COMPOSITION, MINERALOGY AND CHRONOLOGY OF MARE BASALTS IN VON KÁRMÁN CRATER: A CANDIDATE LANDING SITE OF CHANG'E-4.

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Introduction: China's Chang'e-4 will conduct the first lunar landing and roving mission on the lunar farside in late 2018. One candidate landing site is the Von Kármán crater in the South-Pole Aitken basin [1]. Von Kármán crater (44.45°S/176.3°E; diameter: 186 km) is a degraded Nectarian impact crater, flooded with mare basalt units [2, 3]. Chang'e-4 would select a flat, safe lava flow plain to land on and then release a rover to traverse around and perform detailed geologic investigations. Here we report spectroscopic, compositional and chronological investigations of the mare basalt units in Von Kármán crater, with an intent to recognize their scientific potential from a remote sensing view, which should be better understood before the Chang'e-4 mission's operations.

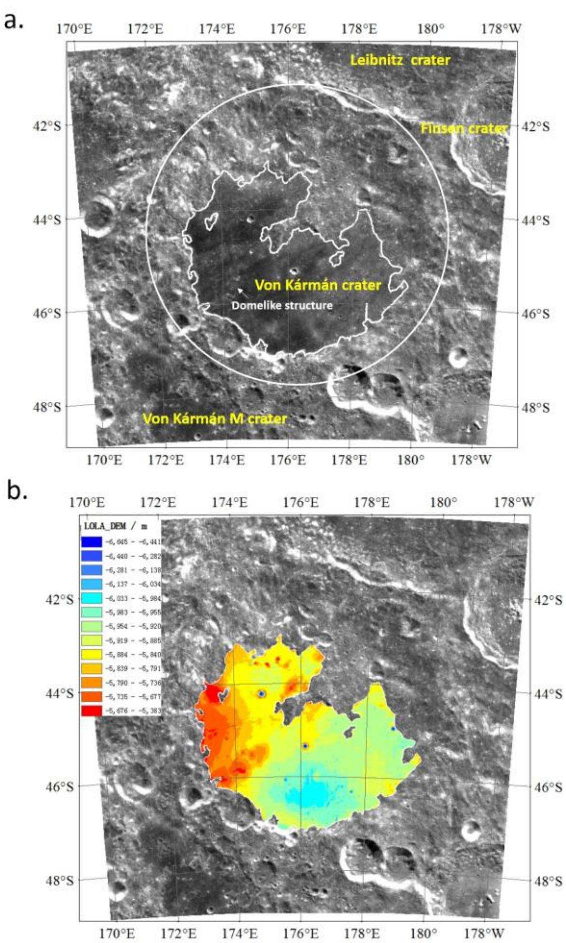

Figure 1. The Chang'e-1 CCD image (a) and LOLA DEM data (b) of Von Kármán crater.

Geologic context of Von Kármán crater: We employ the Chang'e-1 CCD and LOLA data to describe the geologic context as shown in Fig.1. Von Kármán crater is thought to have excavated materials of the relatively older pre-Nectarian Von Kármán M cater and is extensively overprinted by the young Finsen crater located to the northeast [3]. The dark basaltic units (indicated by the white polygon in Fig. 1a) occupy the interior of Von Kármán crater, measured to be 1.063×10^4 km^2 in area. Topographic variations (Fig 1b) of the lava plain mainly range from ~-5700 to ~-6000 m, and the western part is higher than the southern part. A domelike structure in the southwestern part of the unit [3] may represent the vent area for later volcanic flows.

Compositional properties of mare basalts: We use Kaguya Multi-band Imager (MI) data to map the FeO and TiO_2 distributions with algorithms from Refs [4,5] in Von Kármán crater. As seen in Fig 2a-b, the mare surface in Von Kármán crater is relatively low in FeO (~10-16 wt. %) and TiO_2 (~1-3 wt. %) in comparison with basalt at the Chang'e-3 landing site (i.e., ~22.8 wt. % FeO and ~5.0 wt. % TiO_2) [6]. Many fresh craters excavated relatively FeO and TiO_2 rich underlying basaltic materials, indicating the degree of reworking and gardening of the surface basaltic materials may be high. The contamination and mixing of Finsen ejecta with local mare materials is evident by light-colored linear patterns of relatively low FeO and TiO_2 clusters pointing toward Finsen crater. Using TiO_2 content as the discriminator for lava units, we divide the mare region in Von Kármán crater into two units, i.e., Low-Ti unit (LT, 3 wt. % > TiO_2 > 1.5 wt. %) and Finsen ejecta unit (FE, TiO_2 < 1.5 wt. %), as shown in Fig. 2c.

Spectral and mineralogical properties of mare basalts: We employ orbital hyperspectral imaging data from Chandrayaan-1 Moon Mineralogy Mapper (M^3) to evaluate the spectral and mineralogical variations of the LT and FE units. From the false color image (Fig. 2d), mare basaltic materials show hues between yellow and red, indicating they are rich in mafic minerals. Ejecta from Finsen crater make the mixed mare materials appear bluish in color. We conducted a spectral survey of fresh small craters in basaltic areas in order to evaluate their mineralogical properties. As shown by two representative spectra in Fig. 2e, the two units are both dominated by pyroxene with slightly different chemistries. Pyroxene in FE unit seems to be more Mg-rich and Fe-poor than that of LT unit, indicated by the shorter 1 µm (~935 nm for FE versus ~968 nm for LT) and 2 µm (~2069 nm for FE versus ~2145 nm for LT) absorption centers. We also estimate the mineral modes by using Modified Gaussian Modeling (MGM) deconvolution, and the result suggests LT unit has more High-Ca pyroxene (HCP) relative to Low-Ca pyroxene (LCP) than FE unit (i.e., HCP/LCP≈1.3 for LT, HCP/LCP≈0.7 for FE). However, different from the basalts at the Chang'e-3 landing site [6], the spectral data of these two units don't show olivine features.

Chronology of mare basalts: There are two previous crater size-frequency distribution (CSFD) measurements of mare basalts for chronology in Von Kármán crater. Haruyama et al. (2009) [7] obtained a modal age of 3.35 Ga for these mare deposits, whereas a recent study by Pasckert et al. (2018) [3] derived an age of 3.15 Ga and inferred a buried lava flow to have an age of 3.75 Ga. We determined absolute model ages for LT and FE units by performing CSFD measurements with high spatial resolution (~10 m/pixel) Kaguya Terrain Camera (TC) images. As shown in Fig. 2f, the age of LT unit is determined as ~ 3.43 Ga by craters from 350 m to 2 km, similar to that of Haruyama et al. (2009)[7], while the larger craters (>2 km) yield an age of ~3.70 Ga; the age of FE unit is identified as ~3.15 Ga and ~3.65 Ga, which seems to be more consistent with Pasckert et al.(2008)[3].

Conclusions: Our study provides some mineralogical and geological information about the basaltic units in Von Kármán crater. A mission in this region will encounter a flat, safe landing site, and a roving capability could be used to test hypotheses concerning the variability of compositions and whether the apparent variation is due mainly to contamination of otherwise homogeneous Von Kármán basalts. Such in-situ analysis will help to evaluate the mineral chemistries and subsurface structures in-situ by Visible and Near-infrared Imaging Spectrometer (VNIS) and Lunar Penetrating Radar (LPR) onboard the Chang'e-4 rover, respectively. We anticipate that the Chang'e-4 mission will provide new ground truth from the lunar farside surface, although a location in an area of swirls (e.g., Mare Ingenii) should be considered.

Acknowledgements: This research was supported by the National Natural Science Foundation of China (41473065), Natural Science Foundation of Shandong Province (JQ201511), Qilu (Tang) Young Scholars Program of Shandong University, Weihai (2015WHWLJH14).

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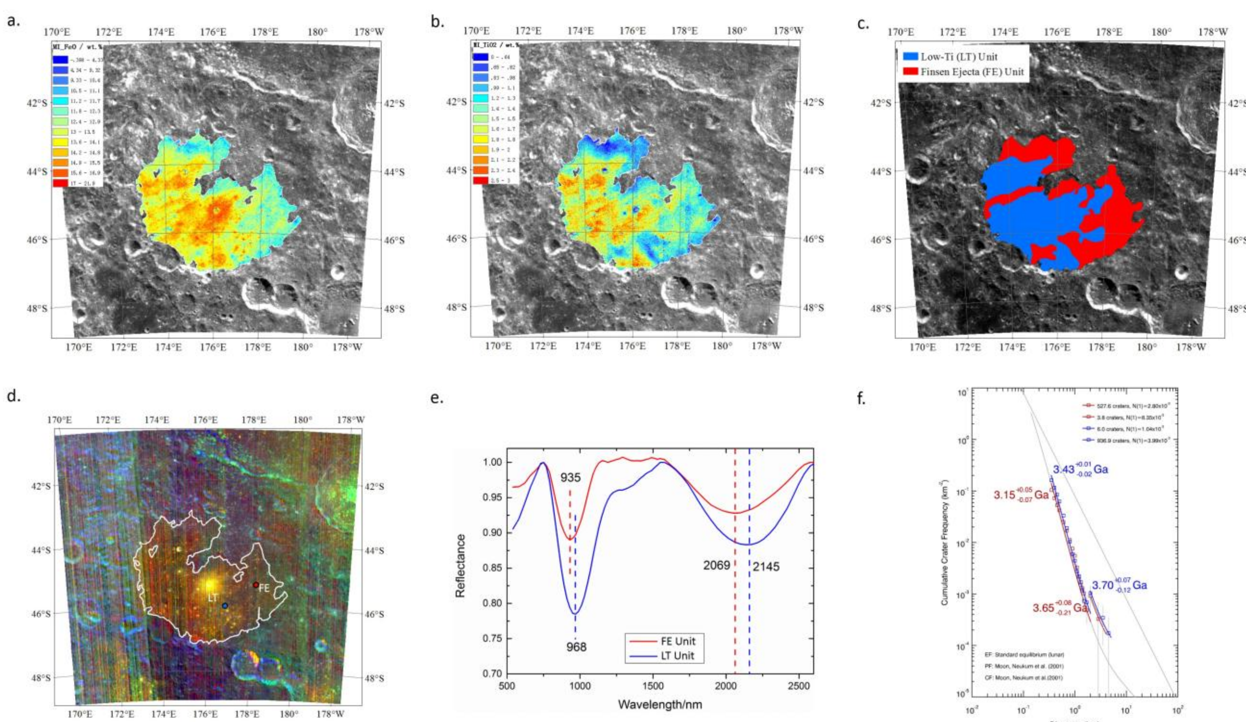

Figure 2. Compositional, spectral and chronological analysis of Von Kármán crater. (a) FeO map; (b) TiO_2 map; (c) Low-Ti (LT) and Finsen Ejecta (FE) units; (d) False color image (R=IBD1000, G=IBD2000, B=1580 nm albedo); (e) Representative M^3 spectra of LT and FE units; (f) Chronology results of the LT and FE units by CSFD.