Photometric Characterization of the Chang'e 3 Landing Site Using LROC NAC Images

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Background

On 14 Dec. 2013, China's Chang'e 3 soft landed at 44.12°N, 340.49°E in Mare Imbrium [1, 2].

Goals of this study:

1) Investigate the change in reflectance at the landing site related to the impingement of rocket exhaust from the lander (blast zone, "BZ") [3,4].

2) Use Lunar Reconnaissance Orbiter (LRO) Narrow Angle Camera (NAC) images to compare with reflectance before landing (Fig. 1) and to compare with 40-year old disturbances at the Apollo, Luna, and Surveyor landing sites.

Methods

Reflectance profiles - used to extract reflectance values within the BZ, and to measure spatial extent of disturbed area (Fig. 3).

1) a-a' – across northernmost tip of BZ
2) b-b' – across the center of BZ
3) c-c' – N-S; crosses the lander. Also taken across the site before landing for comparison.

Hapke photometric modeling - used to fit reflectance (*I/F*) data, which is normalized to the Lommel-Seeliger function (*IoF/LS*) to reduce effects of different illumination geometries [5,6].

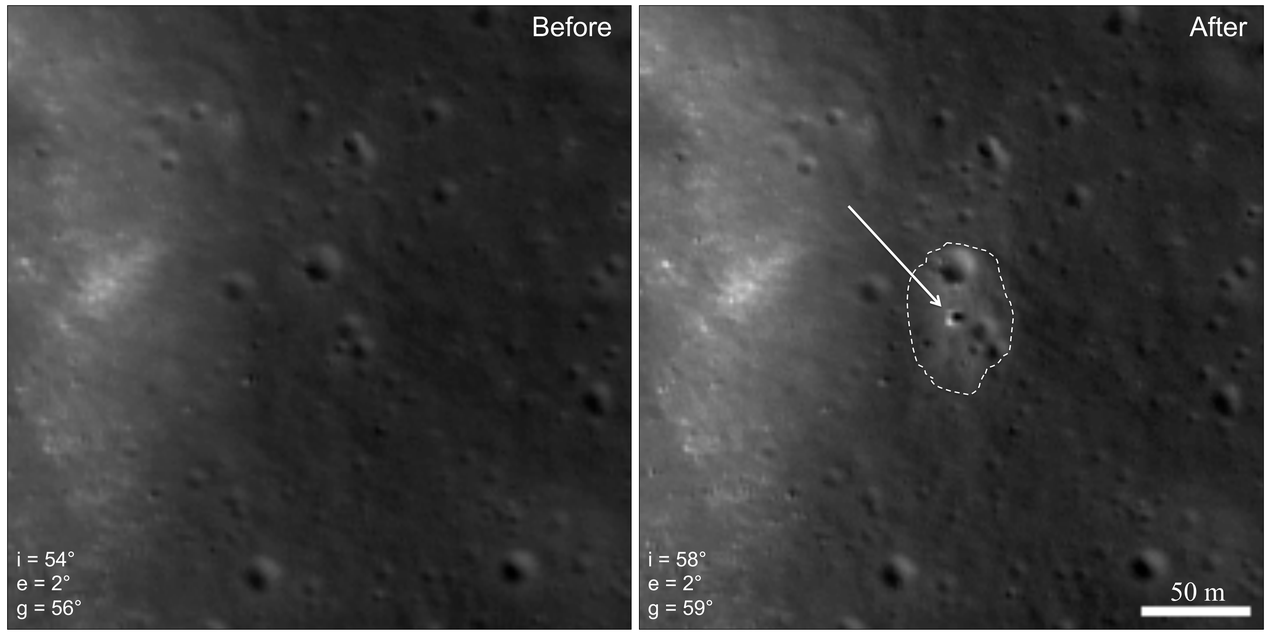


Fig. 1: Images of the Chang'e 3 landing site, before (left; NAC image M183661683L) and after (right; NAC image M1144936321L) landing. Dashed line outlines the area of increased reflectance (blast zone); arrow points to lander.

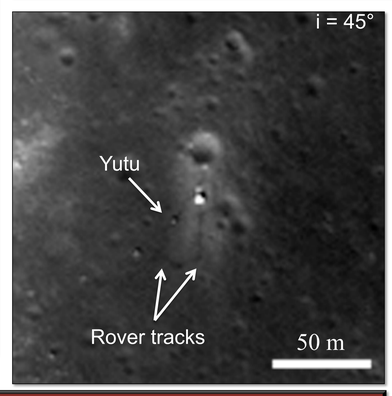
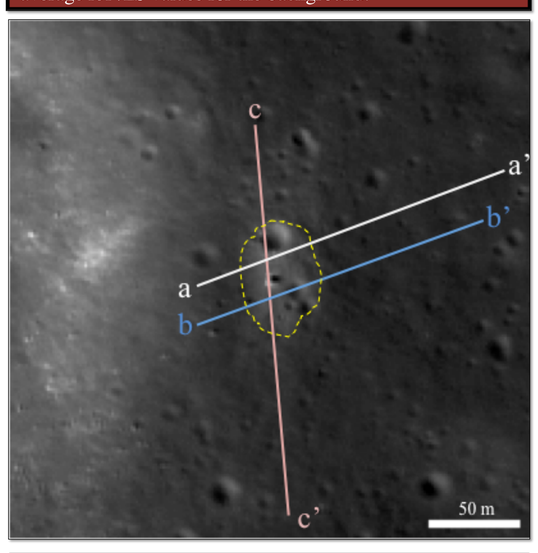
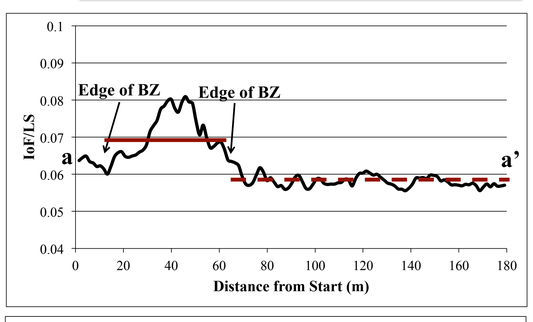
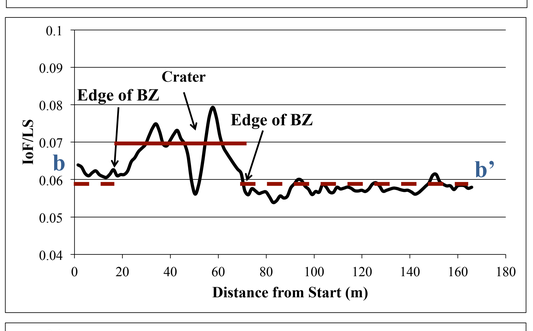


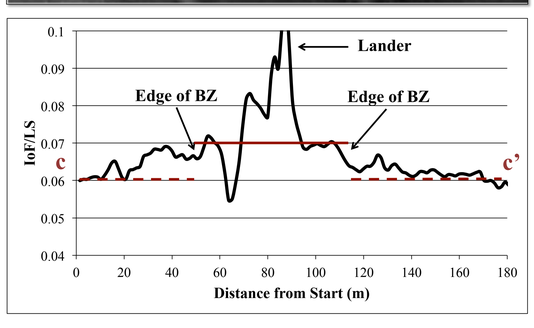
Fig 2.: Lower incidence angle image (M1147290066R), showing Yutu rover tracks.

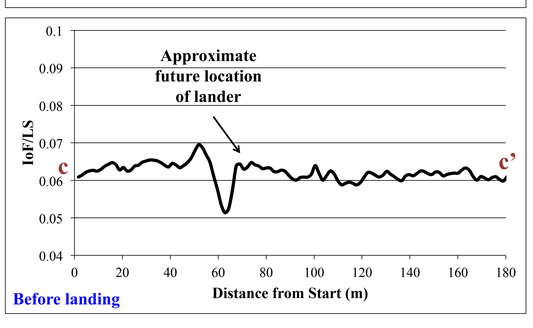
Fig. 3: Reflectance profiles before and after landing; dashed yellow line outlines the BZ. NAC image M1144936321L, 59° phase angle. Profile before landing taken from image M183661683L; 56° phase angle. Solid lines in plots indicate average *IoF/LS* values for the BZ, dashed lines indicate average *IoF/LS* values for the background.











Results

- Reflectance profile shapes are consistent with trends observed at Apollo, Luna, and Surveyor landing sites [3].
- Magnitude of reflectance increase is ~12% after landing (at 45° phase angle; Table 1).
- Average area of Apollo BZ is 10 times larger than average Luna BZ and 80 times larger than average Surveyor BZ [3].
- The Chang'e 3 BZ area measurement falls close to the expected value, based on the Surveyor, Luna, & Apollo correlation (Fig. 4; Table 2) and variations in descent trajectory and topography.

Table 1: Average reflectance (*IoF/LS*) values for the BZ and background areas at the Apollo, Luna, Surveyor, and Chang'e 3 landing sites (for 45° phase angle).

	IoF/LS blast zone	*IoF/LS* background	percent increase
Apollo 11	0.081	0.070	16
Apollo 12	0.098	0.085	14
Apollo 14	0.112	0.097	15
Apollo 15	0.092	0.076	21
Apollo 16	0.184	0.164	12
Apollo 17	0.083	0.072	15
average	**0.108**	**0.094**	**16**
Luna 16	0.071	0.064	11
Luna 17	0.077	0.065	18
Luna 20	0.137	0.127	8
Luna 23	0.088	0.080	10
Luna 24	0.089	0.078	14
average	**0.092**	**0.083**	**12**
Surveyor 1	0.061	0.052	17
Surveyor 5	0.075	0.061	23
Surveyor 6	0.077	0.067	15
Surveyor 7	0.163	0.155	5
average	**0.094**	**0.084**	**15**
Chang'e 3	**0.065**	**0.058**	**12**

Comparison with Apollo, Luna, and Surveyor

Reflectance increase

(at 45° phase angle; normalized using Hapke photometric function [3,6]*):*

Apollo: 16%
Luna: 12%
Surveyor: 15%
Chang'e 3: 12%

Blast zone elliptical area

Apollo*: 23,800 m^2
Luna: 4100 m^2
Surveyor: 300 m^2
Chang'e 3: ~2100 m^2

*excluding Apollo 12

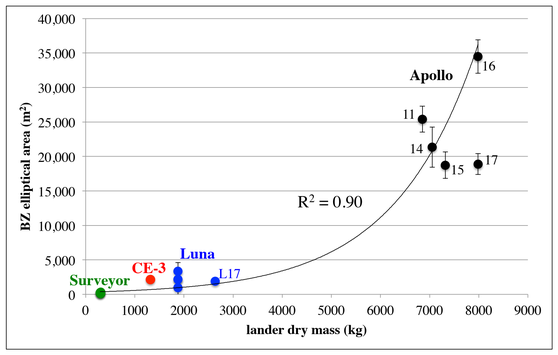


Fig. 4: Plot of lander mass versus blast zone elliptical area for the Apollo, Luna, Surveyor, and Chang'e 3 landing sites. Variations largely a function of descent parameters.

Table 2: Average mass, thrust and BZ area values for Apollo, Luna, Surveyor, and Chang'e 3 [7,8].

	dry mass (kg)	max thrust (kN)	BZ area (m^2)
Apollo	7440	45	23800
Luna	2070	18.9	4100
Surveyor	300	0.46	300
Chang'e 3	1320	7.5	2100

Scan to see an LROC Featured Image of the Chang'e 3 landing site!

Conclusions

- Reflectance increase at the Chang'e 3 landing site (Table 1) compares favorably with the average increase in reflectance for other landing sites [3].
- Variations in descent trajectory and maneuvering or different engine configuration and design likely contributed to BZ size variations between Apollo, Luna, Surveyor, and Chang'e 3 landing sites (Table 2).
- Based on reflectance changes (Table 1), we infer that lunar surface features (mm – cm scale) are not significantly altered on a time scale of decades by rocket exhaust impingement.

References

[1] Wagner, R. et al. (2014), this Conf., Abstract #2259. [2] Robinson et al. (2014), this Conf., Abstract #1859. [3] Clegg R. N. et al. (2014), *Icarus*, 227, 176-194. [4] Kaydash V. et al. (2011), *Icarus, 211*, 89-96. [5] Hapke B. W. (2001), *Icarus*, *167*, 523-524. [6] Hapke B. W. et al. (2012), *JGR, 117*. [7] National Space Science Data Center (NSSDC). [8] Harvey, B. (2007), *Soviet and Russian Lunar Exploration*.