Scientific Aspects of the Korean Lunar Exploration

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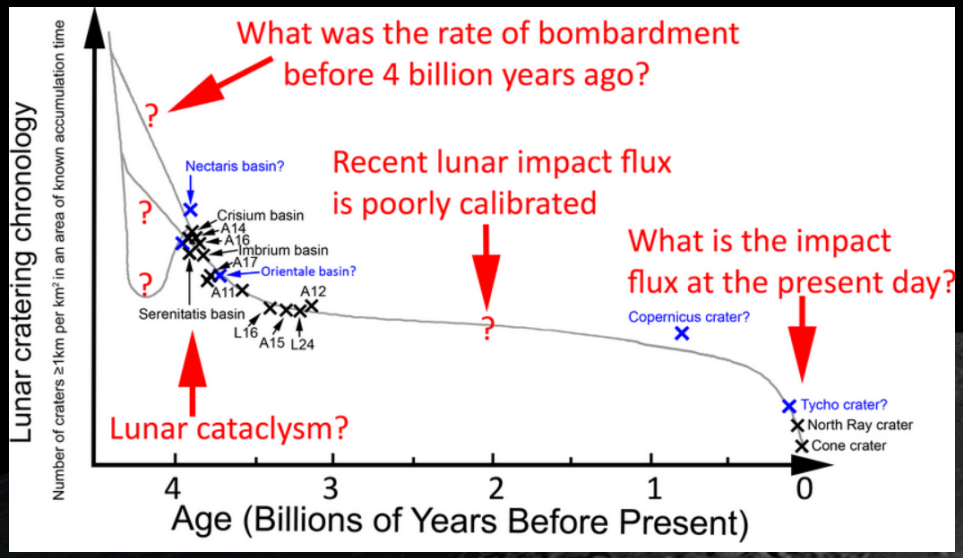
Lunar Science

- Bombardment history of Solar System♪
- Surface properties of airless body♪
- Plasma environment near/of the Moon♪
- Volatiles, Mineralogy♪

Bombardment history

- Crater Size Frequency Distribution
- Current small body configuration in our solar system



Bombardment history

- New born lunar crater
- Secondary crater

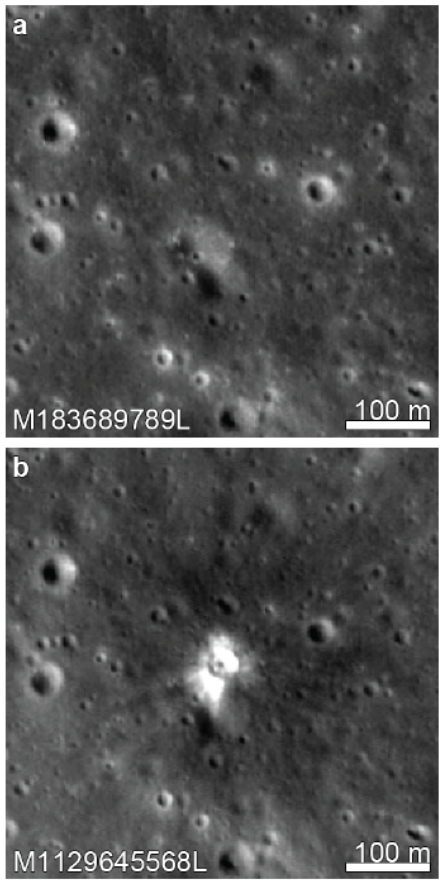


Figure 1. a) Pre-impact NAC image of the 17 March event, b) post impact image showing newly formed 18-m diameter crater and associated regolith changes.

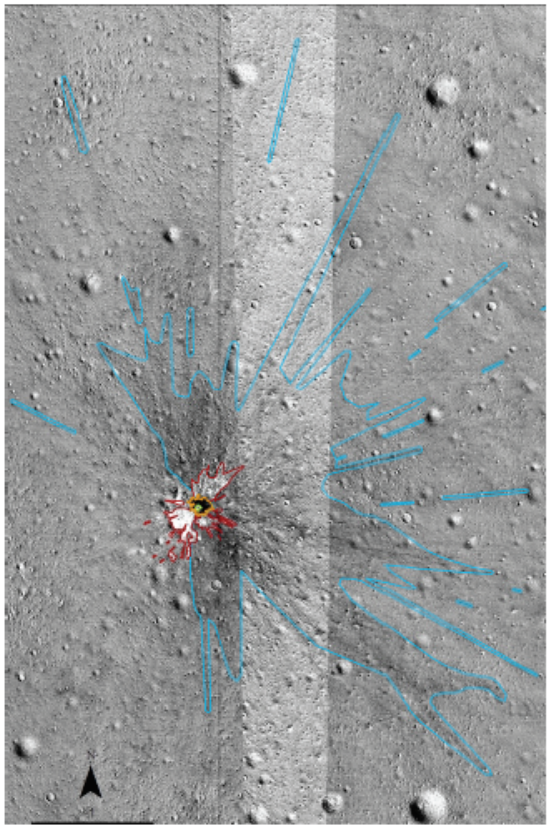
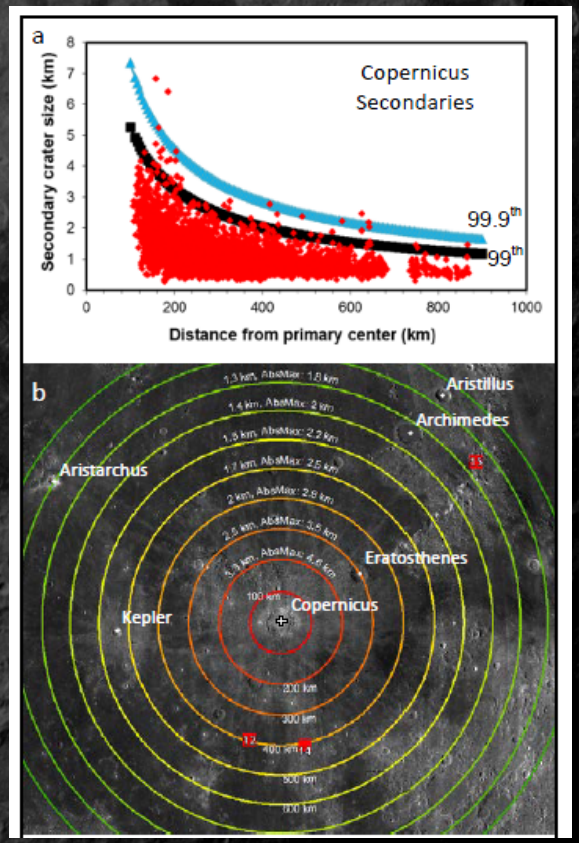


Figure 2. Temporal ratio (before M183689789L / after M1129645568L) orange outline delimits proximal high reflectance ejecta, red line is the boundary of low reflectance ejecta, blue outline shows boundary of high reflectance outer continuous ejecta, scale bar is 1000 meters.



(LPSC, 2014)♪

- Crater Study
  - Depth vs Diameter (d/D ratio)

    (SLC: Small Lunar Crater < 200 m)
  - Mean Wall Slope (MWS)

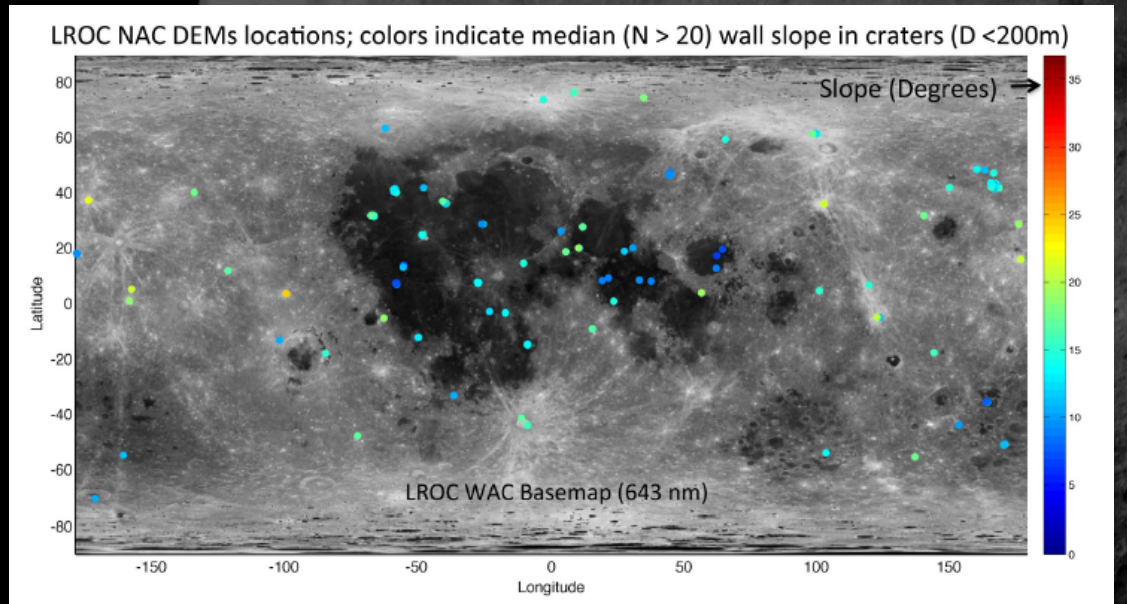


Figure 3: Global distribution of NAC DEMs used in this study. Some locations have multiple DEMs. The colorbar indicates the median wall slope

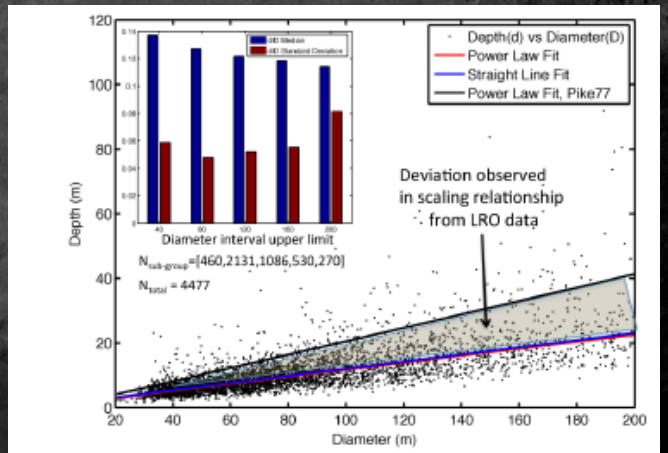


Figure 1: Depth vs Diameter from observed SLC. Fit to observations is shown as solid lines. Bar chart (inset) shows diameter range median and standard deviation values

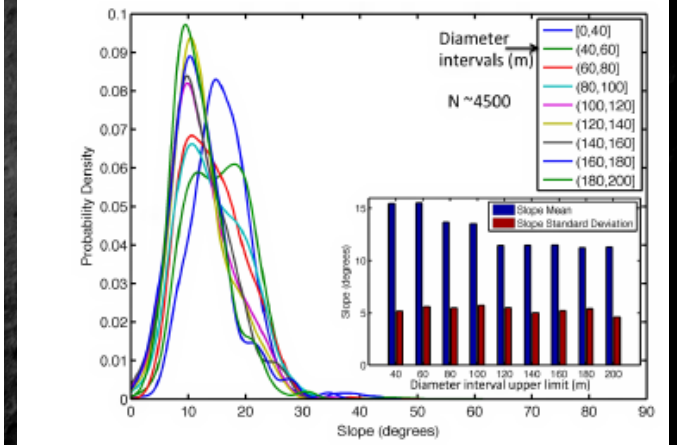
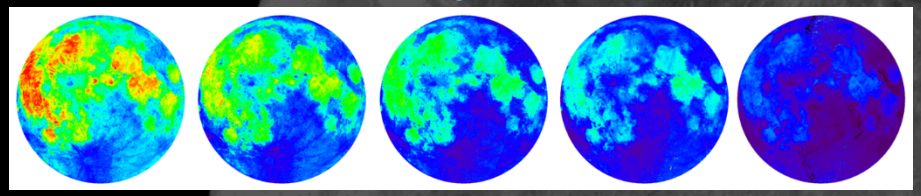


Figure 2: Wall slope statistics for SLC. Bar chart (inset) shows diameter range median and standard deviation values

(LPSC, 2014)♪

Lunar surface properties

- Polarimetry (see Poster by C.K. Sim)
  - Surface roughness
  - Space weathering



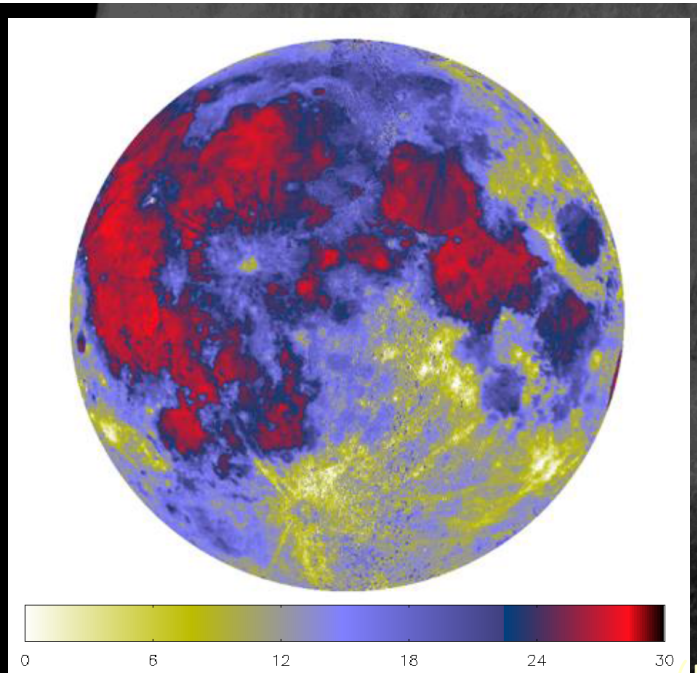


Figure 1. The map of the polarization maximum from the V band. The color bar is in units of percent.

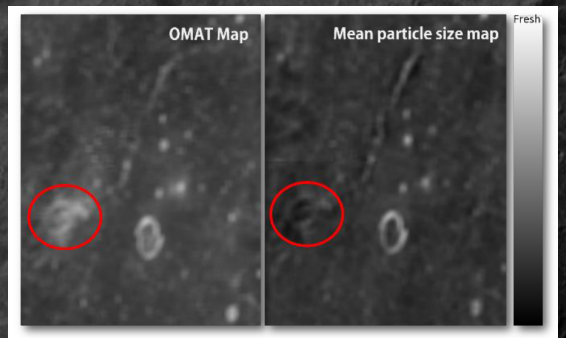


Figure 2. OMAT and mean particle size maps. Red circles mark the location of Reiner Gamma swirl. Brighter color indicates fresher soil in the OMAT map, and larger particle size in the mean particle size map.

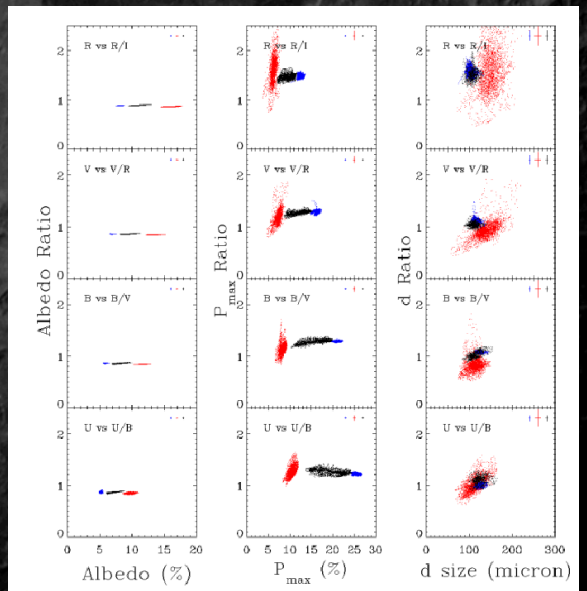


Figure 3. Wavelength dependencies of the albedo, polarization maximum, and mean particle size for maria (blue), Reiner Gamma swirl (black), and highlands (red).

LPSC, 2014

Lunar surface properties

- UV reflectance
  - Space weathering
  - Water ice in FUV(160-180 nm)

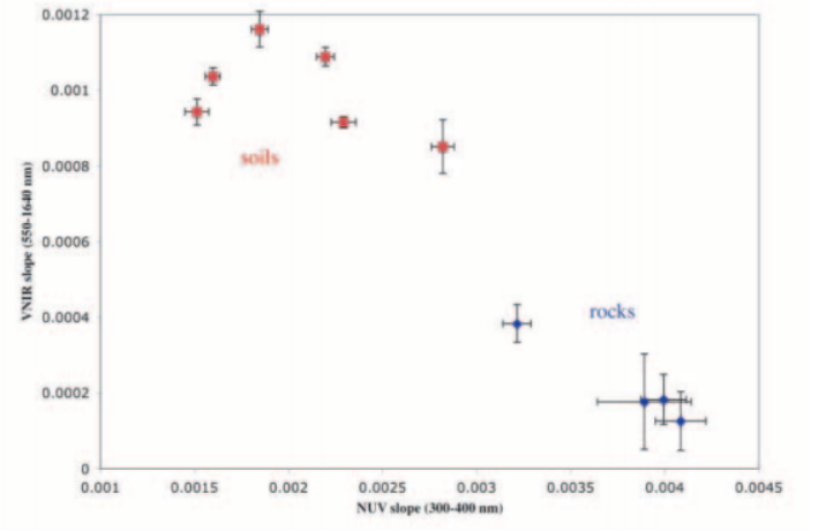


FIG. 2.—Spectral slopes (in units of reflectance nm^{-1}) of lunar samples, showing trends with weathering. Error bars represent the 1 σ uncertainty on the computed slopes. Lunar soils are redder at VNIR wavelengths and bluer in the UV than lunar rocks.

(Handrix, 2006)♪

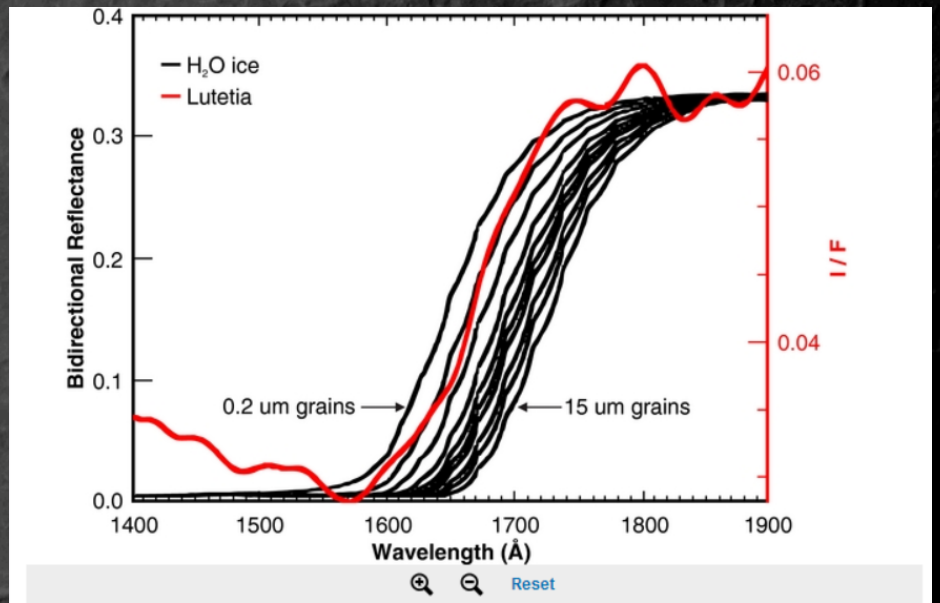


Figure 3. As illustrated by this comparison of laboratory spectra to our data, water ice has a strong absorption edge at the same wavelength where we see an absorption feature in the Lutetia spectrum. This spectrum (red line) is taken from *Rosetta* Alice observations near closest approach. The H_2O curves (black lines) are from Hendrix et al.'s (2008) Hapke reflectance calculations for water ice based on laboratory-derived optical constants.

(Stern, 2011)♪

Mineralogy

- Surface mineralogy (Olivine, Pyroxene, etc.)
  - Band assignment: 0.5-1.5 ㎛

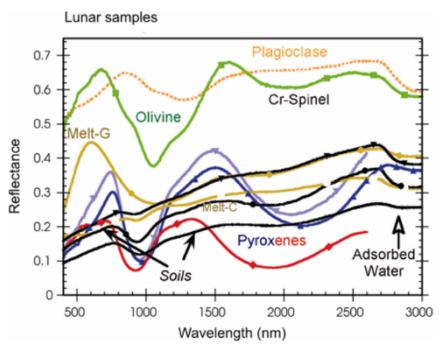


Figure 1. Reflectance spectra of lunar minerals and soils over the spectral range of M³. High spectral resolution allows superimposed features to be deconvolved for identification. The weak feature near 2900 nm is due to trace amounts of (terrestrial) water remaining on the samples even in a purged laboratory environment.

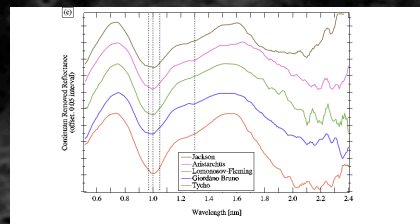


Figure 1: (a) The global distribution of HCP points. The background map is the albedo map based on R_p [9]. (b) The same as (a), but for BHCP with $R_p \geq 0.1$. (c) The continuum-removed reflectance spectra measured at SP observational points in several BHCP points. All spectra have been vertically offset for clarity, and the tick intervals of the vertical axes are 0.05. Vertical lines are at 0.97, 1.00, 1.05, 1.30 μm, respectively.

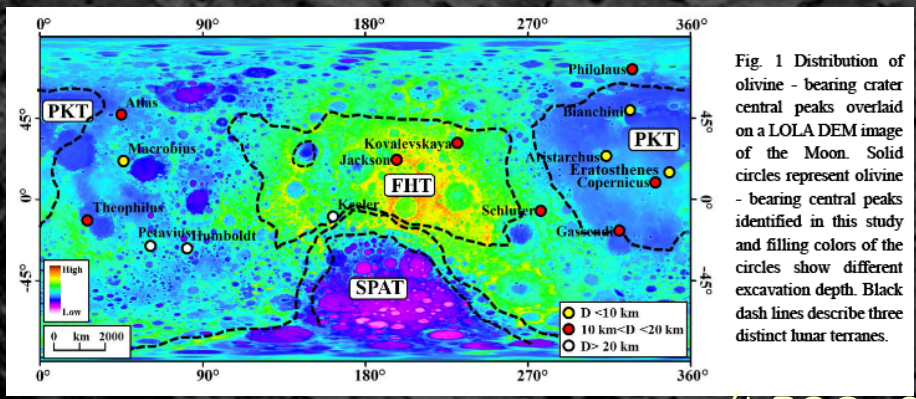


Fig. 1 Distribution of olivine - bearing crater central peaks overlaid on a LOLA DEM image of the Moon. Solid circles represent olivine - bearing central peaks identified in this study and filling colors of the circles show different excavation depth. Black dash lines describe three distinct lunar terranes.

(LPSC, 2014)♪

Regolith Study using IR Spectral Imager

- Regolith Study
  - The regolith analysis of the lunar swirl regions
  - Surface anomaly study
  - Band assignment: 0.5-2.5 ㎛
  - Spectral resolution: ~10 ㎚

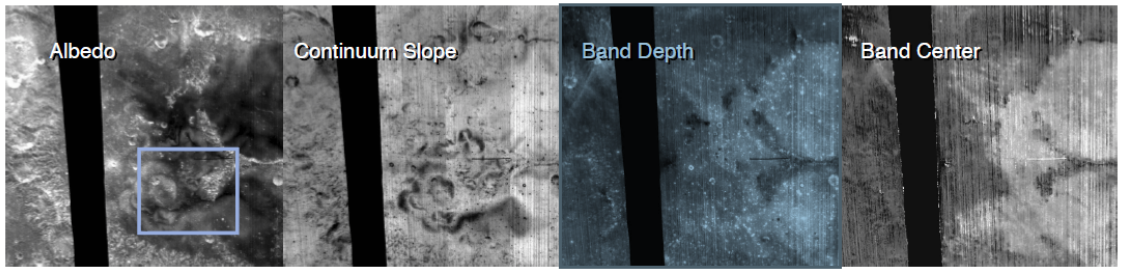


Fig. 1. M^3 mosaic of western Ingenii. Left to right: 1489nm brightness (SUP image), scaled 1µm continuum, 1µm band depth, 2 µm band center. All values are low to high = dark to bright. Swirls are apparent in the albedo and continuum measurements, but not in the mafic band strength nor in band center (pyroxene composition) variations.

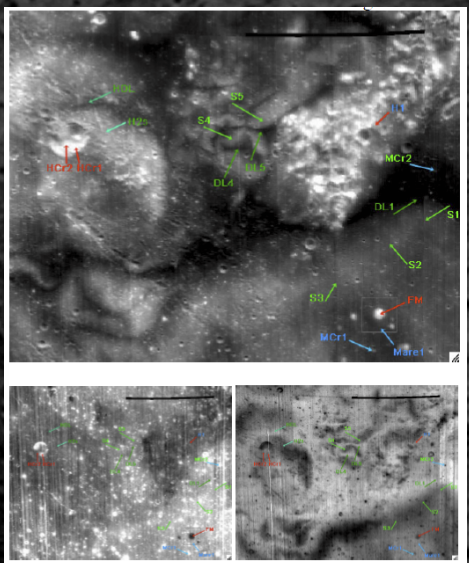


Fig. 2. Subsection of M3 mosaic for the Ingenii region. Top) 1489 reflectance image from SUP data. Bottom). Estimated 1 µm Band Depth (left) and Normalized Continuum Slope across 1 µm (right).

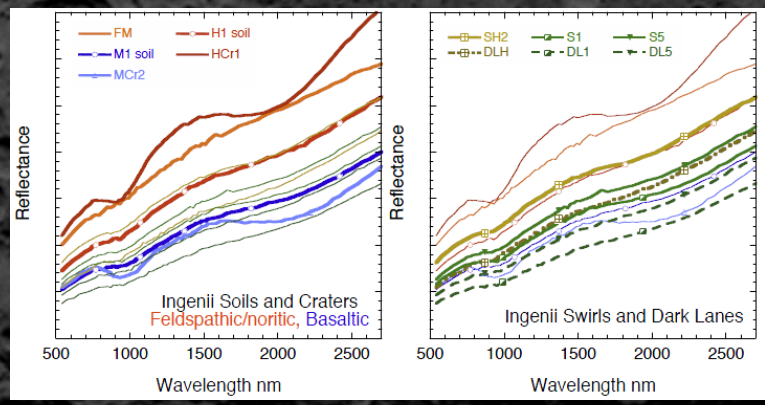


Fig. 3. M3 reflectance spectra (3x3 pixels) of areas in Ingenii. Both figures are the same, but the left highlights normal local craters and soil and the right highlights swirls (solid) and nearby dark lanes (dashed).

Acknowledgements: This research is supported through NASA SSERVI.

Water

- Study of Water Abundance
  - Study early lunar volcanic processes
  - Search H_2O-rich site
  - Band assignment: 2.6-3.6 ㎛
  - Spectral resolution: ~10 ㎚

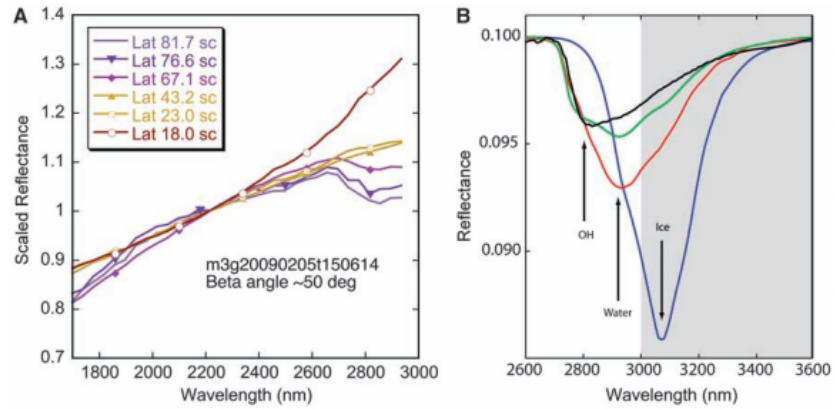


Fig. 3. **(A)** Scaled reflectance spectra for M^3 image strip M3G200902005T-150614. All spectra are 7-by-7–pixel averages, and no thermal emission has been removed to allow the measured flux to be compared. The strongest detected 3-μm feature (~10%) occurs at cool, high latitudes, and the measured strength gradually decreases to zero toward mid-latitudes (where thermal emission is necessarily less well constrained by M^3). At lower latitudes (18°), the additional thermal emission component becomes evident at wavelengths above ~2200 nm (*14*, *15*). **(B)** Model near-infrared reflectance spectra of H_2O and OH applicable for lunar comparisons. These spectra are highly dependent on physical state. A model of a thin layer of H_2O water (red) and ice (blue) on a 10% reflective surface equivalent to ~1000-ppm abundance is distinct from anorthite (green) and a lunar glass analog (black). The shaded area extends beyond the spectral range of M^3. Calculations are based on optical constants from (*27*–*29*), assuming no scattering in the H_2O or OH and with a 100-μm path length within the substrate.

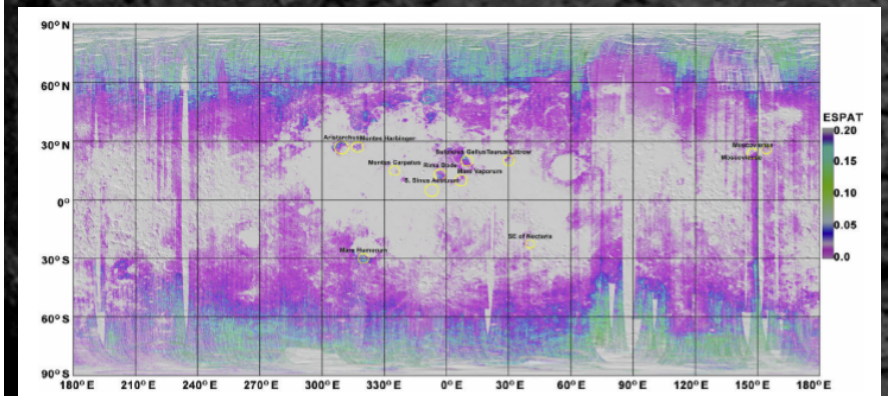


Figure 1. Quantitative mapping of lunar surface hydration (ESPAT) and large pyroclastic deposits (yellow circles) between 30°N and 30°S; wt.% water can be estimated by multiplying the ESPAT value by 2 for pyroclastic deposits.

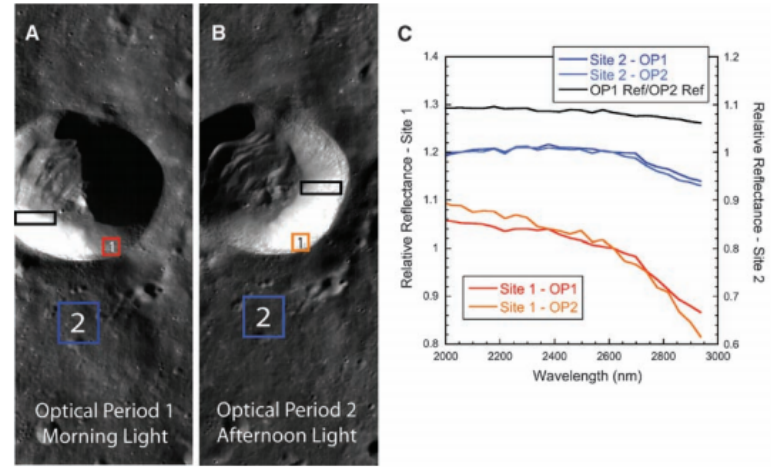


Fig. 4. M^3 data taken two months apart during morning **(A)** [optical period 1 (OP1)] and afternoon **(B)** [optical period 2 (OP2)] solar illumination. The large 30-km Chadwick crater is located on the farside at 258.7°E, 52.7°S. Spectra in panel **(C)** are scaled reflectance for areas 1 and 2, relative to a local area of strong solar illumination that exhibits a relatively weak 3-μm band in the scene (this reference location varies with geometry). Background soil region 2 (50 by 50 pixels) exhibits a moderately weak and consistent 3-μm band strength. Region 1 within the crater (20 by 20 pixels) exhibits a more prominent apparent band strength, perhaps sensitive to solar illumination. Black boxes in (A) and (B) (50 by 15 pixels) indicate that the reference area selected for spectral ratios.

Lunar Plasma ♪

- In-situ measurement of mini-mag etosphere♪
- Monitor space weather effect on t e Moon♪
  - Monitor solar wind or tail plasma♪
- Potential profile & plasma characte ristics over the meso-scale altitude♪
- Exospheric desorption at dawn t minator & polar 'water history', s ace charging, dust, wake ♪

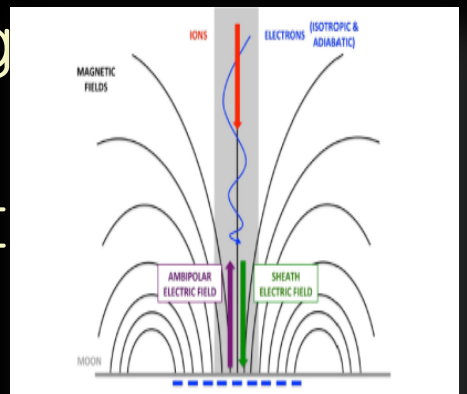
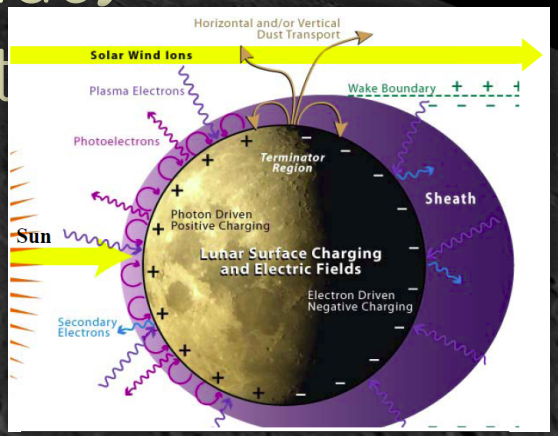


Figure 1. A cartoon illustrating the geometry and various particle populations and fields present in the model as explained in the text.



Summary

- Bombardment history
  - Spatial resolution
  - Crater study: Crater Size Frequency Distribution (CSFD), d/D ratio,
    Mean Wall Slope (MWS), New born lunar crater, Landing site search
- Surface properties
  - Lunar roughness & Space weathering: Multi-band Polarimetry
  - Space weathering in UV: UV Camera
- Mineralogy & Water
  - IR spectral range: 0.5-1.5 ㎛, 2.7-3.8 ㎛
  - Surface mineralogy (Olivine, Pyroxene, etc.)
  - Lunar swirl regions: Higher spatial resolution
  - Water