and carry out a comprehensive investigation of the material at the basin's floor.

4. CONCLUSION

Based on SLDEM 2015 data, Clementine UV/VIS data, kaguya MI data, and Chang 'e-2 microwave radiometer data, this paper analyzes Mare Smythii's geology, topography, material composition, microwave thermal radiation and other characteristics, and makes suggestions and analyses on the location of Mare Smythii lunar long-term research station. The main conclusions are as follows:

(1) From the point of view of scientific research, astronomical observation and meeting the needs of energy and resources for long-term residence, this study proposes to establish a lunar scientific research station in the central latitude and longitude of (88 °E, 1 °N).

(2) According to the scientific objectives of the structural characteristics of Mare Smythii, the floor-fractured craters and the distribution of the material composition at the basin's floor, three routes were designed.

The establishment of a long-term lunar research station in Mare Smythii to carry out systematic and comprehensive scientific exploration will help to reconstruct the evolution history of the material composition of the early lunar impact events and the evolution history of the Lunar volcanism, which is of great significance to promote the development of lunar science.

5. ACKNOWLEDGMENTS

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MRM data is available from China's Lunar and Planetary Data System (https://moon.bao.ac.cn/ce5web/), Kaguya MI is available from JAXA's SELENE Data Archive (https://darts.isas.jaxa.jp/planet/pdap/selene/index.html.en), LROC WAC data were downloaded from LROC PDS Archive (http://pds.lroc.asu.edu/data/). Clementine UV/VIS data is available from Planetary Data System (https://pds-geosciences.wustl.edu).

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6. REFERENCES

[1] M. B. Duke, W. W. Mendell, B. B. Roberts, *et al*., "Strategies for a permanent lunar base," *Lunar Base Agriculture: Soils for Plant Growth*, pp. 23-35, 1989.

[2] L. Xiao, L. Qiao, Z. Y. Xiao, et al., "Major scientific objectives and candidate landing sites suggested for future lunar explorations" *Sci Sin-Phys Mech Astron*, vol. 46, no.2, pp. 9-30, 2016.

[3] J. J. Gillis and P. D. Spudis, "Geology of the Smythii and Marginis region of the Moon: Using integrated remotely sensed data," *Journal of Geophysical Research: Planets*, vol. 105, no. E2, pp. 4217-4233, 2000.

[4] P. D. Spudis and L. L. Hood, "Geological and geophysical investigations from a lunar base at Mars Smythii," in *Second Conference on Lunar Bases & Space Activities 21st Century*, pp. 163-174, 1992.

[5] Z. G. Meng, W. Q. Chang, C. Shen, et. al., "Site selection and potential scientific targets analysis of mare smythii for constructing long-term lunar research station," *Journal of Deep Space Exploration*, vol. 9. no. 5, pp. 521-531, 2022.

[6] J. D. Menges and K. M. Cannon, "The search for natural landing pads on the Moon and Mars," *LPI Contributions*, pp. 1559, 2020.
[7] P. G. Lucey, D. T. Blewett, B.L. Jolliff, "Lunar iron and titanium abundance algorithms based on final processing of Clementine ultraviolet - visible images," *Journal of Geophysical Research: Planets*, vol. 105. no. E8, pp. 20297-20305, 2000.
[8] M. Lemelin, P. G. Lucey, E. Song, "Lunar central peak mineralogy and iron content using the Kaguya Multiband Imager: Reassessment of the compositional structure of the lunar crust," *Journal of Geophysical Research: Planets*, vol. 120, no. 5, pp. 869-887, 2015.
[9] C. Liu, L. S. Mei, Z. G. Meng, et al, "Special thermophysical features of floor materials in mare smythii indicated by CE-2 CELMS data," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensin,* no. 14, pp. 8135-8143, 2021.
[10] K. Ishiyama and A. Kumamoto, "Volcanic history in the Smythii basin based on SELENE radar observation," *Scientific reports*, vol. 9, no.1, pp. 14502, 2019.