THE REGOLITH PROPERTIES OF THE RÜMKER REGION OF THE MOON (CHANG'E-5 LANDING REGION) AND THE GROUND DRILLING SIMULATION.

Yuqi Qian[1], Long Xiao[1*], Yong Pang[2], Guoxing Wang[2], and Siyuan Zhao[1]. [1]Planetary Science Institute, China University of Geosciences (Wuhan), Wuhan, 430074, China (longxiao@cug.edu.cn), [2]Beijing Spacecrafts, China Academy of Space Technology, Beijing, 100094, China.

Introduction: In Apollo-Luna Era, ~383 kg lunar samples were brought back [1], that has made fundamental achievements about lunar science and still shed light on lunar research until today. Scheduled in 2019, China's Chang'e-5 sample return mission (CE-5), planning to return up to 2 kg lunar samples [2-3], will provide a new opportunity to boost lunar science again. In order to pick a science-rich site, many studies have been conducted and the Rümker region was selected and characterized for its geomorphology and geology [e.g. 4-6]. However, it is equally important to analyze the engineering constraints of the area to ensure a successful mission. Among which, the regolith properties are one of the key factors that has large impact for robotic drilling for the mission. Therefore, the purpose of this study is to analyze the regolith properties and report the preliminary ground drilling simulation results to support the mission.

Regolith Properties: There is two ways to acquire samples of CE-5, grasp from the surface and drill from subsurface. For drilling, influence factors include the regolith composition, thickness of regolith layer, grain size and grain size distribution, etc. In this study, we assessed the lunar regolith properties by both remote sensing methods and comparing with the Apollo/Luna samples.

Composition. The FeO and TiO_2 concentration map derived from the Kaguya Multiband Imager data (Fig. 1) [7] and the spectra from Moon Mineralogy Mapper (M^3, Fig. 2) [8] were used to investigate the elemental and mineral composition of the Rümker region. This region is characterized by two distinct mare regolith, corresponding with the Imbrian-aged (Im1, Im2, and Im3) and Eratosthenian-aged mare units (Em1, Em3, Em4) (Fig. 1). Both of the western and eastern maria are dominated by low-Ti (<6 wt. %) basaltic regolith. However, the TiO_2 content of the eastern maria regolith are apparently higher than that of western, which reach up to 7.5 wt. % in the center of Em4. And the FeO contents of the regolith show similar trend of the TiO_2 contents.

To extract mineral compositions, the mean spectra of 12 circular areas (15 km in diameter) are computed (Fig. 2) and further continuum removed following the method described by [9-10] to decrease the space weathering effects. The spectra extracted from the Rümker region are all characterized by the diagnostic absorptions of pyroxene at 1000 nm and 2000 nm. The western maria (Im1, Im2, and Im3) have larger absorption depth at both 1000 nm and 2000 nm than the eastern Eratosthenian-aged maria (Em3, and Em4). However, the Eratosthenian-aged Em1 is more similar with the Imbrian-aged maria in mineralogy. The Band II absorption of the western maria locate at 2200 nm, and the eastern maria show a 2300 nm absorption feature, both of which belong to high-Ca pyroxene type but the eastern maria are probably richer in iron or calcium [11-12].

Thickness. The regolith thickness of the Rümker region was calculated by [13] using crater morphology method based on the transition of simple, flat-bottomed, central mound, and concentric craters with the regolith thickness [14-15]. In total, 958 concentric craters were used and the thicknesses were mapped [13]. The regolith thickness in the Rümker region ranges from 3.06 m to 14.67 m, and match well with the geologic boundaries by [5]. The western maria have thicker regolith than the eastern maria, and the thickest place locate at the northwest of the region. The thinnest layer is in the southeast of the Rümker region, but it is still larger than the designed drilling depth of 2 meter [13].

Ground Drilling Simulation: The ground drilling test was performed on the terrestrial drilling system that resemble the one on the CE-5 spacecraft, which can provide vacuum environment of the regolith simulants. The lunar simulants used in this study is CUG-1A produced by China University of Geosciences (Wuhan) which is a basaltic simulant that have different grain sizes [16].

The mechanic properties of lunar simulants are determined by composition, relative compaction, particle density, internal friction angle, viscosity, grain size, and grain size distribution. On a given rock type (most of the Rümker region is dominated by mare basalts), the grain size and the relative compaction are two main factors affect the drilling factors, therefore, tested in this study.

Series of experiments were performed on lunar simulants in different grain size and compaction conditions. Results reveal that high compaction simulants need larger force to take up in drilling. The particles smaller than 1 mm have little impact on internal friction angle how Froude number and inertia number in grain flow model.

References: [1]Grant H. H. et al. (1991) *Lunar sourcebook: a user's guide to the moon*. [2] Xu L. et al. (2018) *49th LPSC*, Abstract #1856. [3] Zeng X. et al. (2017) *EGU*, 19, 2026. [4] Zhao J. et al. (2017) *JGR: Planets*, 122, 1419-1442. [5] Qian Y. et al. (2018) *JGR: Planets*, 123, 1407-1430. [6] Wu B. et al. (2019) *JGR: Planets*, accepted. [7] Otake H. et al. (2012) *43rd LPSC*, Abstract #1905. [8] Pieters C. M. et al (2009) *Current Science*, 96, 500-505. [9] Horgan B. H. N. et al. (2014) *Icarus*, 234, 132-154. [10] Martinot M. et al. (2018). *JGR: Planets*, 123, 612-629. [11] Cloutis D. and Gaffey M. J. (1991) *JGR: Planets*, 96, 22809-22826. [12] Klima R. L. et al. (2007) *MPS*, 42, 235-253. [13] Yue Z. et al. (2018) *Icarus*, submitted. [14] Oberbeck V. R. and Quaide W. (1967) *JGR*, 72, 4697-4704. [15] Quaide W. L. and Oberbeck V. R. *JGR*, 73, 5247-5270. [16] He X. et al. (2010) *41st LPSC*, Abstract #1183.

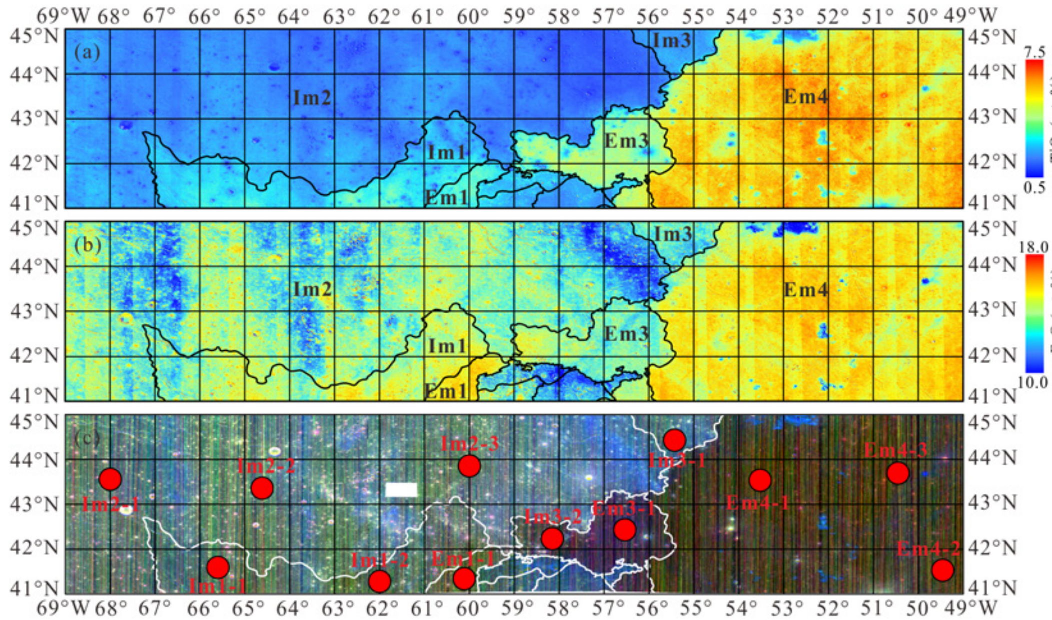

Figure 1. Kaguya MI data derived TiO_2 map (a), FeO map (b) and M^3 derived IBD color composite of the Rümker region. The black (white) lines denote the geologic boundaries delineated by [5]. The red dots (15 km in diameter) denote the calculating area of the mean spectra in Figure 2.

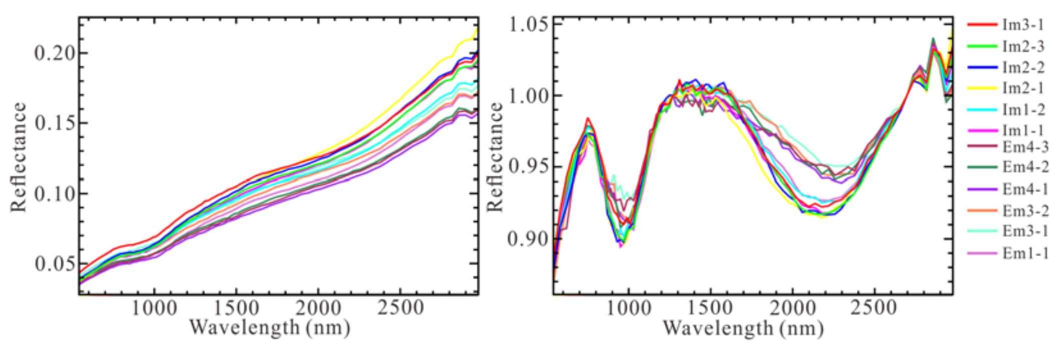

Figure 2. (a) Mean spectral of the lunar regolith denoted by the red dots in Fig. 1; (b) continuum-removed spectral.