THICKNESS OF EJECTA MATERIALS AT THE CHANG'E-4 LANDING SITE AND ITS COMPARISON WITH YUTU-2 RADAR DATA. L. Y. Xu[1], X. Y. Zhang[1], L. Qiao[2], J. L. Lai[3], and M.-H. Zhu[1], [1] State Key Laboratory of Lunar and Planetary Sciences, Macau University of Science and Technology, Macau, China (lyxu@must.edu.mo), [2] School of Space Science and Physics, Shandong University, Weihai, Shandong, China [3]School of Science, Jiangxi University of Science and Technology, Ganzhou, China.

Introduction: The landing site of China's Chang'e-4 (CE-4) probe is located on the mare basalts within the Von Kármán crater on the lunar far side. The 186-km-diameter Von Kármán crater locates inside the huge South Pole-Aitken (SPA) basin, the largest and oldest known impact structure on the Moon [1,2]. Although Von Kármán is an ancient crater with a pre-Nectarian age [3], the crater floor was resurfaced by younger multiple-phase Imbrian-aged mare basalts [3,4], followed by the delivery of impact ejecta from many postdated craters on the Moon.

Evaluating the sources and amounts of foreign materials at the CE-4 landing site is essential for analyzing the local stratigraphy and geologic history. After the landing, the visible and near infrared spectrometer (VNIS) onboard the Yutu-2 rover found that the mafic materials around the landing site are dominated by orthopyroxene, different from the clinopyroxene-dominated mare basalts. Some researchers [5-7] suggested that these materials are likely originated from the nearby Finsen crater, a 73 km-diameter, Eratosthenian-aged crater [8]. In addition, the lunar penetrating radar (LPR) onboard the Yutu-2 rover also suggests that the uppermost stratigraphy at the CE-4 landing site is a fine regolith layer underlain by several impact ejecta deposit layers, including that from Finsen crater [9].

However, the foreign materials delivered from relatively distant sources have not yet been carefully surveyed, and Finsen ejecta may not be the only principal source for the materials detected by Yutu-2. Furthermore, various empirical ejecta distribution models have been widely used to estimate ejecta thickness in different studies, while few assessments and comparisons of these models have been conducted. In this study, we examine all possible principal sources of foreign materials at the CE-4 landing site, quantitatively evaluate their contributions to the local stratigraphy, and analyze their effects on the *in-situ* observations of Yutu-2. In addition, the ejecta thickness and local stratigraphy derived from different models are analyzed and compared in detail.

Data and Methods: Because prior crater counting analyses determined that the Von Kármán mare units formed in the Late Imbrian Epoch [4,5], we focus on craters contemporaneous with and younger than this epoch throughout the Moon in this study (Figure 1). We take 10 cm as the threshold and consider that only the ejecta thicker than it can be potentially distinguished from the low frequency channel LPR observations of Yutu-2. The stratigraphic ages of surveyed craters mainly refer to the geologic map of Fortezzo et al. [8] and cross-cutting relationships. The Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) mosaic image is used to evaluate the geologic context of these craters.

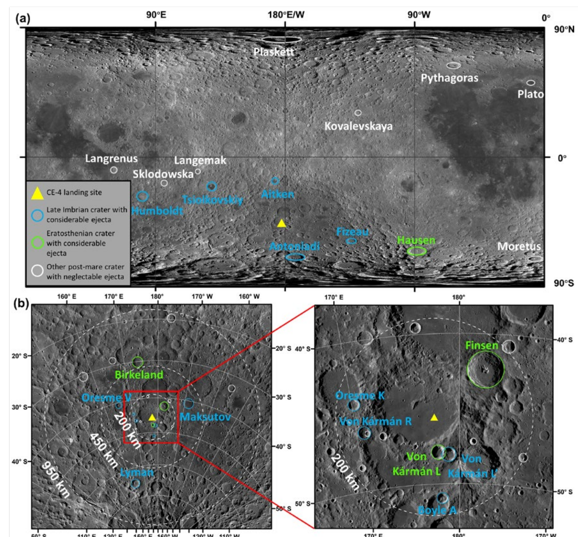

Figure 1. Locations of all post-mare craters surveyed in this study: (a) craters with D > 100 km and (b) craters with D < 100 km. The base image is a LROC WAC mosaic image. Craters in color labels The dashed white circles in (b) mark the examined boundaries of spherical distances of 950, 450, and 200 km from the CE-4 landing site.

Four models are used to estimate the primary ejecta thickness for detailed comparison: Pike's model [10], McGetchin's model [11], Housen's model [12], and Sharpton's model [13]. In addition, since the ejecta distance after ballistic trajectories are actually not great-circle distances, and the ejecta cannot be treated simply as being deposited on a flat surface for distant ejecta, distance corrections and deposition corrections are taken into considerations [14,15]. We use the mixing model of Petro and Pieters [16] to evaluate the degree of mixing and the local materials excavated by the primary ejecta, which is modified from the initial model of Oberbeck [17].

Results and Discussion: We examine all possible sources (i.e., "post-mare craters") of foreign materials on the mare basalts at the CE-4 landing site and find 16 craters potentially delivering primary ejecta > 10 cm-level in thickness based on Pike's model. The total ejecta thicknesses of these 16 craters are 18.6 m, 5.7 m, 12.7 m, and 9.0 m based on the models of Pike, McGetchin, Housen and Sharpton, respectively.

Four craters are principal foreign material sources to the CE-4 landing site based on Pike's model (Figure 2): Finsen (9.4 m thick), Von Kármán L (3.2 m thick), Von Kármán L' (2.1 m thick), and Maksutov (1.1 m thick). Their most likely emplacement sequence is: Maksutov, Von Kármán L', Von Kármán L, and Finsen from older to younger. Finsen ejecta should be the most dominant materials from the surface to several meters deep at the CE-4 landing site with a ratio of at least 43% regardless of the model choice, as long as the regolith layer is thinner than the ejecta deposits of Finsen, which is consistent with the VNIS observations of Yutu-2 [5,7].

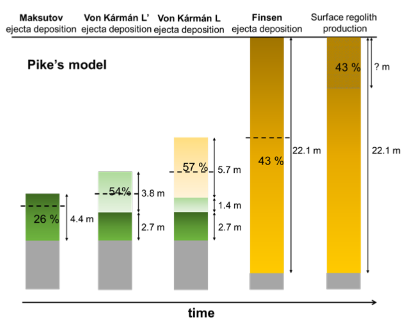

Figure 2. Illustration of the homogeneous mixing scenario showing the evolution of the stratigraphy with time at the CE-4 landing site under Pike's model [12]. The percentage values are the ratio of the foreign materials at the topmost layer.

Taking the local material excavation and mixture into consideration, these four principal source craters produce ejecta deposits at the CE-4 landing site with total thicknesses of 22.1 m, 6.4 m, 14.0 m, and 10.7 m based on the four ejecta models, respectively. All the post-mare impact ejecta deposits upon local mare basalts at the CE-4 landing site is estimated to be thinner than 30 m.

The ejecta thicknesses estimated from Pike's model are the most consistent with the first five lunar days of the Yutu-2 LPR observations compared with the other three models, and the five layers reflected in the LPR observations (from 0-~40 m deep) correspond well to a fine regolith layer, a Von Kármán L-dominant mixing zone, a Von Kármán L'-dominant mixing zone, a Maksutov-dominant mixing zone, and a local mare basalt layer (Figure 3).

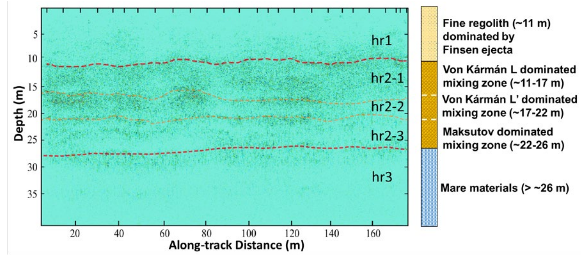

Figure 3. The first five lunar days of the LPR radargram of Yutu-2 and the resultant geologic interpretations. The LPR data are processed with repetitive data removal, including filtering, background removal, amplitude compensation, migration, and topographic correction. "hr" stands for horizontal reflector.

Conclusions: To evaluate the sources and amounts of all principle foreign materials at the CE-4 landing site, we thoroughly examine the ejecta delivered after the formation of the mare basalts at the CE-4 landing site. We find a total of 16 craters that may have delivered ejecta thicker than 10 cm-level superposed on the mare basalts at the CE-4 landing site. Crater Finsen, Von Kármán L, Von Kármán L', and Maksutov are the top four major foreign material sources, and each of them contributed ejecta thicker than 1 m. Our surveys confirm that the ejecta from Finsen crater are the most dominant foreign materials in the uppermost few meters at the CE-4 landing site, and the total impact ejecta deposited upon the mare basalts at the landing site is estimated to be thinner than 30 m. The estimations from Pike's model are the most consistent with the Yutu-2 LPR observations.

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