Opposite Trends of Optical Maturity in Northern and Southern Hemispheres on the Lunar Surface

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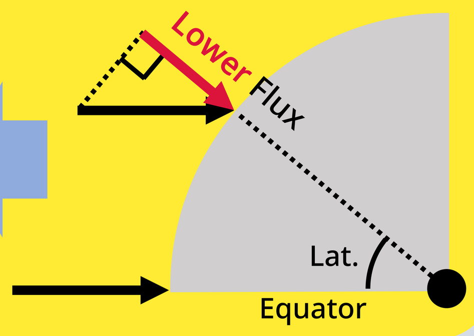
ABSTRACT

- The wall-quadrants of lunar craters are good tools for analyzing the optical maturity (OMAT) difference caused by the flux of space weathering agents (solar wind particles, micro-meteorites, …).
- We find that the OMAT differences between the equator-facing (EF) and pole-facing (PF) walls have opposite trends in the northern and southern hemispheres at lower latitude.
- Below 25 degrees, the EF wall is more mature than the PF wall in the northern hemisphere, but it is the opposite in the southern hemisphere.
- Unlike previously known, the hemispheres seem not to be symmetrically affected along the ecliptic plane.
- Similar trends are confirmed with wall slope and rock abundance estimated using Lunar Orbiter Laser Altimeter (LOLA) and Diviner data of the Lunar Reconnaissance Orbiter (LRO), respectively.

1. INTRODUCTION

What Happened on the Lunar Surface?

At higher latitudes, lunar regolith has brighter reflectance less red less mature caused by lower flux.



Which space weathering agents enter along the ecliptic plane and affect soil maturation more? Solar wind particles or Micro-meteorites?

Apr. 2022

Hemingway et al. (2015) Icarus

Solar wind particles enter along the ecliptic plane! Reduced flux should occur both at swirls and toward higher latitudes.

Aug. 2015

Jeong et al. (2015) ApJS

Micro-meteorites (as well as solar wind particles) enter along the ecliptic plane! Grain size monotonically increases as the latitude increases.

Nov. 2015

Sim et al. (2017) GeoRL

Solar wind particles weather the lunar regolith more than micro-meteorites! Pole-facing walls are brighter and less red (i.e. less mature) than their equator-facing counterparts as latitude increases.

Nov. 2017

Trang et al. (2019) Icarus

Both of them, but it is difficult to estimate what affects more… Nanophase and microphase iron abundances are lower at higher latitudes, which suggests lower solar wind and micro-meteoroid impact flux at these latitudes.

Nov. 2018

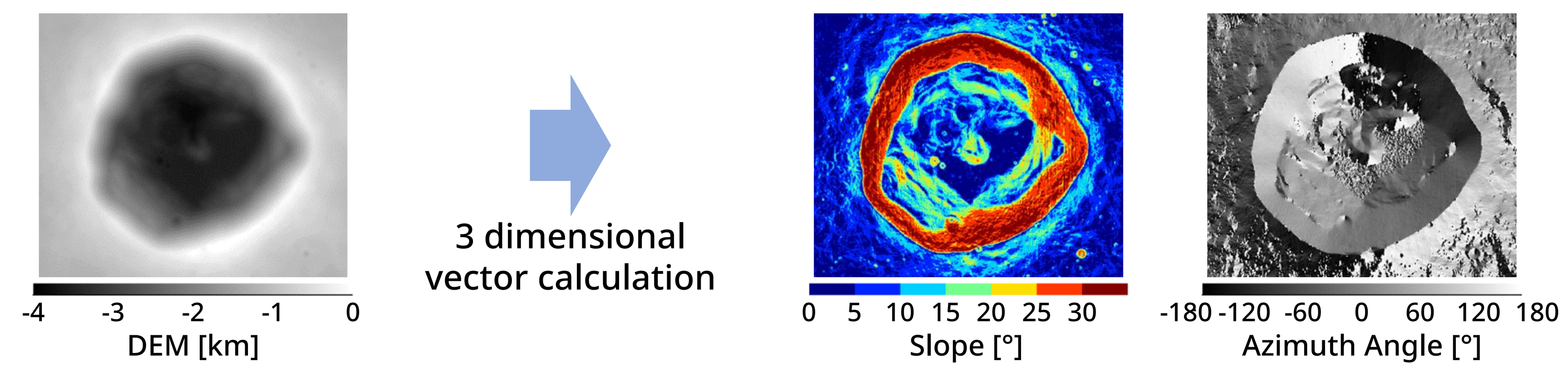
We are carrying on with Sim et al. (2017) with more craters. Thanks a lot for your research!

Apr. 2022

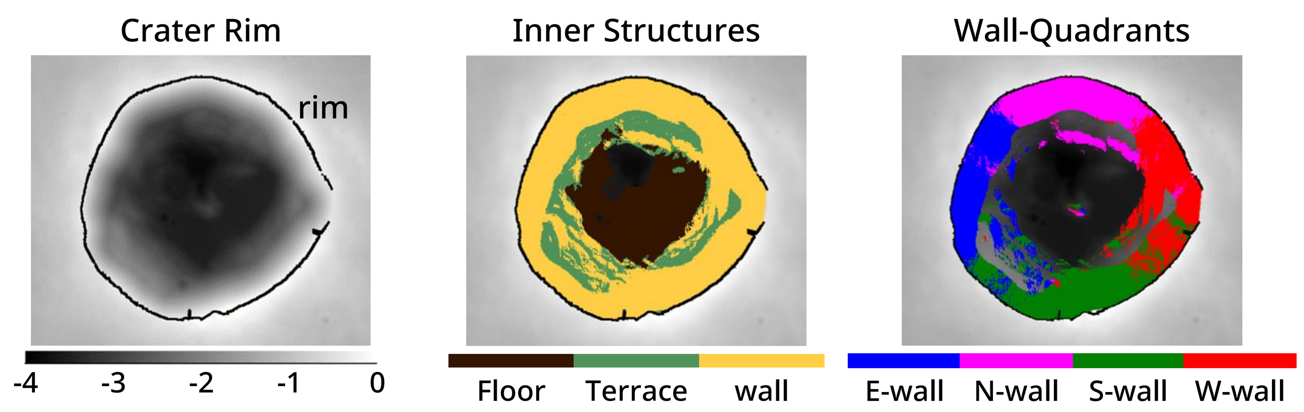
3. METHODS

We improved the analysis methods of Sim et al. (2017).

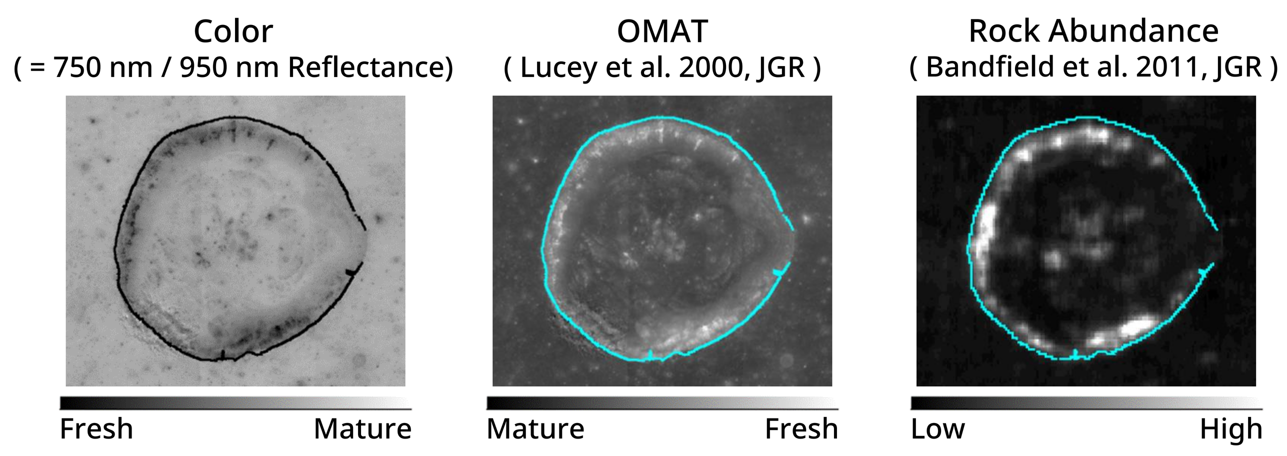
1. **Extract the DEM of craters & Produce slope and azimuth angle of each pixel.**



2. **Detect crater structures & Divide wall-quadrants using the topographic data.**



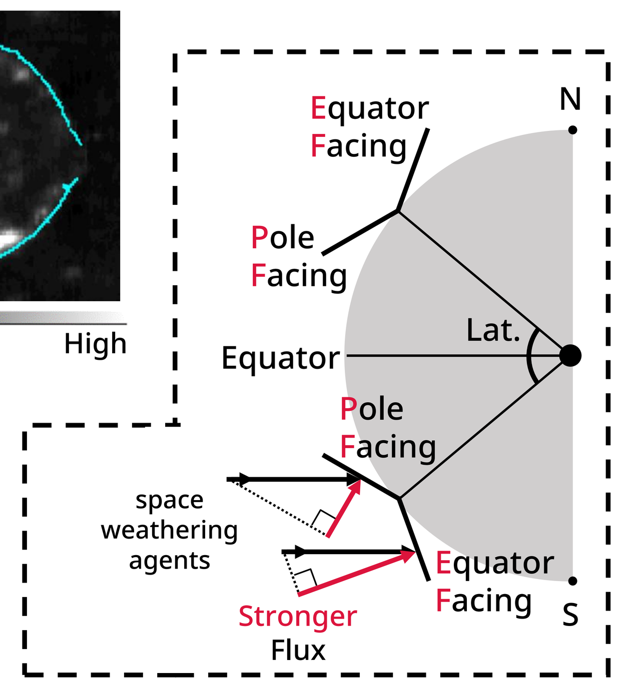
3. **Extract reflectance and roughness data of craters & Align to the DEM data of them.**



4. **Analyze latitudinal trends using EF and PF walls.**

Impact flux of space weathering agents is stronger on EF wall than on PF wall!

★ As latitude increases, flux difference of EF and PF wall increases. (= Δflux [$flux_{EF\ wall} - flux_{PF\ wall}$] increases.)



2. DATA

Lunar Crater Database

- We adopt the lunar crater database provided by Robbins et al. (2018) to consider more and smaller craters than Sim et al. (2017), which used lunar impact crater database provided by the Lunar and Planetary Institute (LPI).
- In this study, our algorithm for detecting craters identifies craters with well-preserved inner structure, particularly outer rim and wall-quadrants.

	Sim et al. (2017)	This Study
Database	LPI (2015)	Robbins et al. (2018)
# of craters	1872 (of 8716)	26,802 (of ~1.3 million)
Information	Central Latitude & Longitude Diameter of Major/Minor-axis	
Diameter	5 ~ 120 km	2 ~ 120 km
Latitude	-50° ~ +50°	-60° ~ +60°

※ Craters smaller than 2 km in diameter cannot be recognized due to spatial resolution (~60 m/pixel) of lunar global map data, even though they are well-preserved.

Lunar Global Map Data

- DEM : the improved lunar digital elevation map created by the LOLA and SELENE Kaguya teams at a typical vertical accuracy ~3 to 4 m
- Reflectance : ultraviolet-visible (415, 750, 900, 950, 1001 nm) and near-infrared (1000, 1050, 1250, 1550 nm) of SELENE multiband imager
- Rock abundance : level 3 gridded data record of LRO Diviner

Mission	LRO + SELENE	SELENE	LRO
Instrument	LOLA + Terrain Camera	Multiband Imager	Diviner
Data Type	DEM	Reflectance (UV—Visible)	Rock Abundance
Resolution	~60 m/pixel		~240 m/pixel

※ All data cover latitudes within ±60°.

4. RESULTS

Figure 1. Result of Sim et al. (2017)

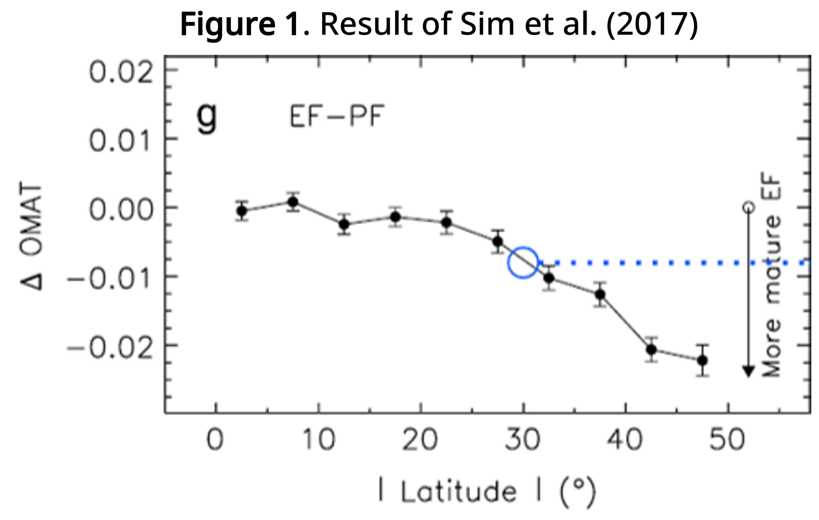
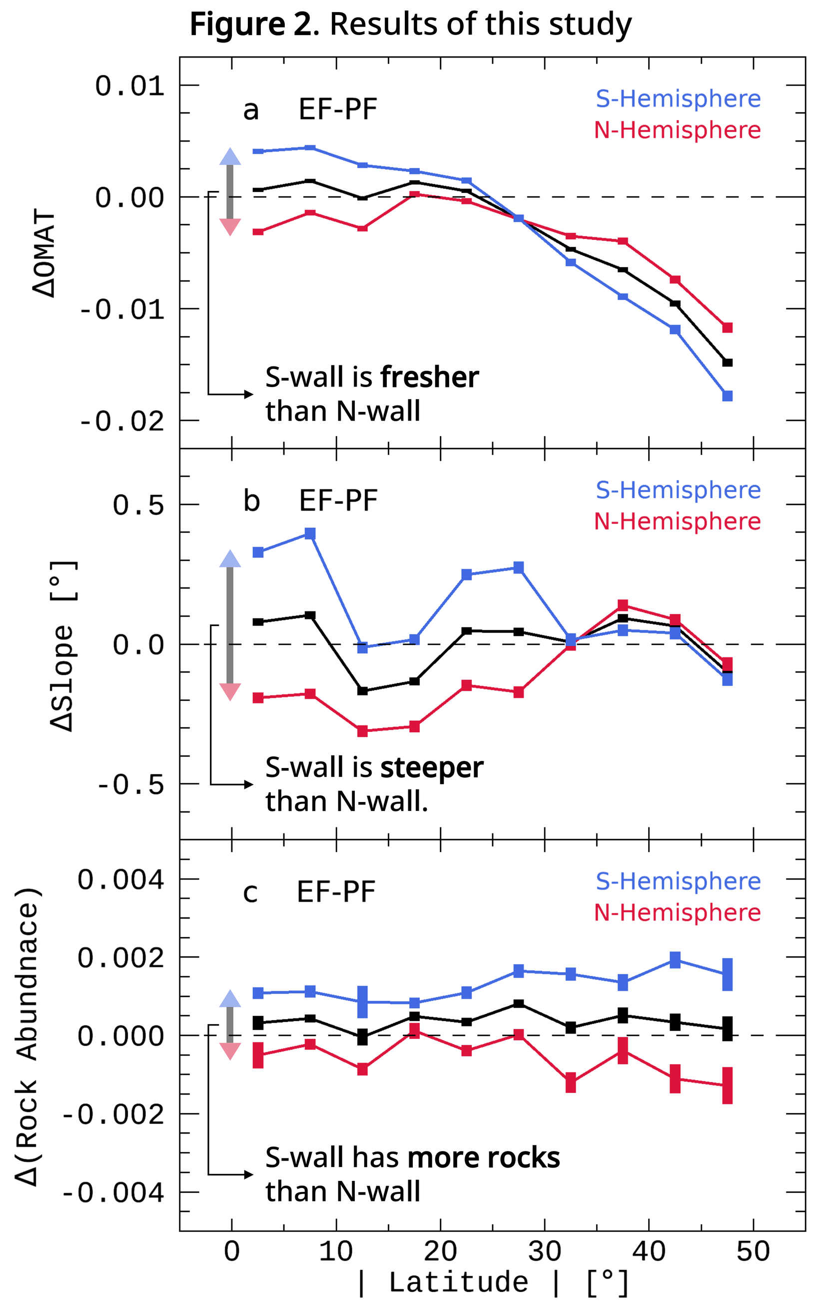


Figure 2. Results of this study

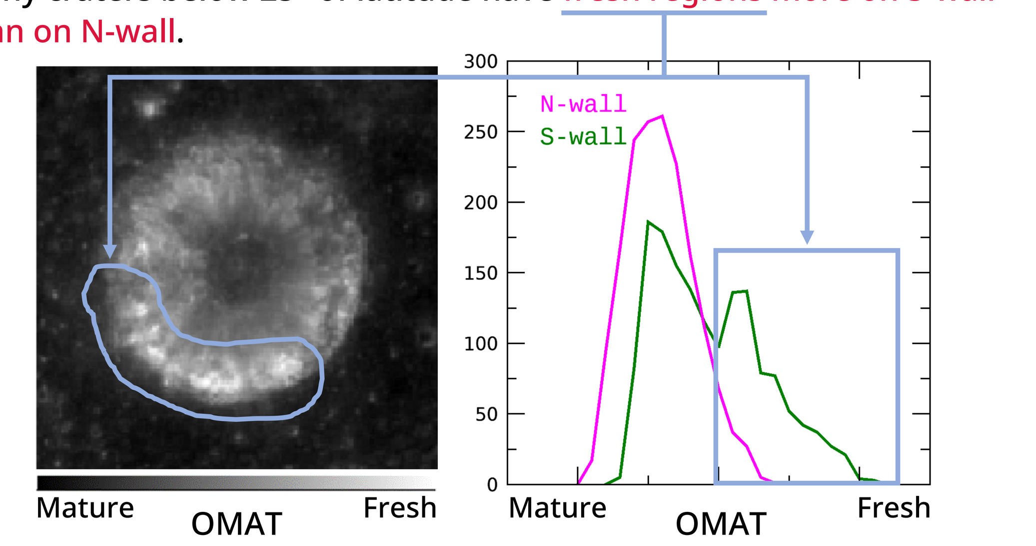


Latitudinal Trends of Δ (= [Equator Facing] – [Pole Facing])

- ΔOMAT of all craters (dark solid line in Figure 2a) is consistent with the previous study (Figure 1), it should be close to zero near the equator and increases toward higher latitudes.
- It means that incident angles of EF and PF walls are similar near the equator because space weathering agents are known to enter along the ecliptic plane.
- For the similar reason, Northern (N) and southern (S) hemispheres should be symmetrical.
- We analyze the ΔOMAT in N and S hemispheres separately in order to confirm the symmetry using more craters than the previous study.
- ★ However, the ΔOMAT in the N (red solid line) and S (blue solid line) hemispheres are not close to zero near the equator and have opposite trends below 25° of latitude.
- ΔSlope and Δ(Rock Abundance) also have the asymmetries and the opposite trends throughout the latitude.

Causes of the opposite trends below 25°

- Many craters below 25° of latitude have fresh regions more on S-wall than on N-wall.



- {ΔOMAT < 0 in the N hemisphere, ΔOMAT > 0 in the S hemisphere} near the equator doesn't mean that N-wall is more weathered by space weathering.
- ★ This means that S-wall become fresh by meteorite hundreds of meters in diameter.
- We assume that the opposite trends near the equator are caused by asymmetric impacts of meteoroids on the Moon.