Provenance of Ejecta and Regolith Thickness in the Vicinity of the Chang'e-6 Landing Site

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Introduction

The South Pole Aitken (SPA[1]) Basin (Fig. 1a), one of the three major geologic terrains in the Moon, is distinguished by its geographical position, considerable scale[2], and great age[3]. It provides a unique window for exploring the lunar interior and early impact history of the Solar System.

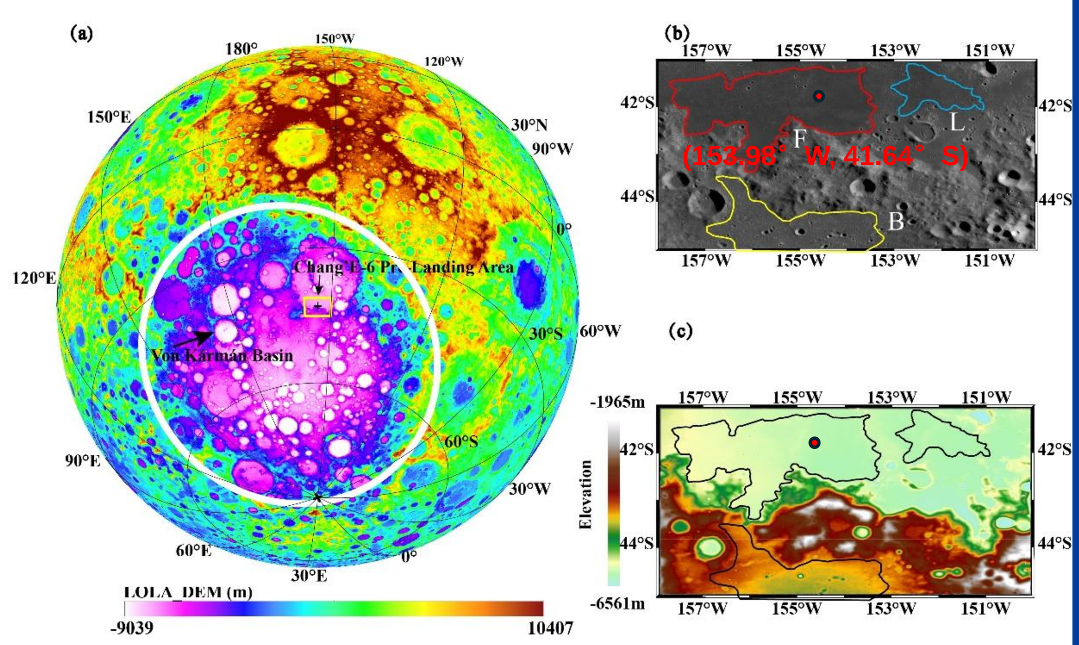

Figure 1. Targeted area. (a) Elevation map of the lunar farside (orthographic projection). LROC DEM image, with a resolution of 100 m/pixel. (b) KAGUYA TC-morning image of the Chang 'e-6 pre-landing area, F, L, B regions. (c) Chang 'E-6 pre-landing zone elevation map, using KAGUYA DTM image.

The Chang'E-6 (CE-6) landed in the Apollo Basin (Fig. 2).

- Thickness and material sources (in-situ materials and exogenous materials) of the lunar regolith layer
- Stratigraphical sequence

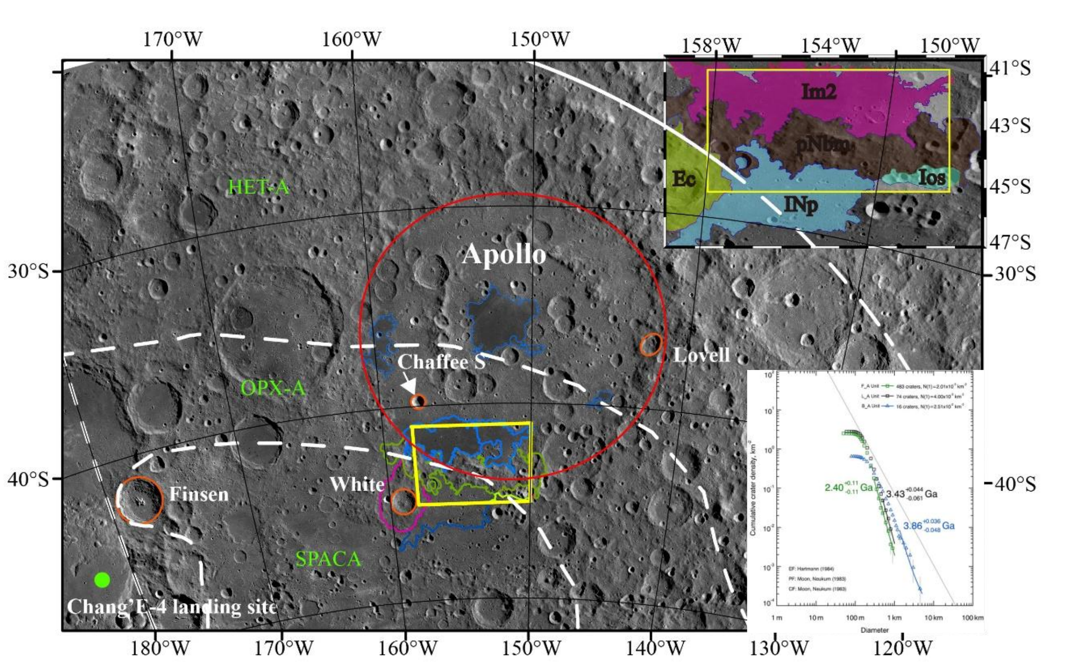

Figure 2. Location map of Apollo Basin, Geological map of the Chang 'E-6 proposed landing area and Dating Age[4] (CSFD) from F,L,B regions.
***pNbm** : pre-Nectarian Basin Massif* ***Inp** : Imbrian Nectarian Plains*
***Ios** : Imbrian Orientale Hevelius Formation, Secondary Crater Facies*
***Im2** : Imbrian Mare, Upper* ***Ec** : Eratosthenian Crater*
*the inner ring SPA Compositional Anomaly" (**SPACA**), the central ring OPX Annulus" (**OPX-A**), and the outer ring Heterogeneous Annulus" (**ET-A**)*

Method

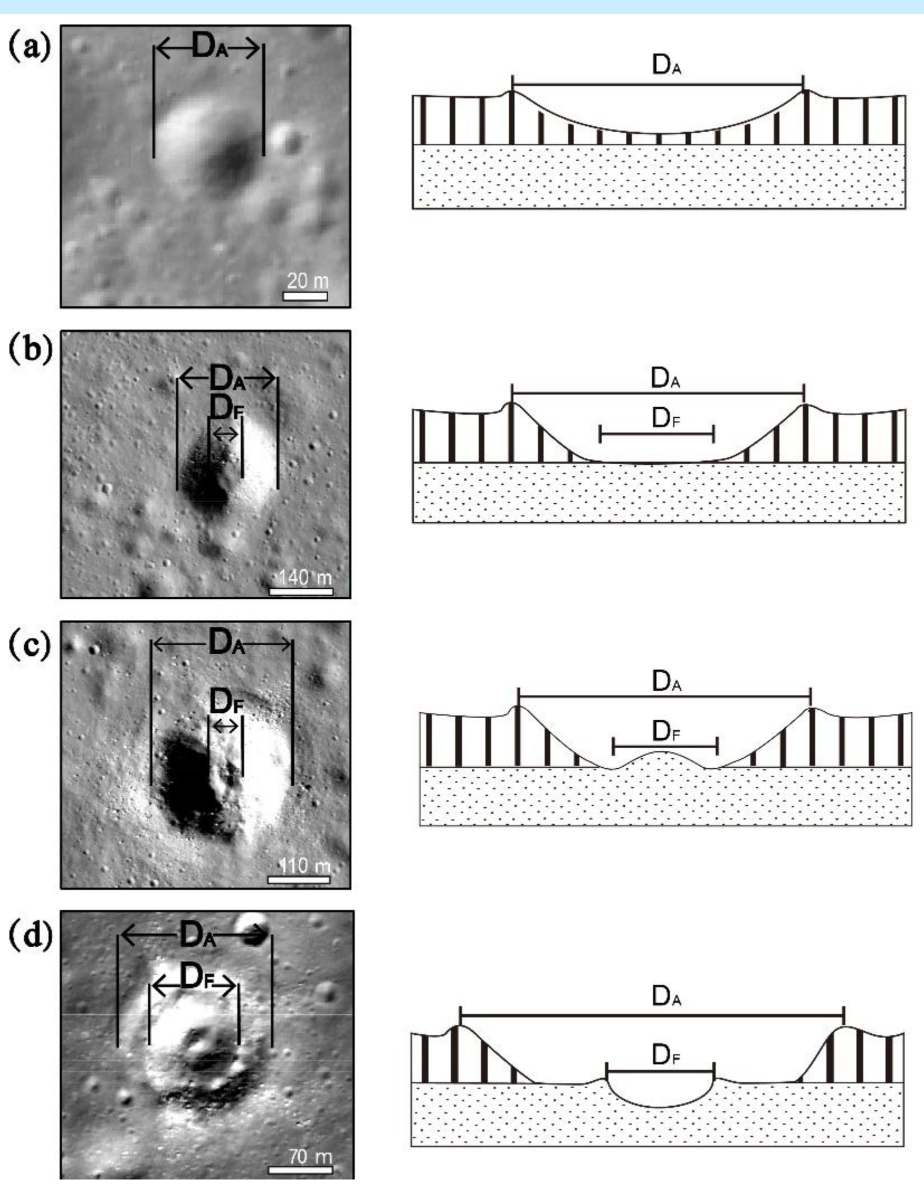

Fig. 3 The four different types of impact craters: (a) normal, (b) flat-bottomed, (c) central mound and (d) concentric craters. NAC images (Left) and simple profile diagrams (Right).

The thickness of lunar regolith

Parameters of the fresh impact crater[5]**:** Angle of repose (α) and angle of illumination (γ), the ratio of the bottom diameter (D_F) to the apparent diameter (D_A) of the craters, denoted as D_F/D_A, is introduced for distinguishing normal, flat-bottomed, central mound, and concentric crater.

$$N=\frac{D_F}{D_A}=\frac{1-\cot\alpha\times\tan\gamma}{1+\cot\alpha\times\tan\gamma} \quad (1)$$

The separates boundary between the flat-bottom crater from the normal crater.

$$N=\frac{D_F}{D_A}=\frac{1-\cot\alpha\times\tan\gamma}{1-0.33\cot\alpha\times\tan\gamma} \quad (2)$$

The separates boundary between the flat-bottom crater from the concentric crater.

$$t=\frac{\left(k-\frac{D_F}{D_A}\right)*D_A*\tan\alpha}{2} \quad (3)$$

The lunar regolith thickness (t) can be estimated from the morphological parameters of small fresh impact craters.

The thickness of Ejecta

$$\delta(t)=0.14\,R_t^{0.74}\,(r/R_t)^{-3.0} \quad (4)$$

McGetchin's Model

$$\delta(t)=0.033\,R_t\,(r/R_t)^{-3.0} \quad (5)$$

Pike's Model (most reliable)

$$\begin{cases} 0.014\,R^{1.01}\left(\frac{r}{R}\right)^{-3} & \text{simple crater} \\ 3.95\,R^{0.399}\left(\frac{r}{R}\right)^{-3} & \text{complex crater} \end{cases} \quad (6)$$

Sharpton's Model

R_t is the transient rim radius of the crater, *R is the final rim radius of the crater,* and *r* is the surface distance from the crater central to the current measurement point.

Potential sources of Ejecta

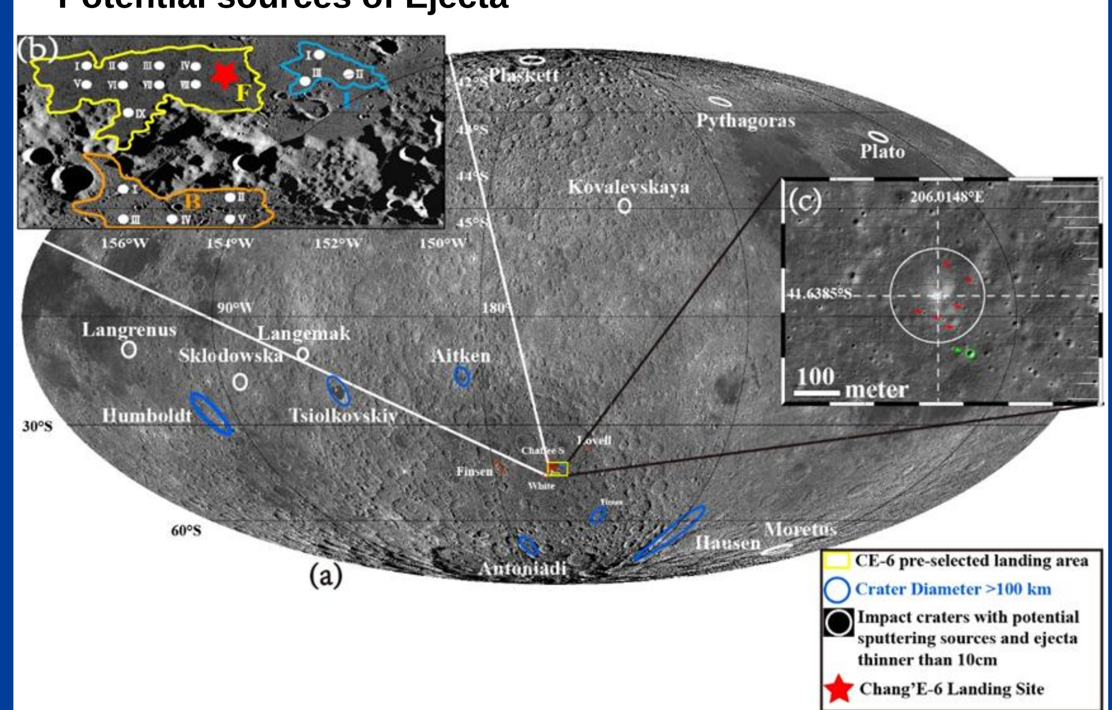

Figure 4: (a) Distribution of ejecta source craters. White circles represent impact craters that potentially contribute to an ejecta layer thicker than 10 cm. Blue ones represent impact craters with a diameter greater than 100 km. Yellow box indicates CE-6 pre-selected landing area. (b) A distribution map of selected points used to calculate the ejecta thickness. The results include CE-6 landing site, 9 points in the F region, 3 points in the L region, and 5 points in the B region. (c)The NAC map of CE-6 landing site. The surrounding area of the CE-6 landing site includes six normal craters (red arrows) and a flat-bottomed crater (green circle).

Conclusions

- Analyzed a total of 44,163 fresh craters from LROC NAC images.
- The thickness of the regolith layer was determined to range from 4 to 8.3 meters, with a noticeable increase towards areas F, L, and B within the designated region.
- The F region shows a relatively high concentration of concentric craters, suggesting a higher probability of rock exposures in this area.
- The ejecta thickness distribution analysis in the landing area using Pike's model ranges from 5 to 29 meters.

References

[1]Jolliff et al.,2000. [2]Garrick-Bethell and Zuber,2009.[3]Hesiinger et al.,2012. [4]Zeng et al., 2023 [5]Quaide and Oberbeck,1968.

Results

Estimated Ejecta Thickness

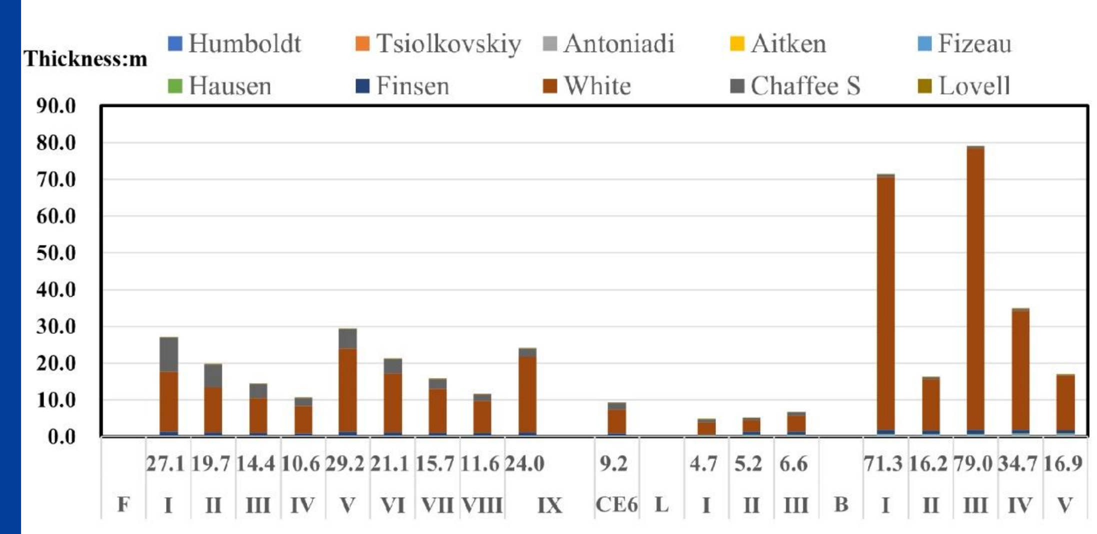

Figure 5. Ejecta thickness in Chang'E-6 selected landing area calculated using Pike's Model. The White crater ejecta contributes the most in the B and F regions.

Regolith Thickness

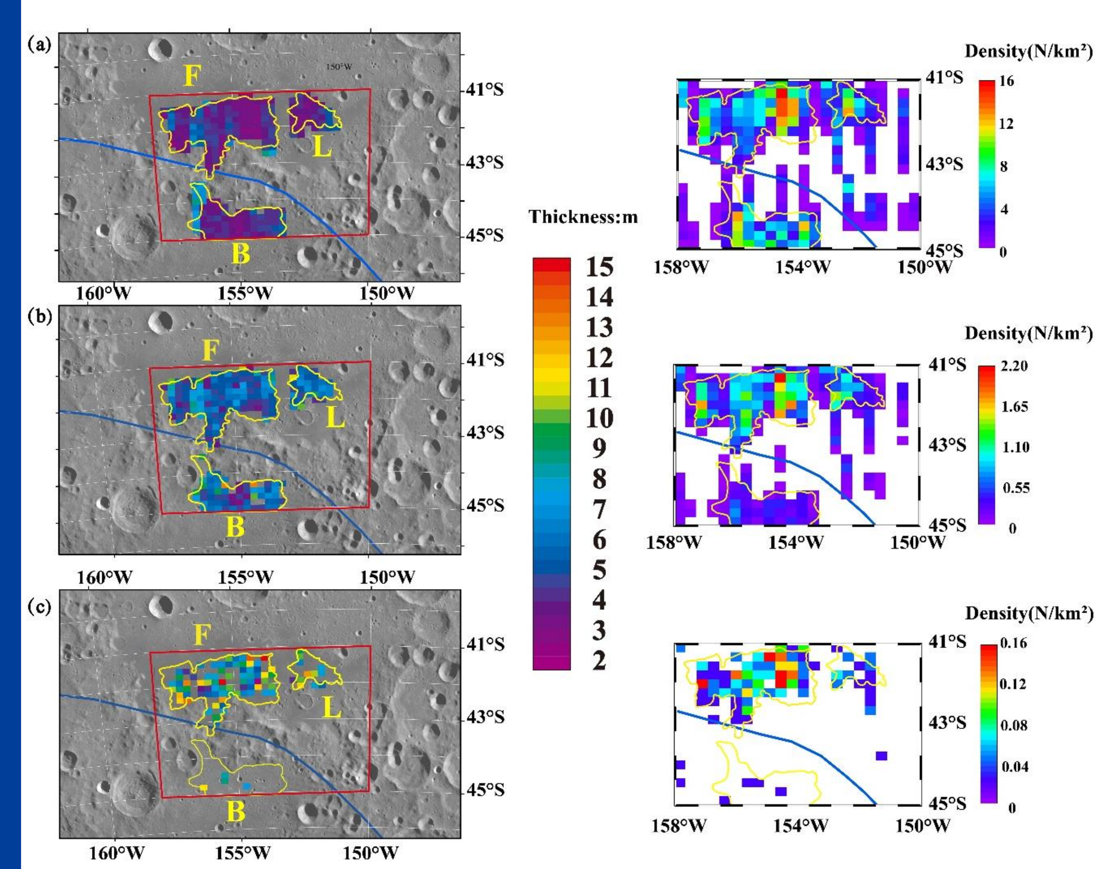

Figure 6. The distribution maps of lunar regolith thickness (left) and crater density image (right) were calculated based on the statistical recurrence of (a) normal, (b) flat-bottomed, and (c) concentric craters.

Stratigraphy Column of the CE-6 selected landing area

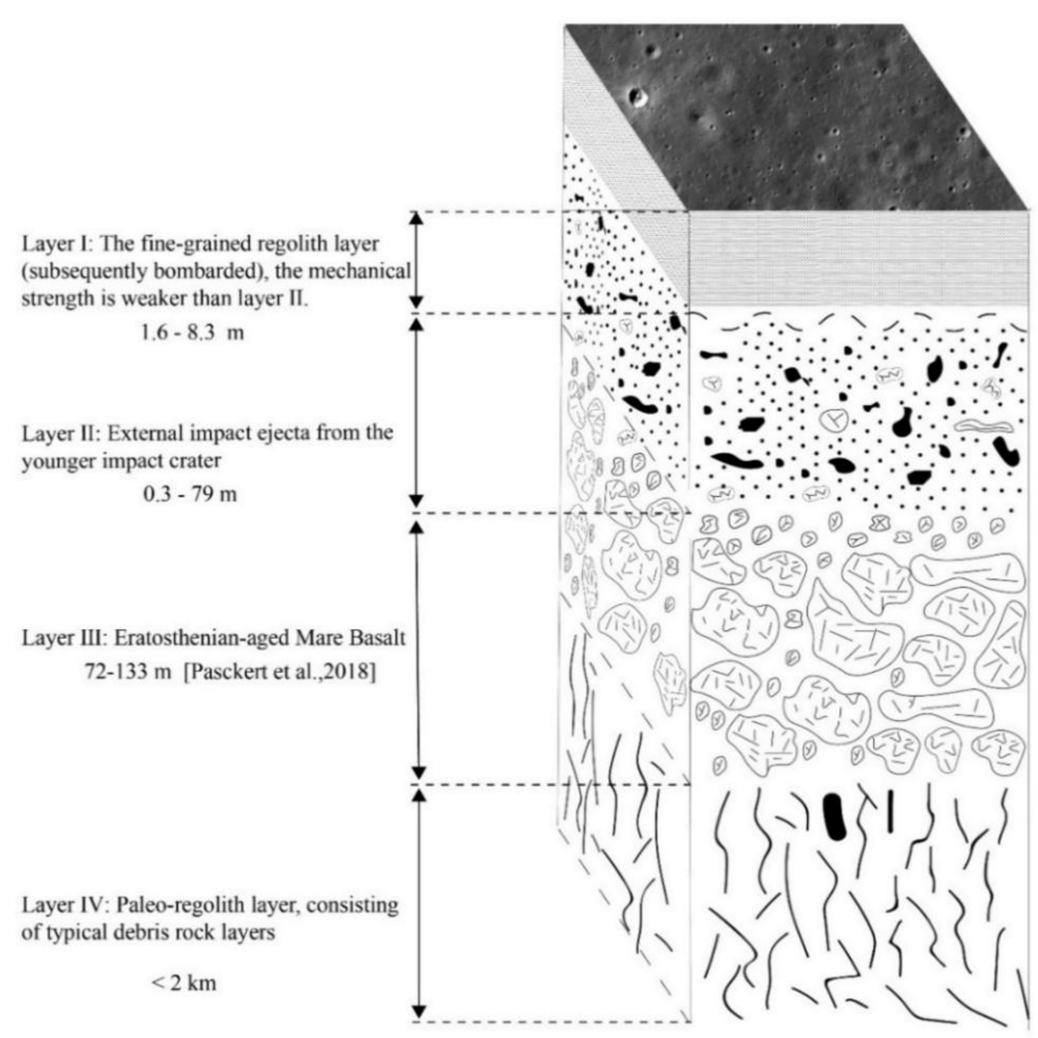

Fig.7: Stratigraphy of the Chang'E-6 Pre-landing region

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