
EUROPLANET 2024
Research Infrastructure

Geology & Planetary Mapping
Winter School

Compositional data handling:
2nd part: Introduction to the Moon spectral high level products

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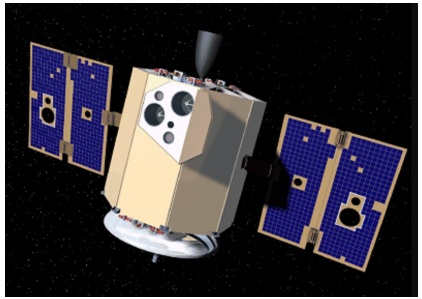
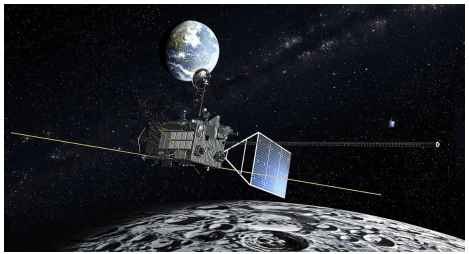
Moon Missions: Moon Mineralogy and Composition

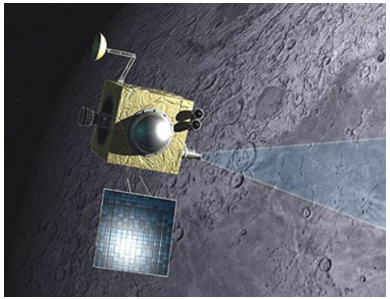
Clementine – NASA (1994)



Kaguya – JAXA (2007-2009)



Chandrayaan-1 – IRSO (2008-2009)



Lunar Reconnaissance Orbiter (LRO), NASAIRSO (2009-Present)

Clementine UVVis camera

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Ultraviolet/Visible camera (UV/Vis)

Kordas, J. F., et al., 1995

UVVis consisted in a catadioptric telescope with an aperture of 46 mm and fused silica lenses focused onto a coated Thompson CCD camera.

UVVis covered a range of wavelengths between 250 and 1000 nm, and it was equipped with a six-position filter wheel: 415 nm, 750 nm, 900 nm, 950 nm, 1000 nm and a broad-band filter covering 400-950 nm.

Pixel resolution varied from 100-325 m during a single orbit mapping run at the Moon.

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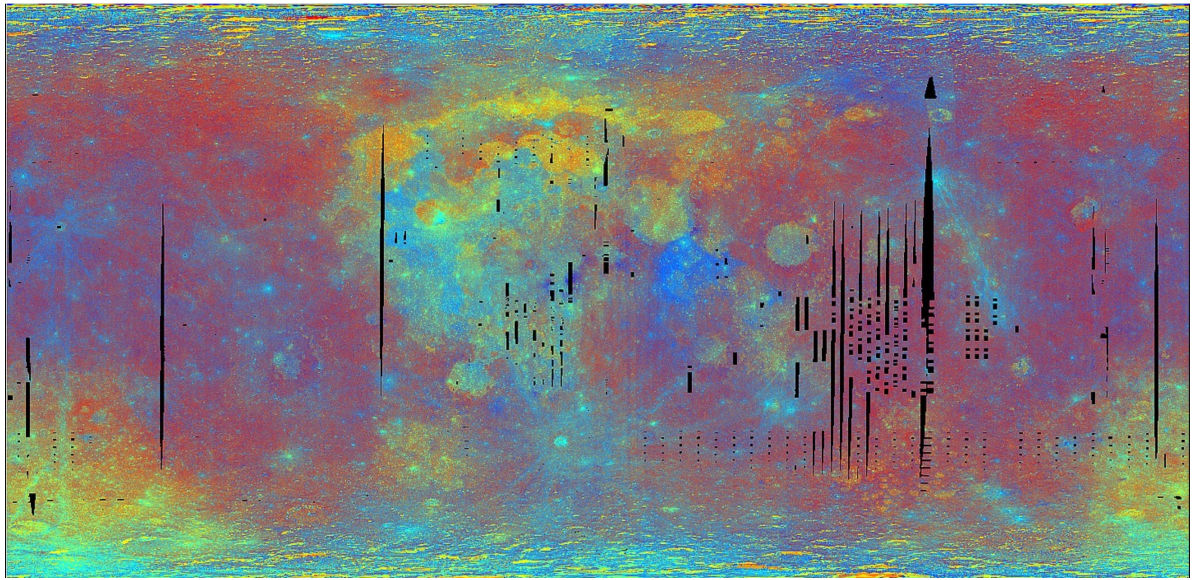
Moon Clementine UVVIS Warped Color Ratio Mosaic

RGB Color composite mosaic at 200 m/pixel



R: 750/415 nm
G: 415/750 nm
B: 750/1000 nm

Interpretation:
Red channel: Low titanium, or high in glass content regions.

Green channel: It is sensitive to the amount of iron in the surface.

Blue channel: High titanium or bright slope and albedo regions.

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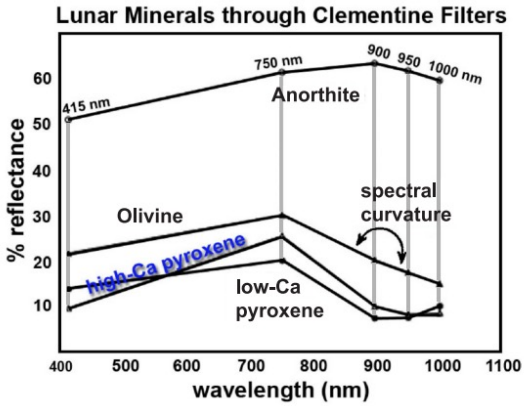
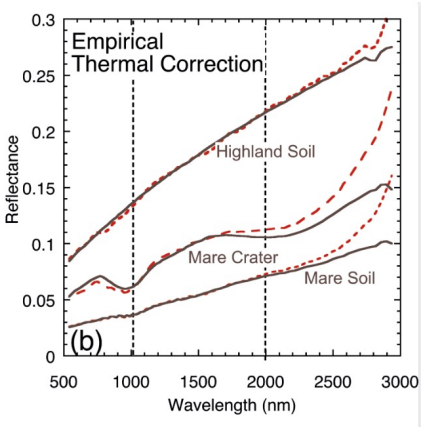
How to choose the spectral ratio

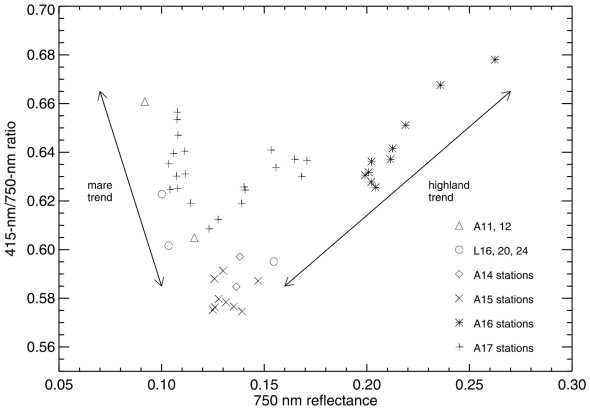
Study the spectral characteristics of the body and compare them with possible analogues.

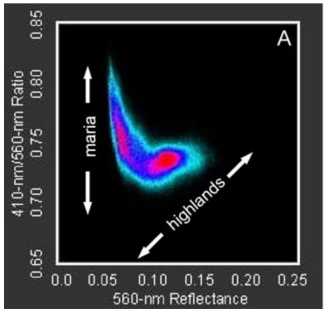


Robinson and Riner 2005



Pieters et al. 2019





Blewett et al. 1997

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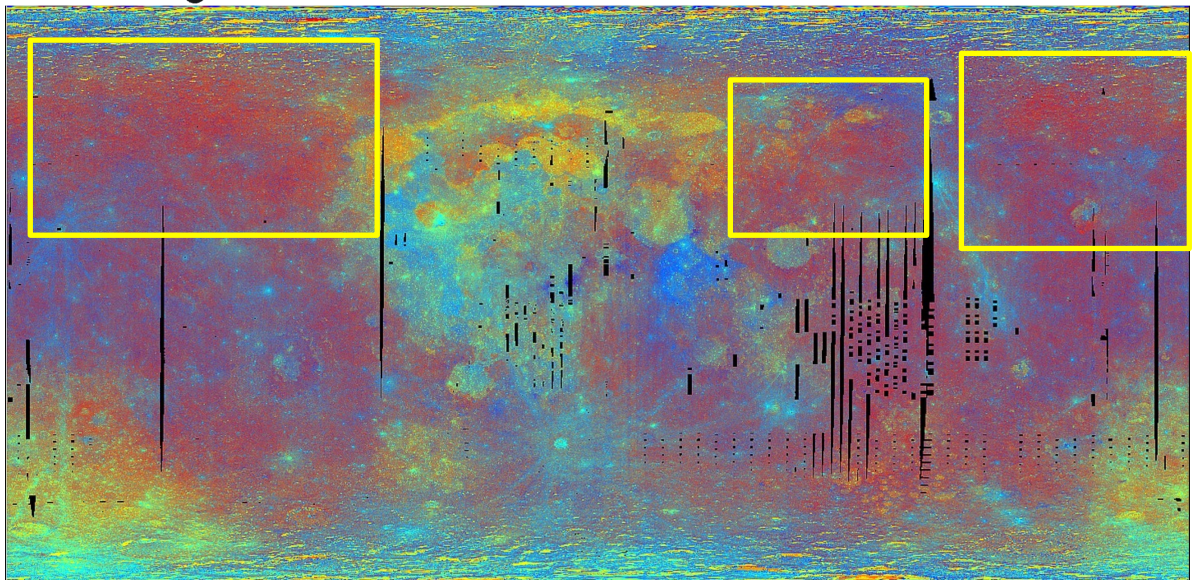
Moon Clementine UVVIS Warped Color Ratio Mosaic



Highlands appears red due to the accumulated glassy agglutinates produced during the bombardment of micrometeorites (maturation).

Pyroclastic deposits are also red because of their naturally high-glass content.

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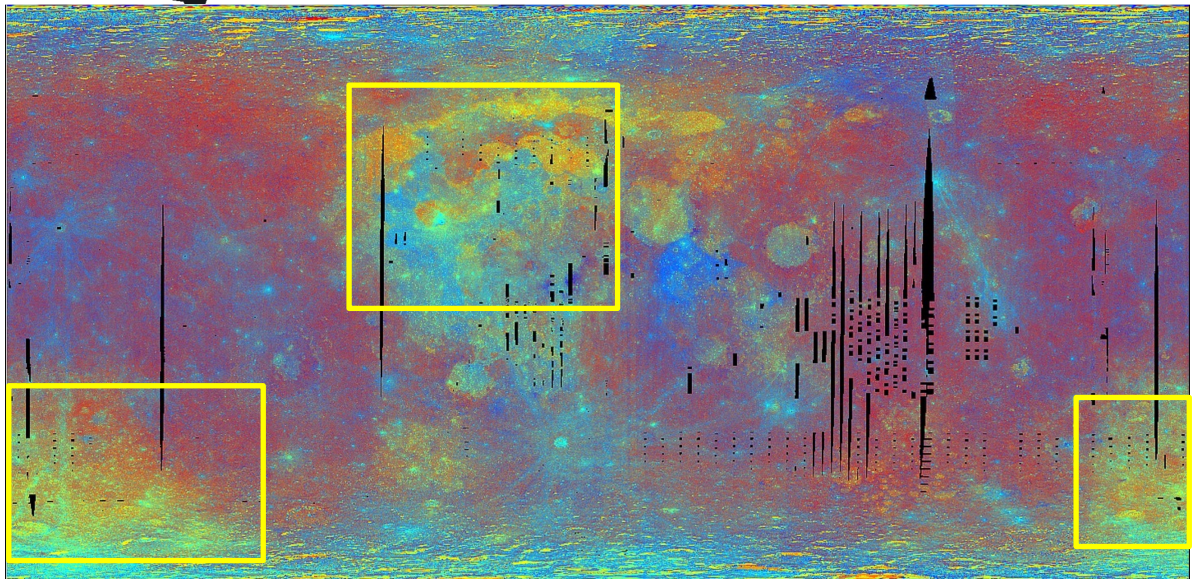
Moon Clementine UVVIS Warped Color Ratio Mosaic



Yellow-green areas concentrated in the maria and in South Polar Aitken (SPA) basin, show the combined effect of concentration of mafic minerals (green) and the glass in the soil produced by maturation (red).

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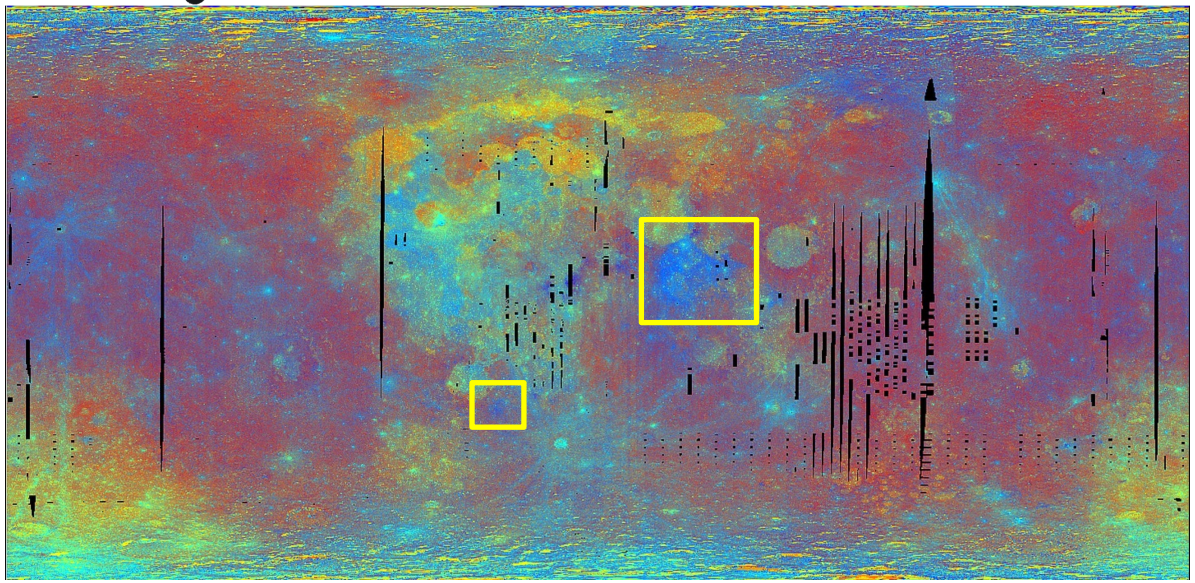
Moon Clementine UVVIS Warped Color Ratio Mosaic



The blue unit in Mare Tranquillitatis represents one of the highest titanium regions compared to the mare units in the neighborhood.

Clementine UVVis Iron and Titanium maps

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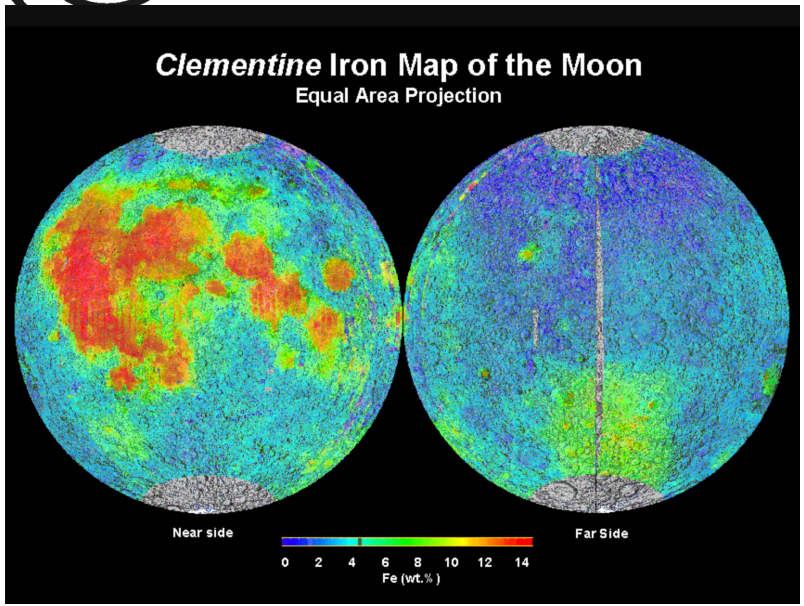
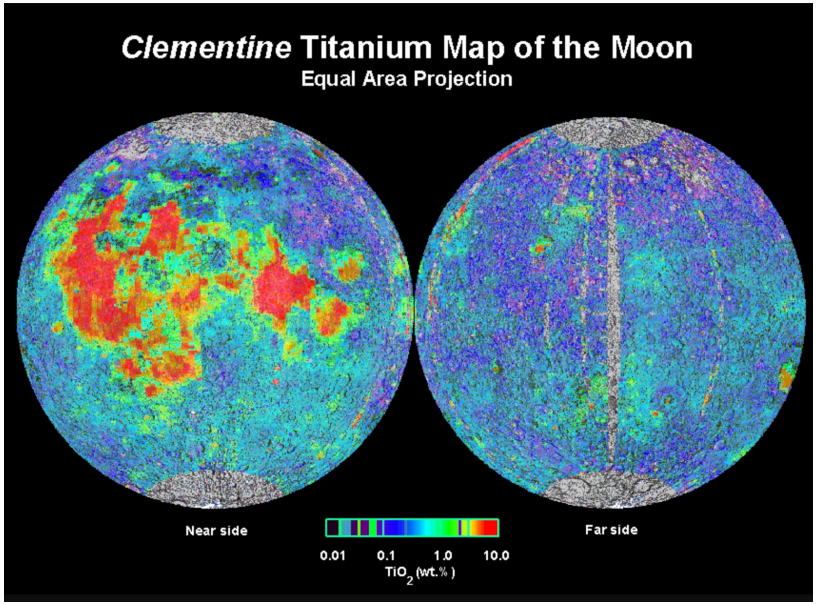
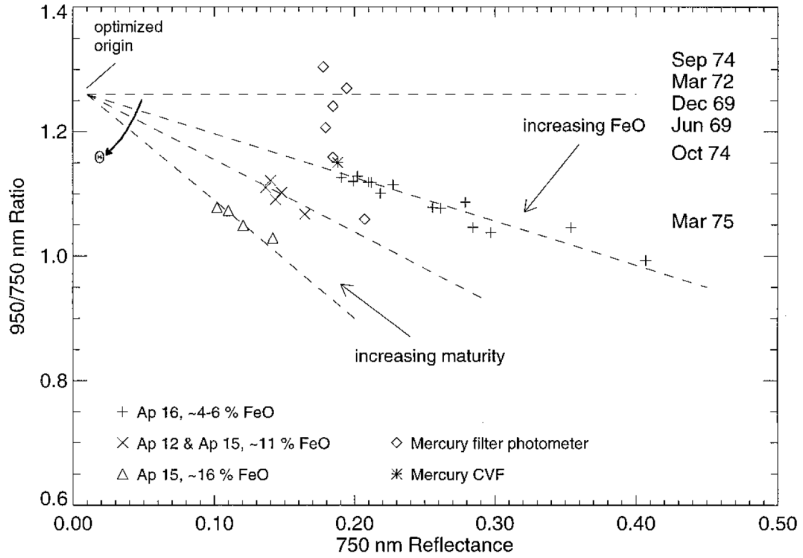
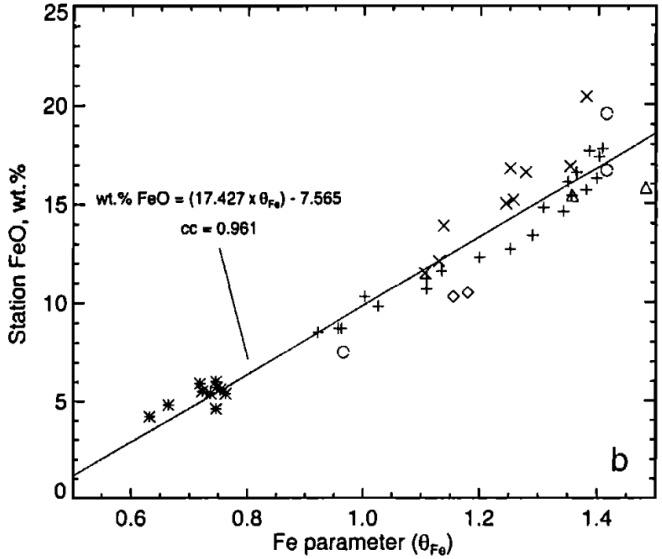




Clementine UVVis Iron and Titanium maps



Blewett et al. 1997



Lucey and Blewett 2000

Kaguya Lunar Imager/SpectroMeter (LISM)

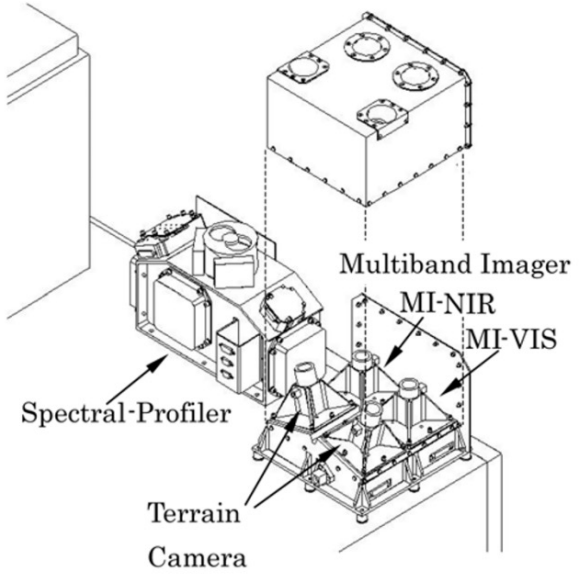


Fig. 1. LISM Radiometer Unit (LRU) of MI/TC and SP on the SELENE (KAGUYA) mission module.

LISM consists of the three subsystems, the Terrain Camera (TC), the Multiband Imager (MI), and the Spectral Profiler (SP)

TC is a push-broom imaging camera with a spatial resolution of 10 m from the 100 km SELENE (KAGUYA) orbit altitude.

MI is a high-resolution multiband imaging camera consisting of visible and near-infrared sensors which have 5 visible and 4 near-infrared bands: UVVIS; 415, 750, 900, 950, 1001 nm, and NIR; 1000, 1050, 1100, 1250 nm

SP is a visible to near-infrared line-profiling spectrometer, covering the range 500–2600 nm.

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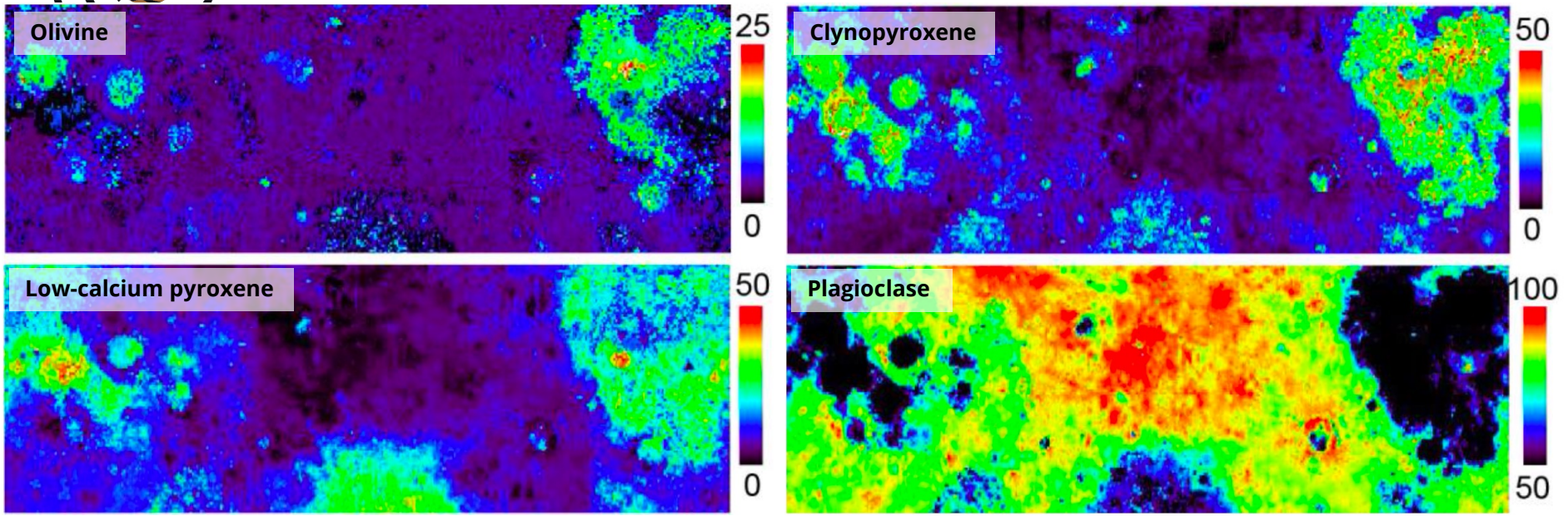
Kaguya Multiband Imager (MI) Maps

Global mineral maps from the Multiband Image data has been better calibrated within ±50° in latitude, spatial resolution 60 m/px.



Lemellin et al., 2016

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Kaguya Multiband Imager (MI) Maps

Lemelin et al. 2016 produced the maps starting from the reflectance spectra of 6601 mixtures of olivine, low-calcium pyroxene, clinopyroxene and plagioclase, at 7 amounts of submicroscopic iron (SMFe).

The reflectance spectra of these mixtures for a grain size of 200 μm have been modeled for plagioclase to account for the band depth observed in the Multiband Imager data.

They compared the modeled spectra that contained ±2 wt% FeO of a given pixel, and assigned the composition to the best spectral match.

They validated the mineral abundances obtained with global elemental maps from Lunar Prospector.

The Lunar Reconnaissance Orbiter Camera - Wide Angle Camera (WAC)

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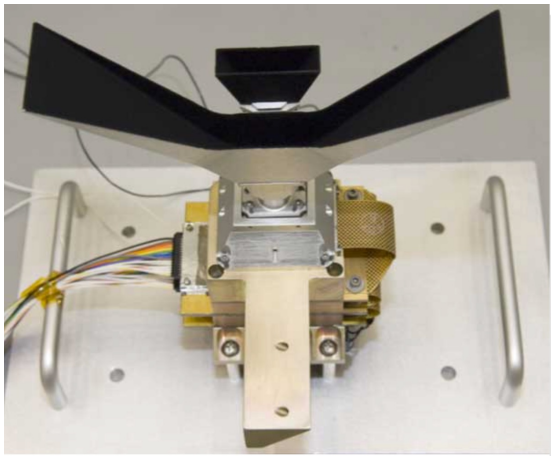
LROC Wide Angle Camera



LROC Wide Angle Camera (WAC)

http://lroc.sese.asu.edu/about

LROC is a system of three cameras mounted on the Lunar Reconnaissance Orbiter (LRO) that capture high resolution black and white images and moderate resolution multi-spectral images of the lunar surface.

LROC consists of two Narrow Angle Cameras (NACs) that are designed to provide 0.5 meter-scale panchromatic images, and a Wide Angle Camera (WAC) that provides images at a scale of 100 meters/pixel in seven color bands.

LROC is equipped with two filters at 321 and 360 nm in UV bands; and 5 filters centered at 415, 566, 604, 643, and 689 nm in visible bands.

LROC-WAC Maps

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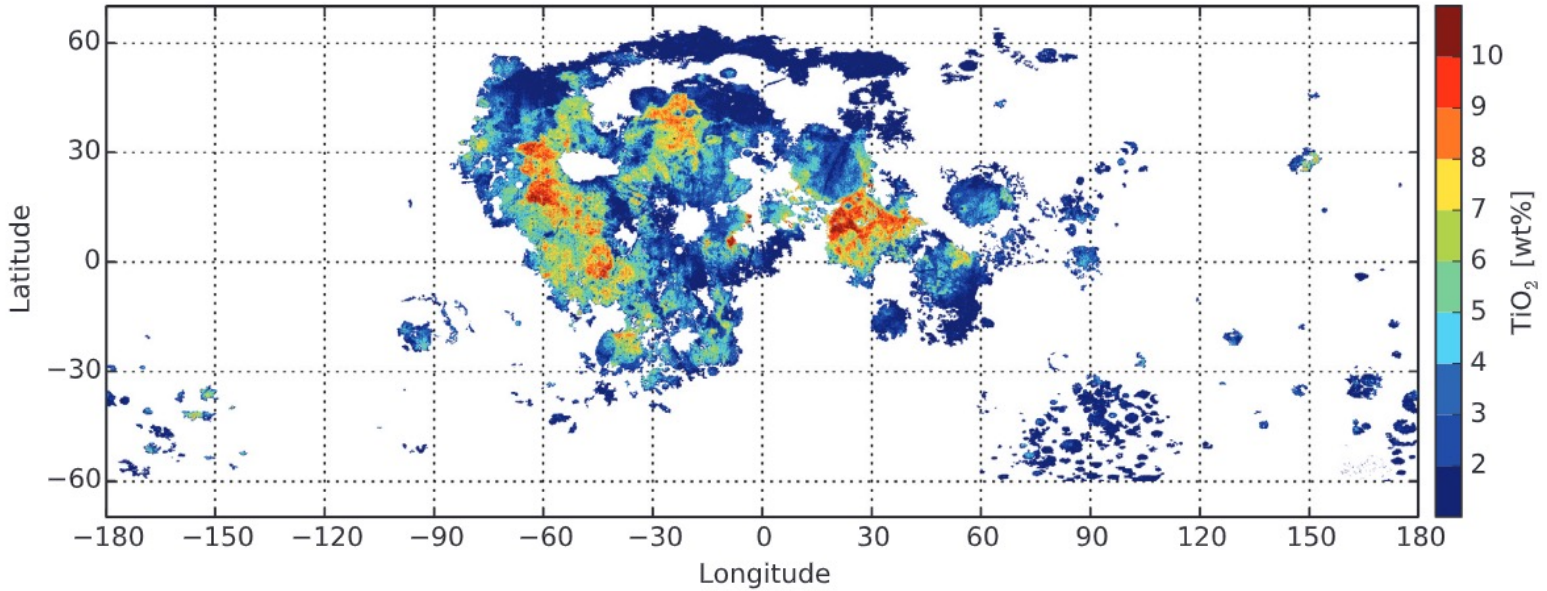
WAC TiO_2 abundance map for lunar mare



Sato et al., 2017

Chandrayaan-1 – Moon Mineralogy Mapper M³

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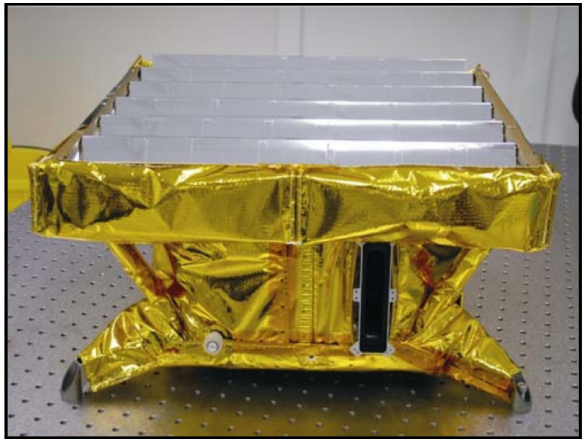
M³



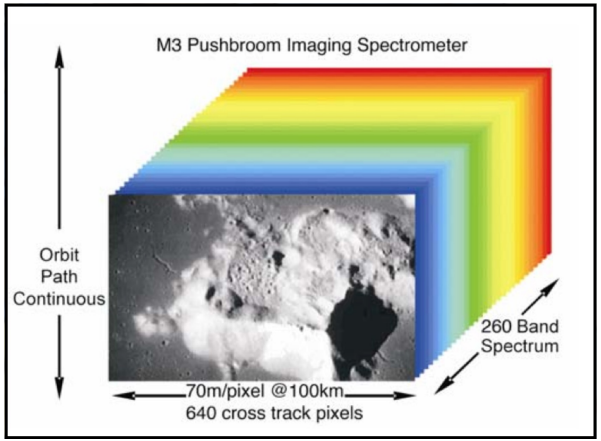


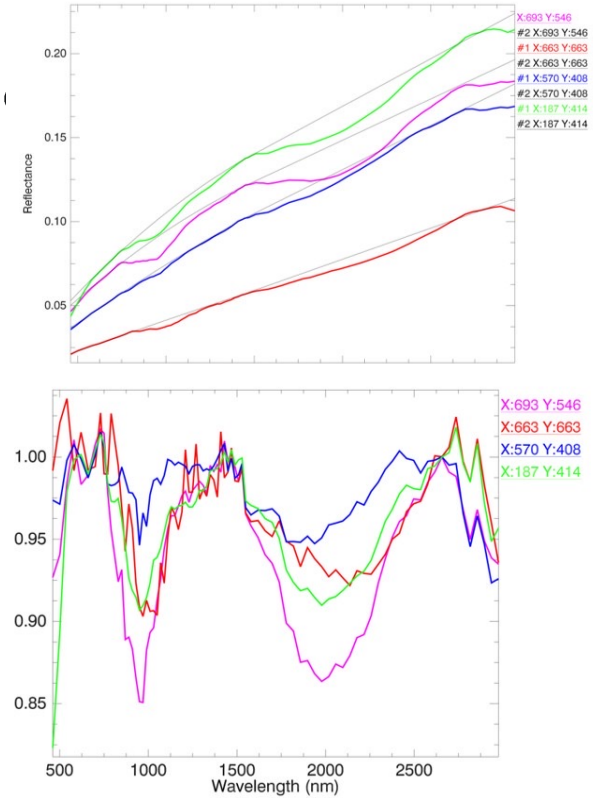
Table 1. The M³ Instrument parameters and measurement modes

Overall
40 km FOV (allows contiguous orbit overlap)*
405–3000 nm spectral range
12 bit/pixel
Target Mode (full resolution):
600 spatial pixels (70 m/pixel)*
260 spectral channels (10 nm/channel)
1 GB/orbit downlink: 10–12° longitude swath
Global Mode (reduced resolution):
300 spatial pixels (140 m/pixel)*
86 spectral channels (mixed 20 and 40 nm/channel)
1 GB/orbit downlink: 135° longitude swath (alternating poles)

*For 100 km lunar polar orbit.

Pieters et al. 2009

Spectral Parameters



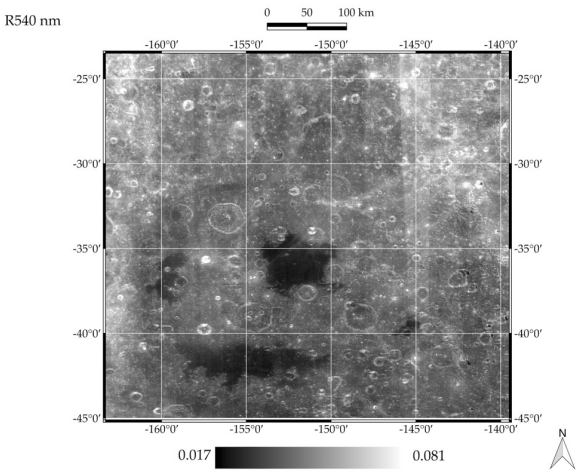
Some of the most significant parameters are:

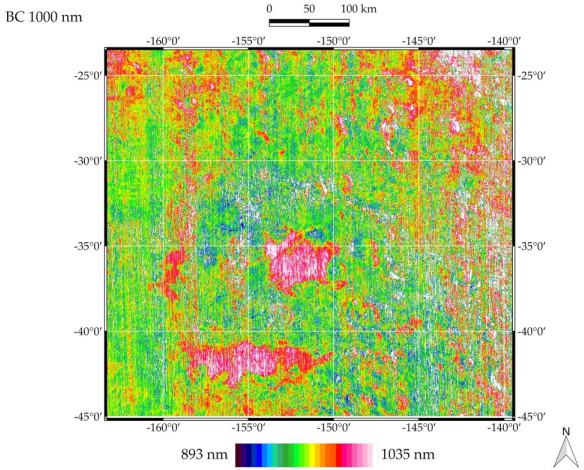
Band center → Information on the mineralogy and composition of phases present.

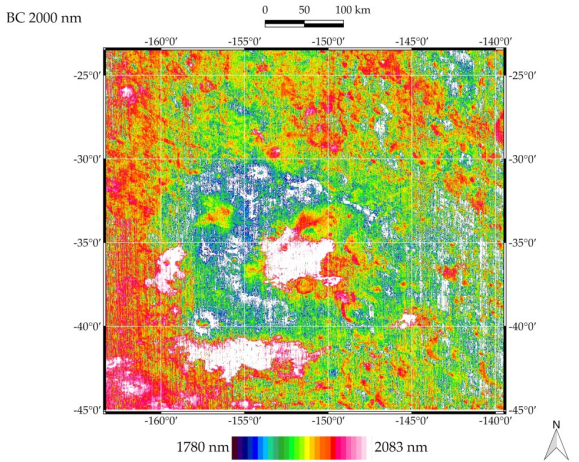
Band depth → Mineralogical abundance, grain size variations, opaque material

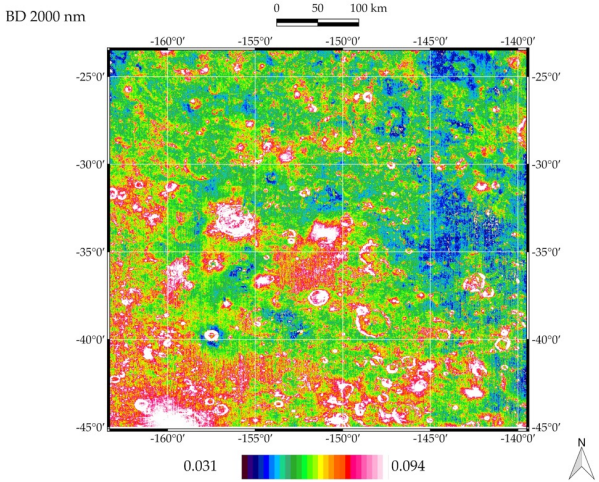
Spectral slope → Terrain maturity, composition and grain size.
Steep (red) spectral slopes: old mature terrains more affected by space weathering, composition, e.g Mercury volcanic origin material (northern smooth plains, Mercury faculae).
Shallow (blue) spectral slopes: Fresh unweathered material (rays, crater ejecta); composition, e.g. dark material, ices

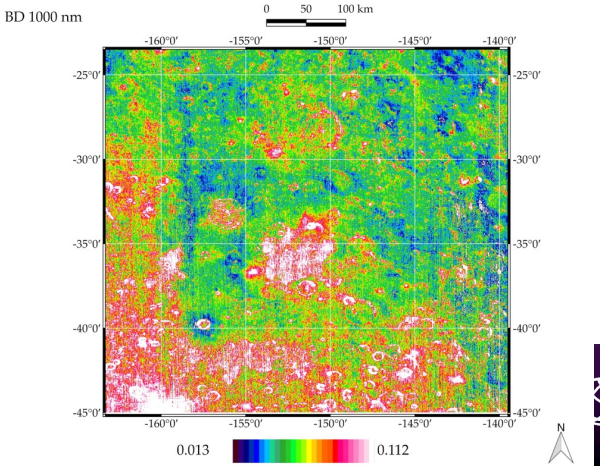
Spectral Parameter Maps derived by M^3 data

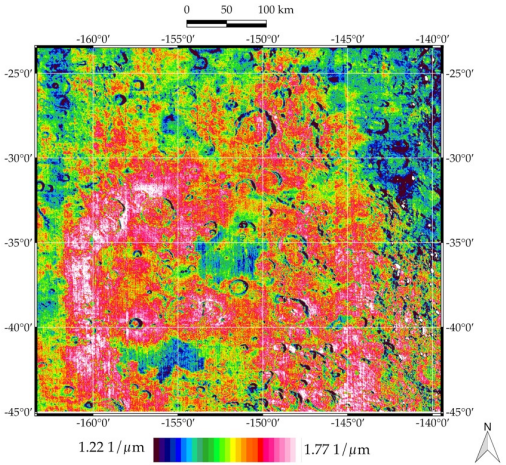












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Thanks for your attention!