GEOLOGICAL INVESTIGATION OF THE CHANG'E-4 LANDING SITE AND THE EXPECTED SCIENTIFIC RETURN FROM THE LUNAR PENETRATING RADAR. D. Guo[1], W. Fa[1], X. Zeng[2], Y. Cai[1], J. Du[1], M. Zhao[1], [1]Institute of Remote Sensing and Geographical Information System, School of Earth and Space Sciences, Peking University, Beijing, China (djguo@pku.edu.cn), [2]Center for Lunar and Planetary Sciences, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang, China.

Introduction: The ~186 km diameter pre-Nectarian crater Von Kármán is located in the northwest of the South Pole-Aitken, the largest and oldest lunar impact basin. Previous study suggests that Von Kármán crater is situated in a region named Mg-pyroxene annulus, characterized by elevated Mg-pyroxene [1]. Von Kármán crater was dated to be ~3.97 Ga [2], and its floor was flooded by mare basalts at ~3.15 or 3.35 Ga [3, 4]. The mare is heavily overlapped by ejecta from surrounding post craters such as the Nectarian Leibnitz crater and the young Eratosthenian Finsen crater [5]. On 3 January 2019, China's Chang'E-4 (CE-4) spacecraft successfully landed on the east floor of Von Kármán crater at 45.5°S, 177.6°E. A comprehensive understanding of the geology of Von Kármán crater (especially its floor) is necessary for the interpretation of the CE-4 data to be received.

The Floor of Von Kármán Crater: *Geomorphology*. Von Kármán is a central peak crater (Fig. 1 A), and the central peak is ~1.6 km high and 14 km wide. The floor of Von Kármán crater is relatively flat with several elevated features. The bidirectional slope calculated from Kaguya Terrain Camera Digital Terrain Model [6] shows that the slope of the mare region is generally smaller than 5° at a baseline of 37 m, and is greater than 10° within the inner wall of post-formed craters. According to the Diviner rock abundance (RA) data [7], mean RA of the Von Kármán region is ~0.002, and RA of young craters (e.g., the *Ba Jie* crater [5]) can be as high as 0.05. The morphology condition and rock distribution favor the movement of CE-4 rover, Yutu 2. A dome was formed at the southwest on the mare (Fig. 1A) and its upmost elevation is ~460 m higher than the background floor.

Spectroscopy. The major geological unit inside Von Kármán crater is the Nectarian mare with materials of low reflectance, which is widely overlapped by extraneous ejecta that appears bright (Fig. 1B). Post impacts that penetrated through the ejecta created craters surrounded by low reflectance mare material, known as dark-haloed craters (DHCs) [8], as shown in Fig. 1B. Mare basalts are rich in pyroxene that has strong spectral absorption at ~1000 nm [9] while the extraneous ejecta is relatively poorer in pyroxene. Therefore, the SELENE multiband imager (MI) data at 950 nm band with a spatial resolution of ~20 m are applied to analyze their reflectance differences. As shown in Fig. 1C, the reflectance of typical mare is less than 0.08, whereas those of the ejecta and highland materials are higher than 0.09, and the intermediate reflectance represents a mixture of the maria basalts and ejecta. The CE-4 landed in the area dominated by ejecta and mare mixture materials and the closest typical DHC (C-1 in Fig. 3A) is ~5 km far on the north east.

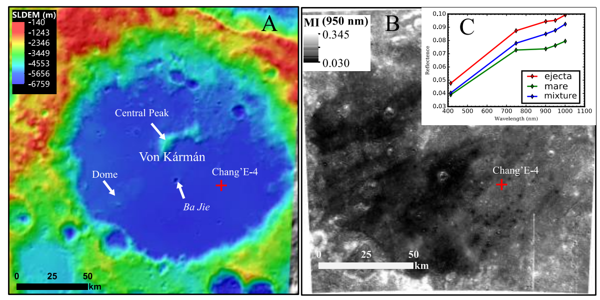

Fig. 1 The SLDEM (A) and the MI 950 nm band reflectance (B) of Von Kármán crater. (C) MI spectrums from three types of locations that represent the extraneous ejecta, mare basalts excavated by a DHC and the mixture of ejecta and mare compositions, respectively.

Geological Units. Based on the spectroscopic and morphological analysis, the Von Kármán floor can be classified into five geological units, as shown in Fig. 2A. The major ejecta on the surface is from the Eratosthenian craters: Finsen and Von Kármán L [5]. The older Nectarian and Imbrian ejecta are underlaid by post ejecta and the more fresh ejecta in this region are too thin to be recognized as an unit. Besides the units mentioned above, the unit massif contains two separated small uplands that are not covered by mare basalts (Fig. 2A). The east one is ~150 m high and the west one is ~ 310 m high.

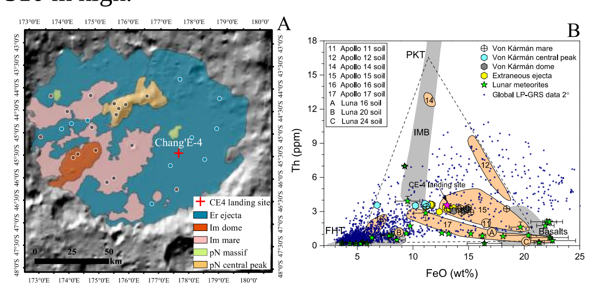

Fig. 2 (A) The geological units in floor of Von Kármán crater, where pN represents pre-Nectarian, Im represents Imbrian, Er represents Eratosthenian. Basemap is LOLA hillshade image. The dots in (A) represent the locations where the composition data are extracted and shown in (B).

Geochemistry. Compared to other types of rocks, lunar mare basalts are rich in iron and titanium, and the thorium contents also varies in different lunar terranes [10]. The geochemistry of different geological units is shown in Fig. 2B. The dome and mare are characterized by higher FeO, whereas the central peak differs from other units by obviously lower FeO. The FeO abundance at the CE-4 landing site is 13.1 wt.% (Fig. 2B), which is smaller than typical value of mare basalts (i.e., FeO > 17 wt. %, [11]) but are smaller than that of highland rocks (i.e., FeO <7 wt.%, [11]). Such intermediate FeO concentration suggests that regolith at the CE-4 landing site could be a mixture of mare components and highland lithologies at or around Von Kármán crater. The chemical similarities (i.e., FeO, Th) between the CE-4 landing site and extraneous ejecta also support this conclusion (Fig. 2B). In addition, Lunar Prospector γ-ray data shows that the Th abundance at the CE-4 landing site is 3.55 ppm, which is distinctly lower than that of KREEP-bearing lithologies of the Apollo PKT samples (>5 ppm [10]). Compared to lunar soils returned by the Apollo and Luna missions, bulk chemical composition of the regolith at the CE-4 landing site (i.e., FeO, Th, Fig. 2B) is more similar to Apollo 15 soils.

Expected Scientific Return from CE-4 Lunar Penetrating Radar: The Yutu-2 rover carries a two-channel Lunar Penetrating Radar (LPR), with center frequencies of 60 and 500 MHz. According to the FeO and TiO_2 abundance, dielectric constant of the landing site is estimated as 2.8+0.014i. Therefore, the penetration depth of the LPR is ~10 m for the 500 MHz channel and ~100 m for the 60 MHz.

The Kaguya Lunar Radar Sounder (LRS) was designed to map the thickness of maria basalts. There are two LRS tracks that are close to the CE-4 landing site. However, no distinct subsurface reflectors were found for the landing region. This implies that thickness of the maria basalts is either smaller than 90 m (subsurface resolution of LRS), or larger than ~1140 m (penetration depth of LRS).

The Miniature Radio Frequency (Mini-RF) radar can penetrate the subsurface to a depth of ~2–3 m. Fig. 3A shows the Mini-RF opposite-sense (OC) image of the landing region. The dark-haloed craters (e.g., crater C-1) generally have stronger echoes and extent further than the continuous ejecta, indicating the existence of surface/subsurface rocks at decimeter scales. The bright regions at C-6 and C-7 are probably ejecta deposits from *Ba Jie* crater on the east. One unusual region is located in the area surrounded by C-1, C-2 and C-7, where the radar echo strength is relatively weak. This region probably represents the undisturbed maria surface that consists of fine-grained regolith. Based on the depth-diameter relationships of impact craters [12], the ejecta thickness is estimated to be ~30–35 m using the DHCs (Fig. 3B).

In the near future, the LPR data, in combination with the LRS and Mini-RF data, can be used to constrain the fine structure of the lunar regolith, extraneous ejecta, and maria basalts. This will provide important information of the history of volcanism on the lunar farside. Also, thickness of the ejecta will be critical to know the impact and weathering processes of the landing site.

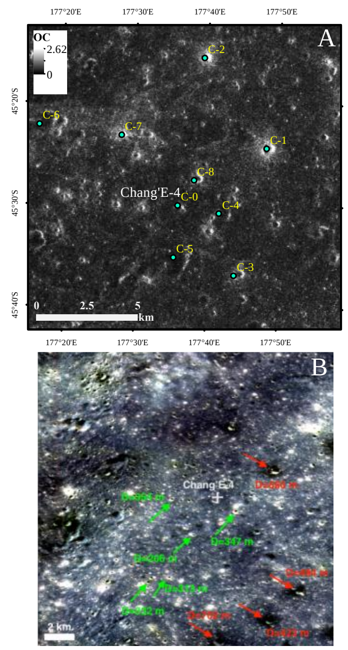

Fig. 3 (A) Mini-RF right looking OC image of the CE-4 landing area. (B) The craters used to constrain the extraneous ejecta thickness where green means undiscover the mare and red means the mare is excavated and the number represents diameter. The background image for (B) is MI data.

Conclusions: Our comprehensive analyses of multiple datasets suggest that the floor of Von Kármán crater consists of five geological units. The CE-4 landing site is geochemically dominated by mixture of mare components and highland lithologies with intermediate FeO and low Th and TiO_2. Plenty of post craters around the landing site show strong radar echoes, indicating rocky structures of the subsurface. The DHC craters suggest the extraneous ejecta is ~30–35 m thick.

References: [1] Moriarty D. P. and Pieters C. M. (2018) *JGR-Planets, 123*, 729–747. [2] Yingst R. A., et al. (2017) *LPS XLVIII*, 1680. [3] Pasckert J. H., et al. (2018) *Icarus, 299*, 538–562. [4] Haruyama J., et al. (2009) *Science, 323*, 905–908. [5] Huang J., et al. (2018) *JGR-Planets, 123*, 1684–1700. [6] Haruyama J., et al. (2014) *LPS XLV*, 1304. [7] Bandfield J. L., et al. (2011) *JGR-Planets, 116*, E12. [8] Bell J. F. and Hawke B. R. (1984) *JGR, 89*, 6899–6910. [9] Uemoto K., et al. (2011) *LPS XLII*, 1722. [10] Jolliff B. L., et al. (2000) *JGR-Planets, 105*, 4197–4216. [11] Korotev R. L., et al. (2009) *Meteoritics & Planet. Sci., 44*, 1287–1322. [12] Melosh H. J. (1989) New York: Oxford University Press.