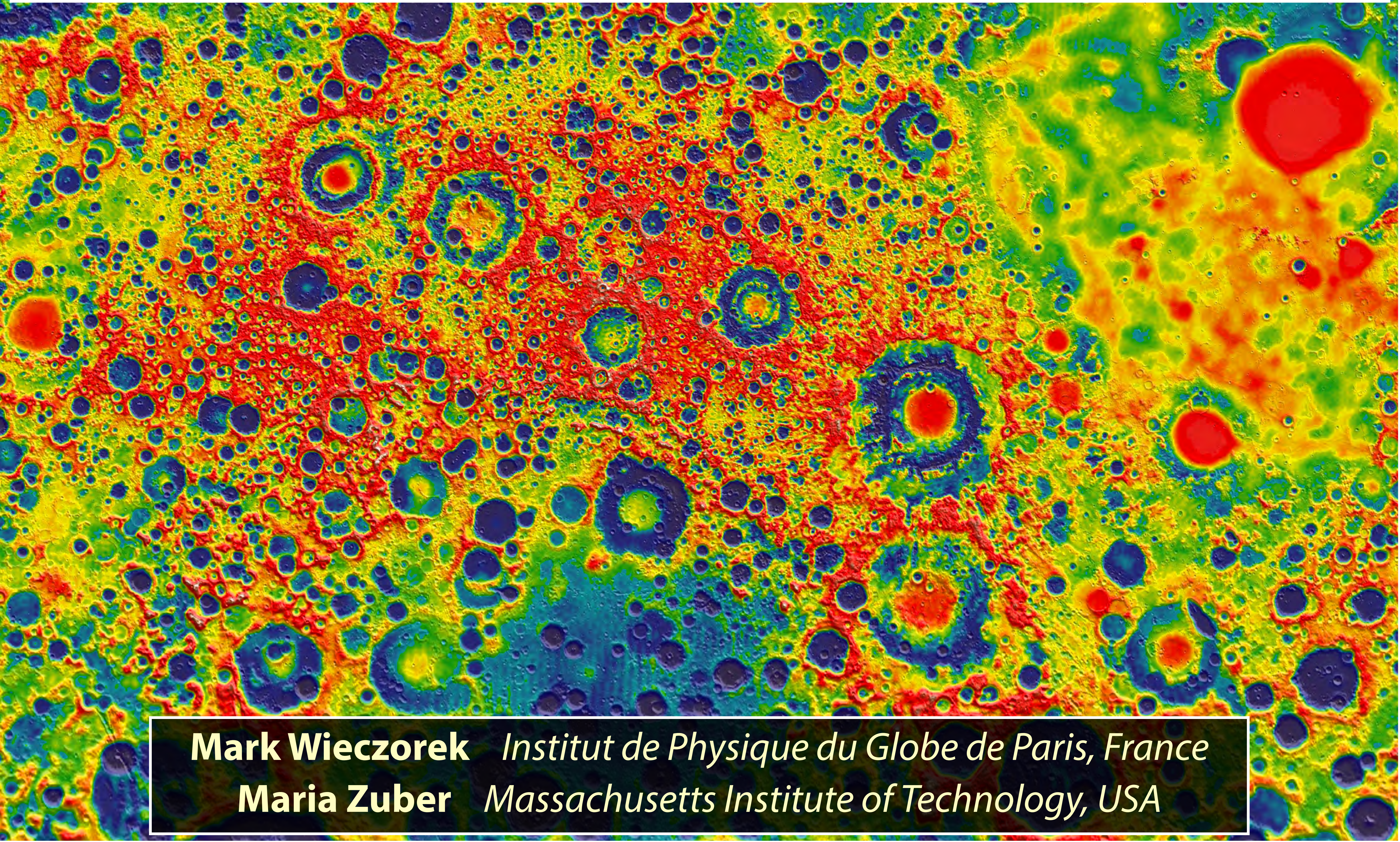
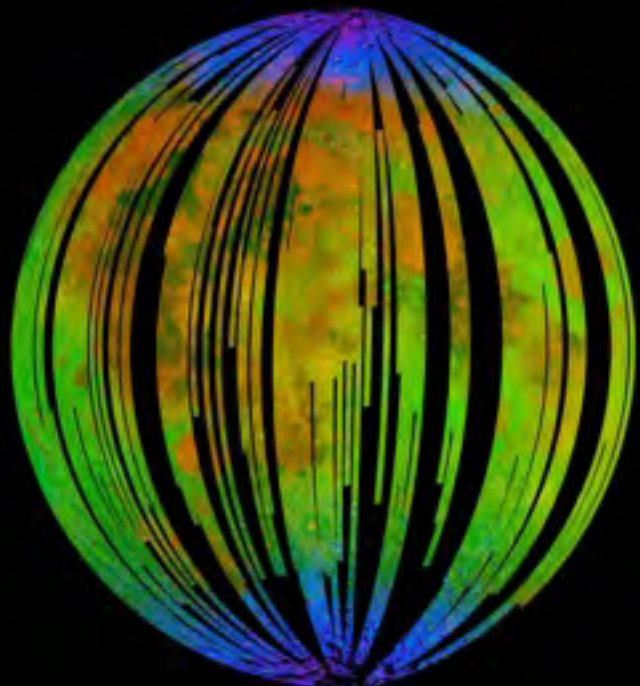
New results from NASA's lunar gravity mapping mission GRAIL



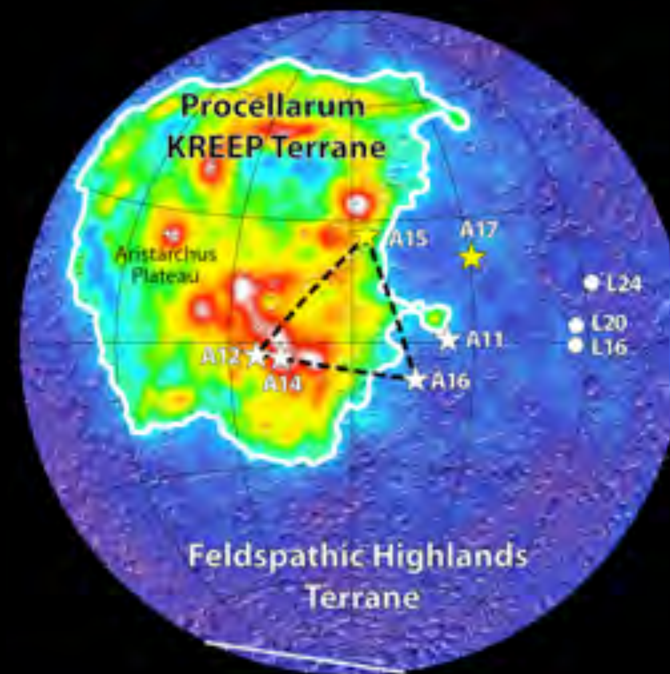
Mark Wieczorek *Institut de Physique du Globe de Paris, France*
Maria Zuber *Massachusetts Institute of Technology, USA*

Lots of data have been collected, but most of these only tell us about the surface



Global spectral mapping

(M3; Chandrayaan-1)



Global compositional mapping

(Lunar Prospector)

Global imaging of the surface

(Lunar Reconnaissance Orbiter)

382 kg of samples from Apollo and Luna

Geophysical data are required to see below the surface.

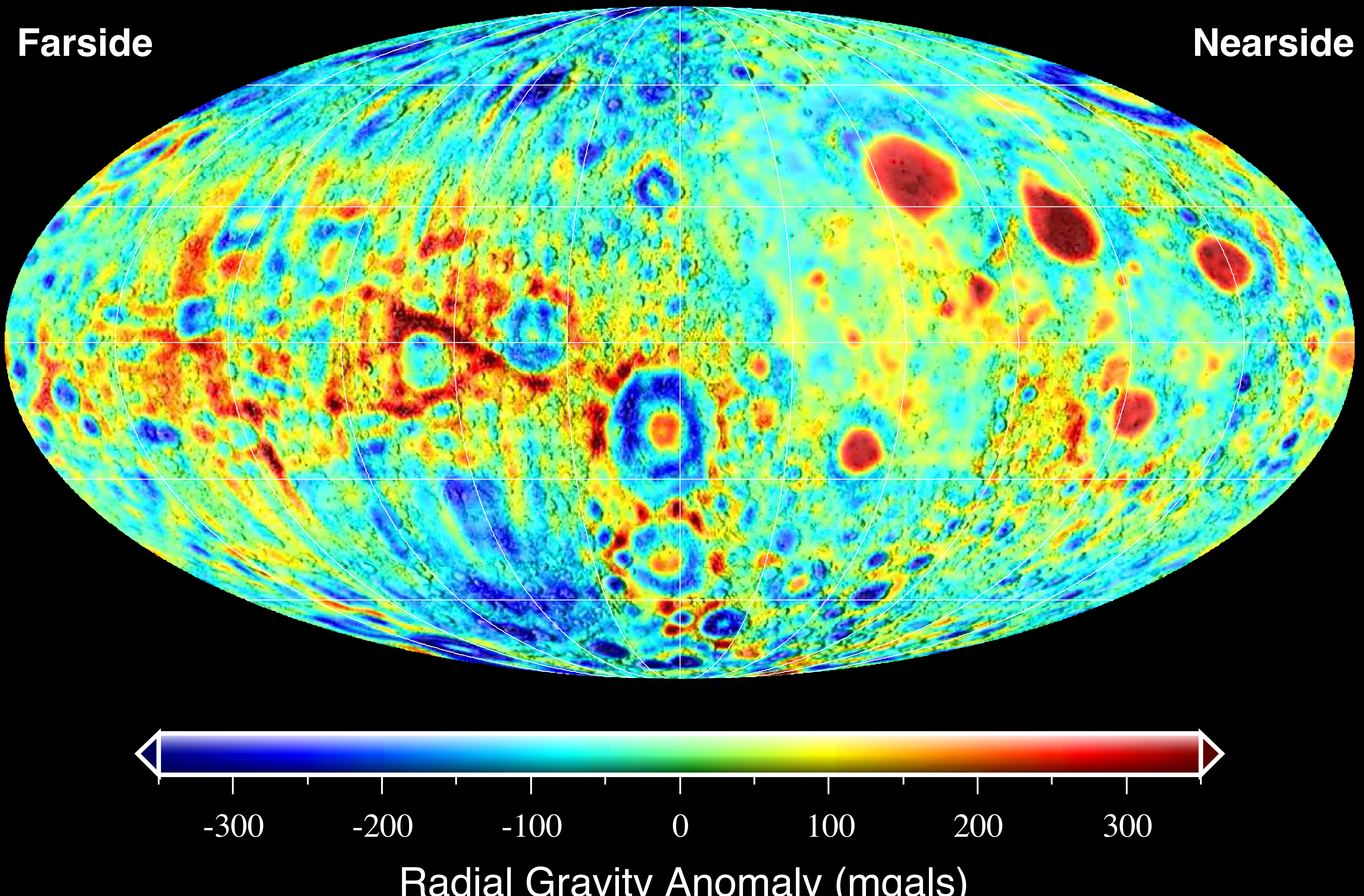
Talk Overview

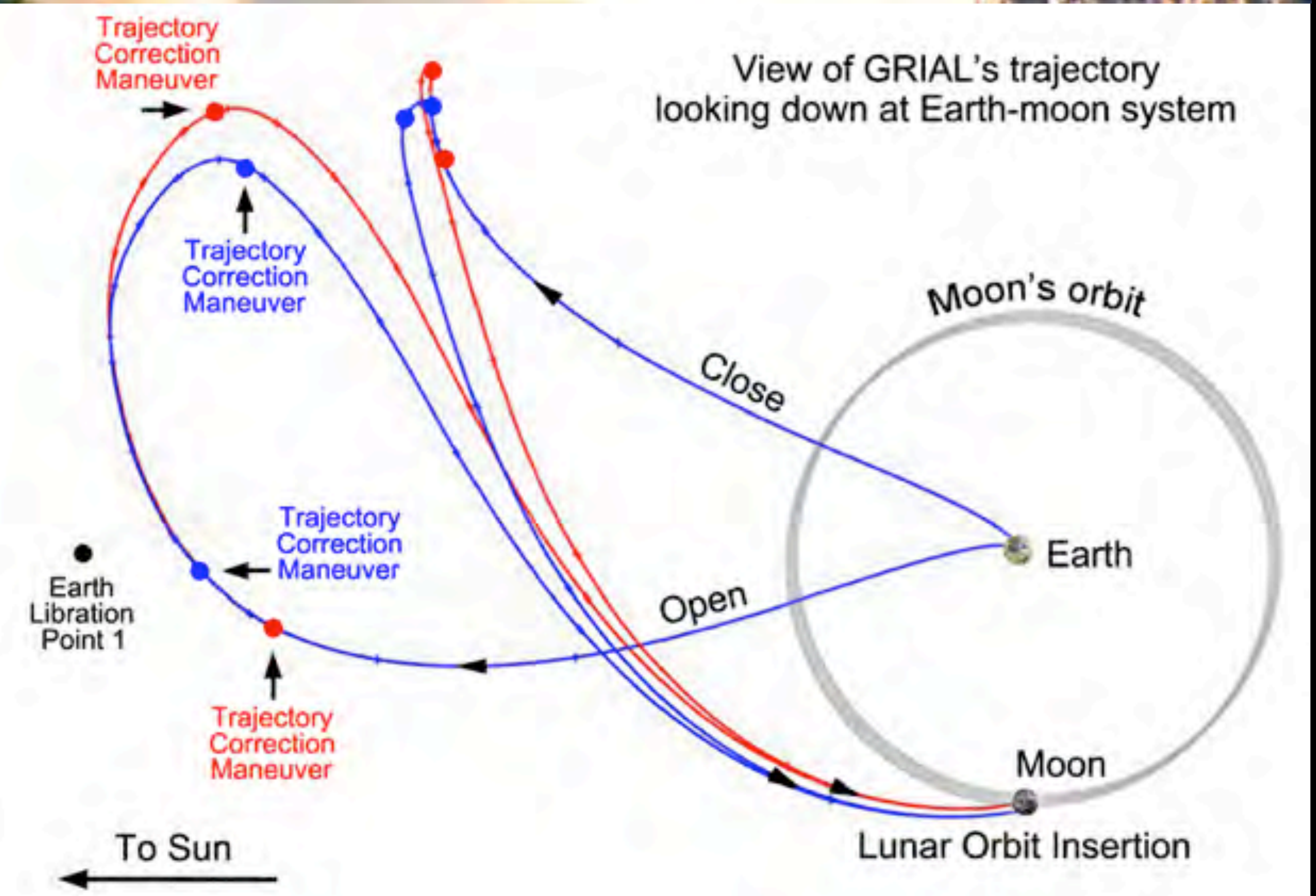
1. The GRAIL mission and initial mapping results

2. Characterization of impact basins

3. Is the mantle exposed on the surface?

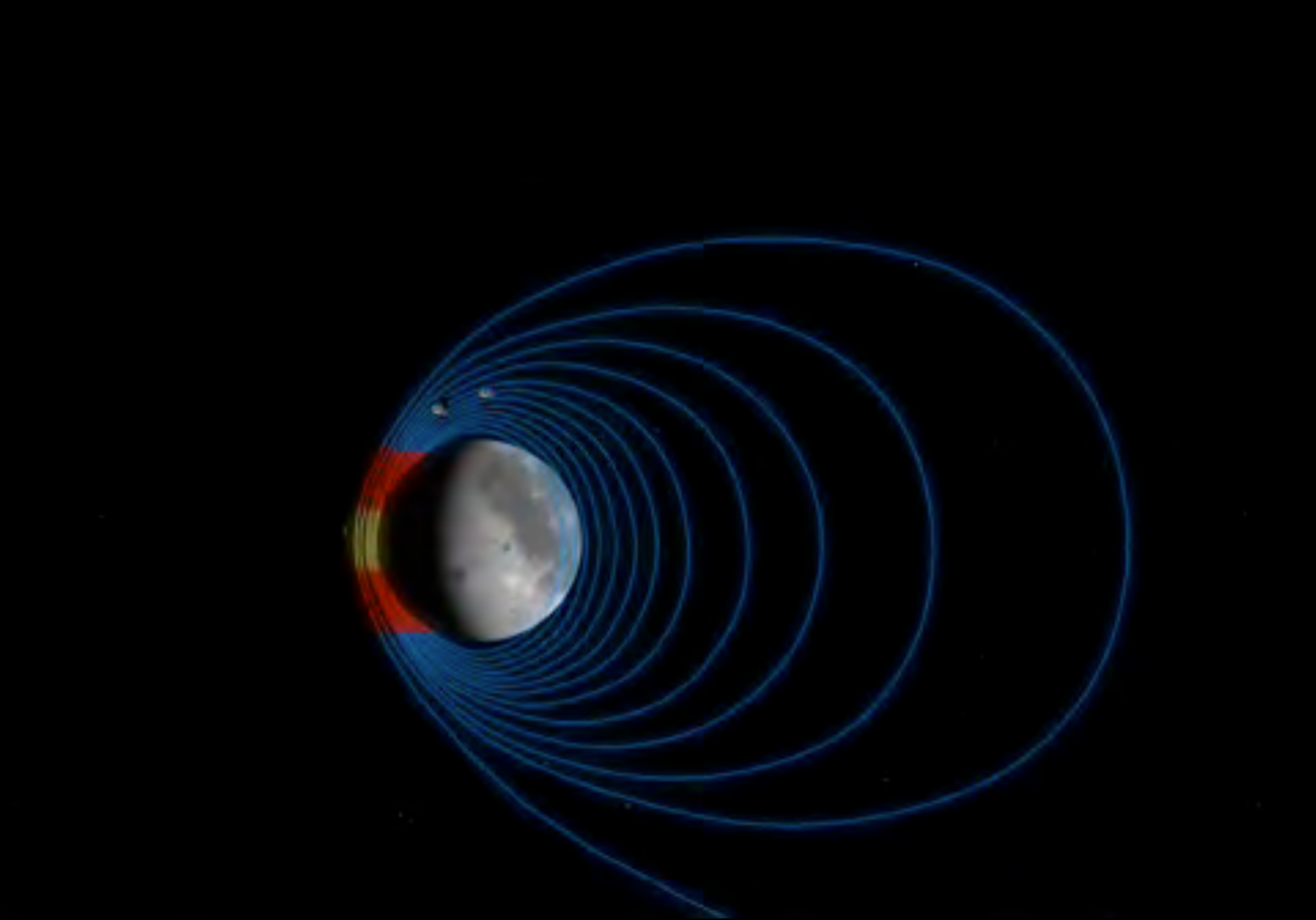
Lunar Prospector gravity field (LP150Q)



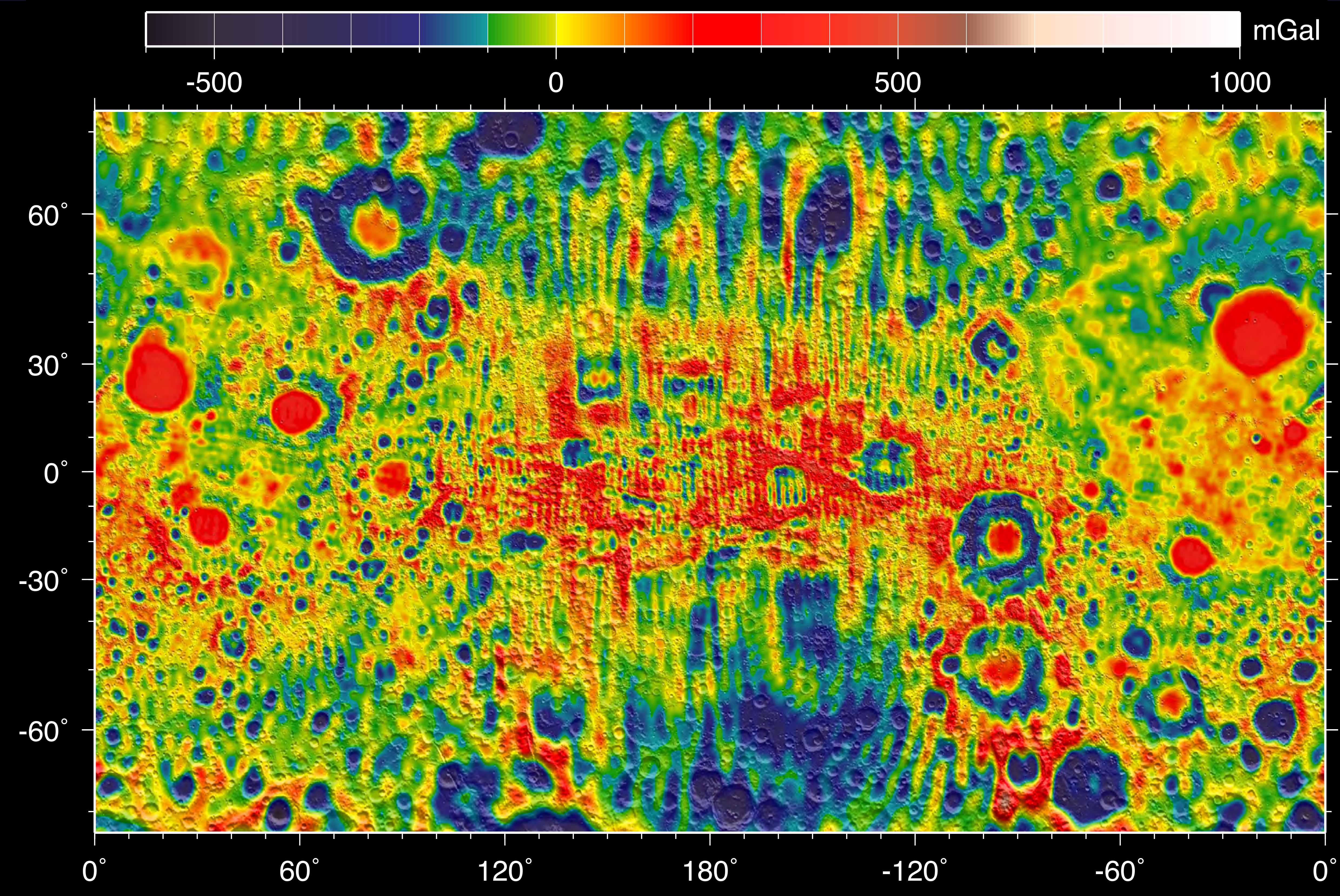


The NASA mission *Gravity Recovery and Interior Laboratory (GRAIL)*

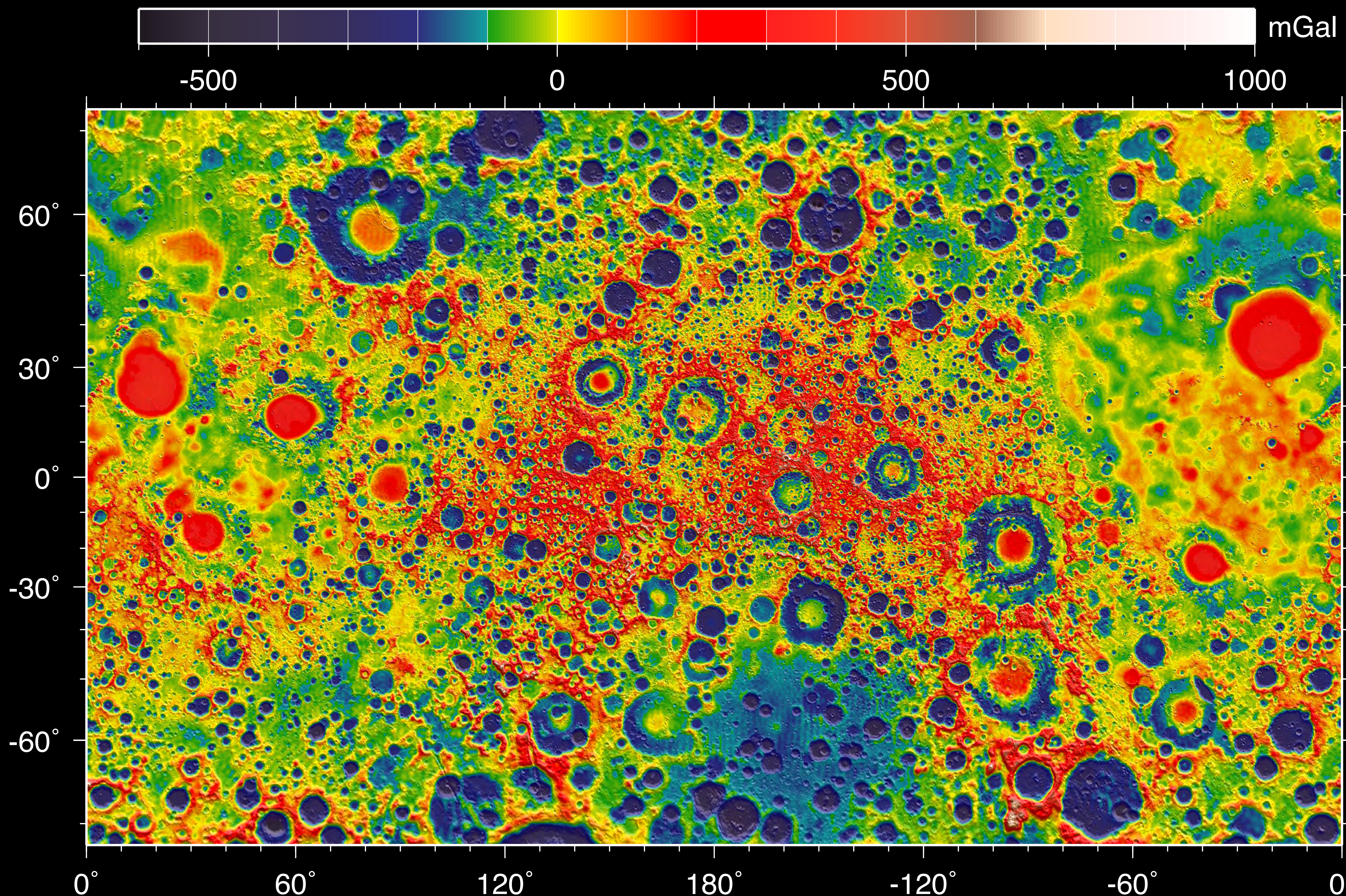
- Discovery class proposal selected in 2007: <450 million USD, with 36 months from selection to launch.
- Launch on Sept. 10, 2011.
- 3 month cruise to the Moon
- Orbit insertion Dec. 31/Jan. 1
- 3 month circularization of orbit
- March 7 - May 29 2012 primary science mission
- Aug. 8 - Dec. 17 extended mission



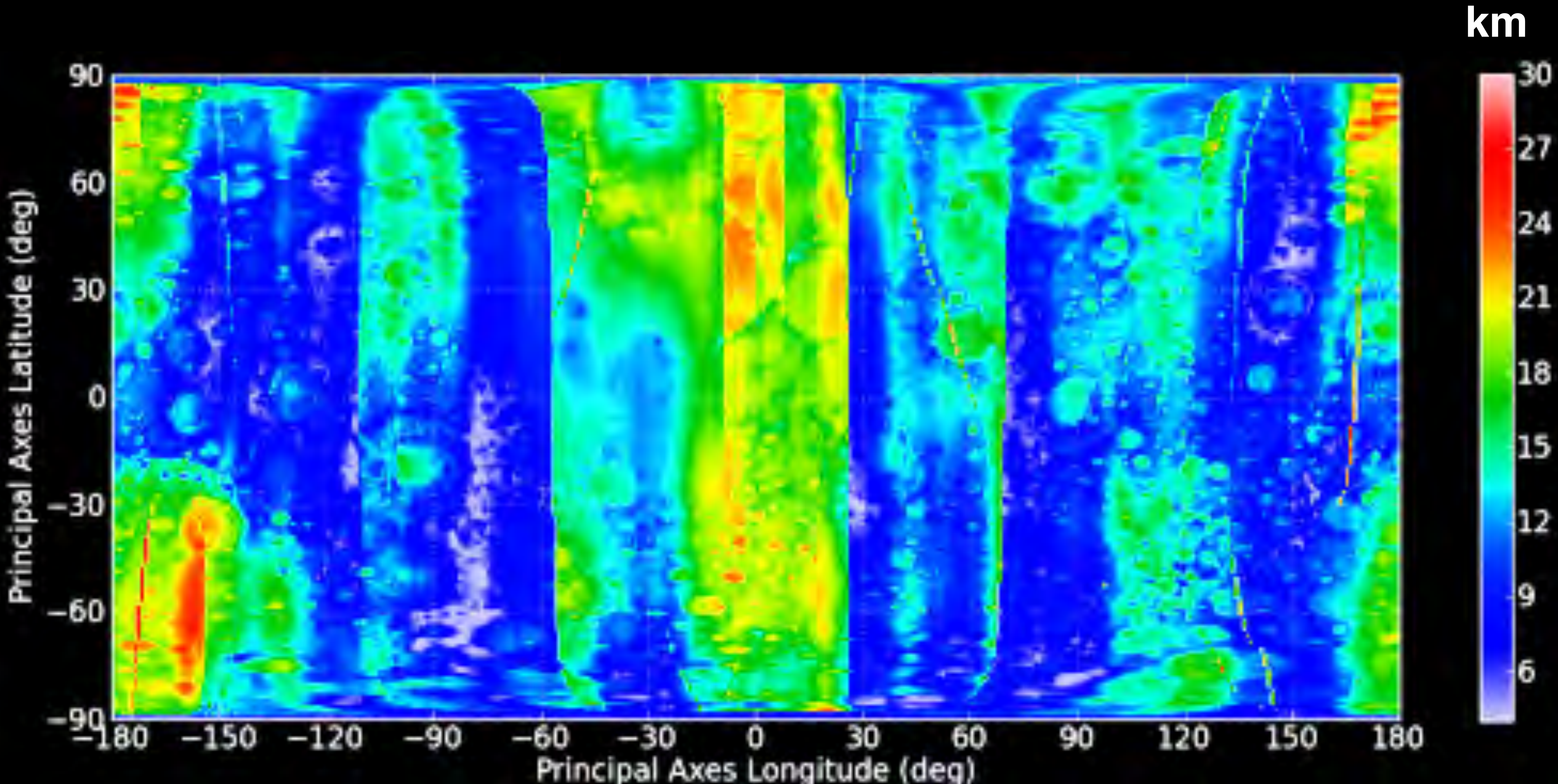
Lunar Prospector field (LP150Q) centered over the farside hemisphere



GRAIL primary mission field (420a)



Minimum altitude of mapping at the end of the extended mission

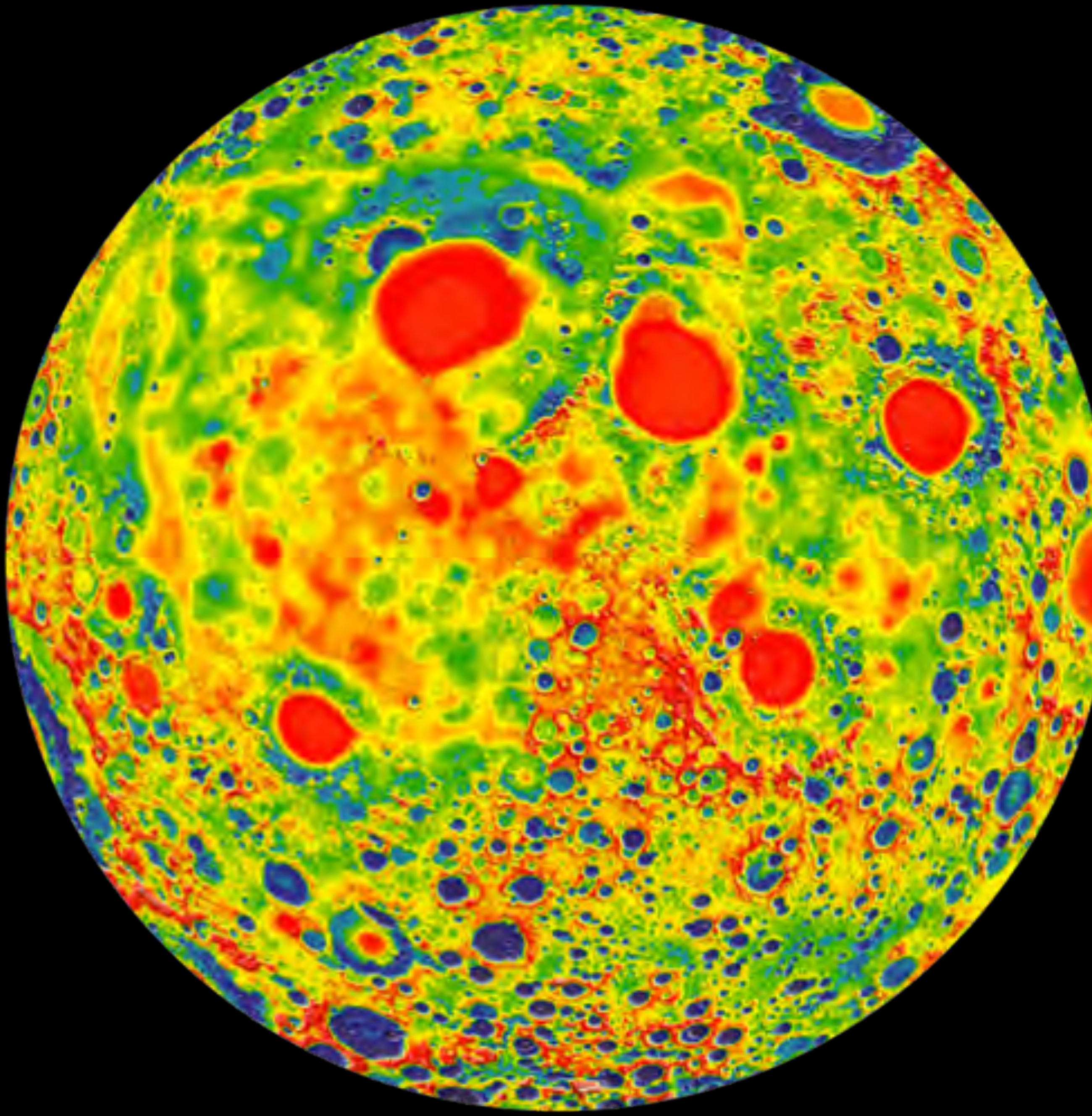


The spatial resolution of the gravity field is approximately equal to the spacecraft altitude.

LOLA topography & GRAIL gravity
(Centered over nearside)

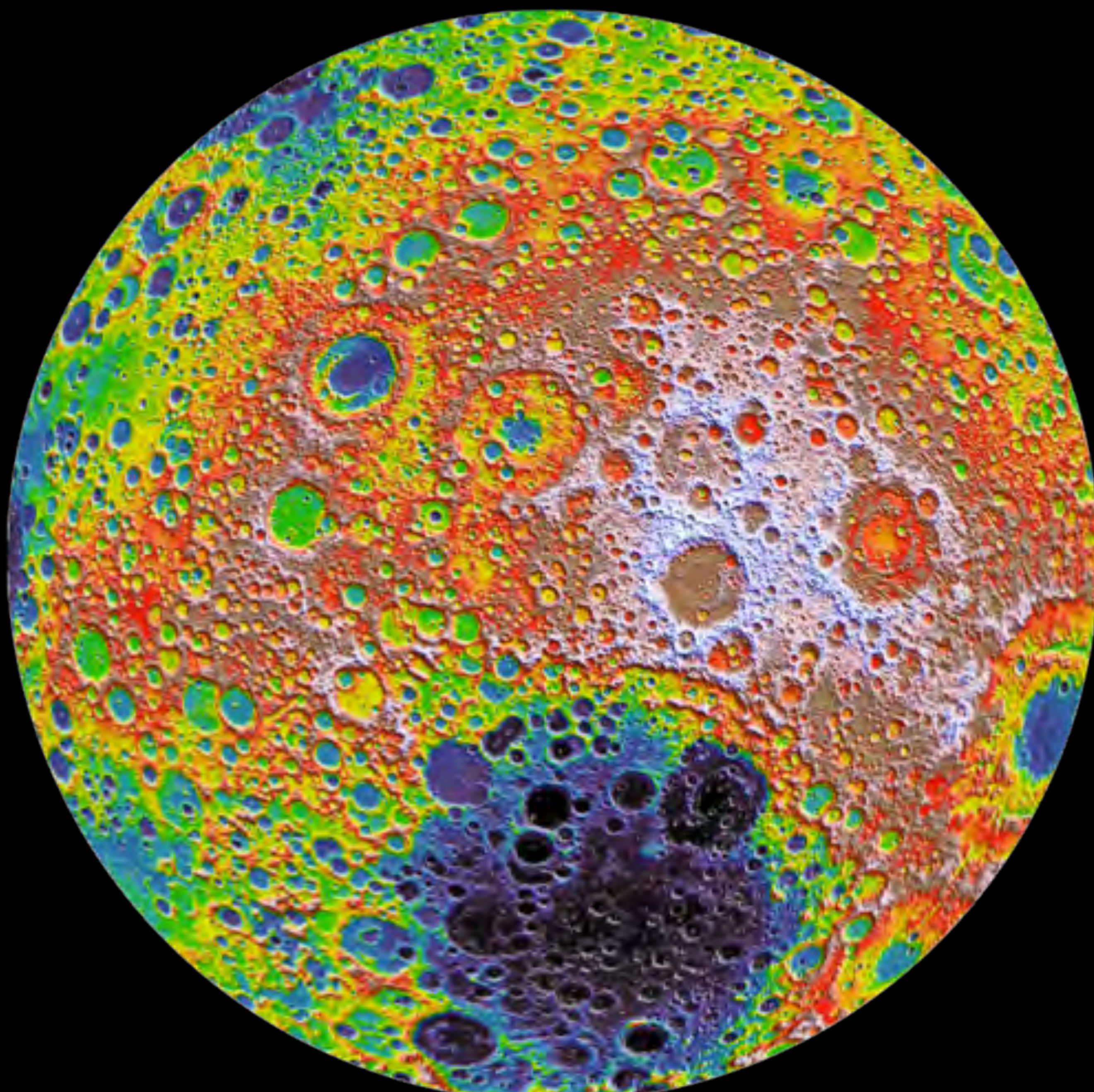
Topography

Free-air gravity

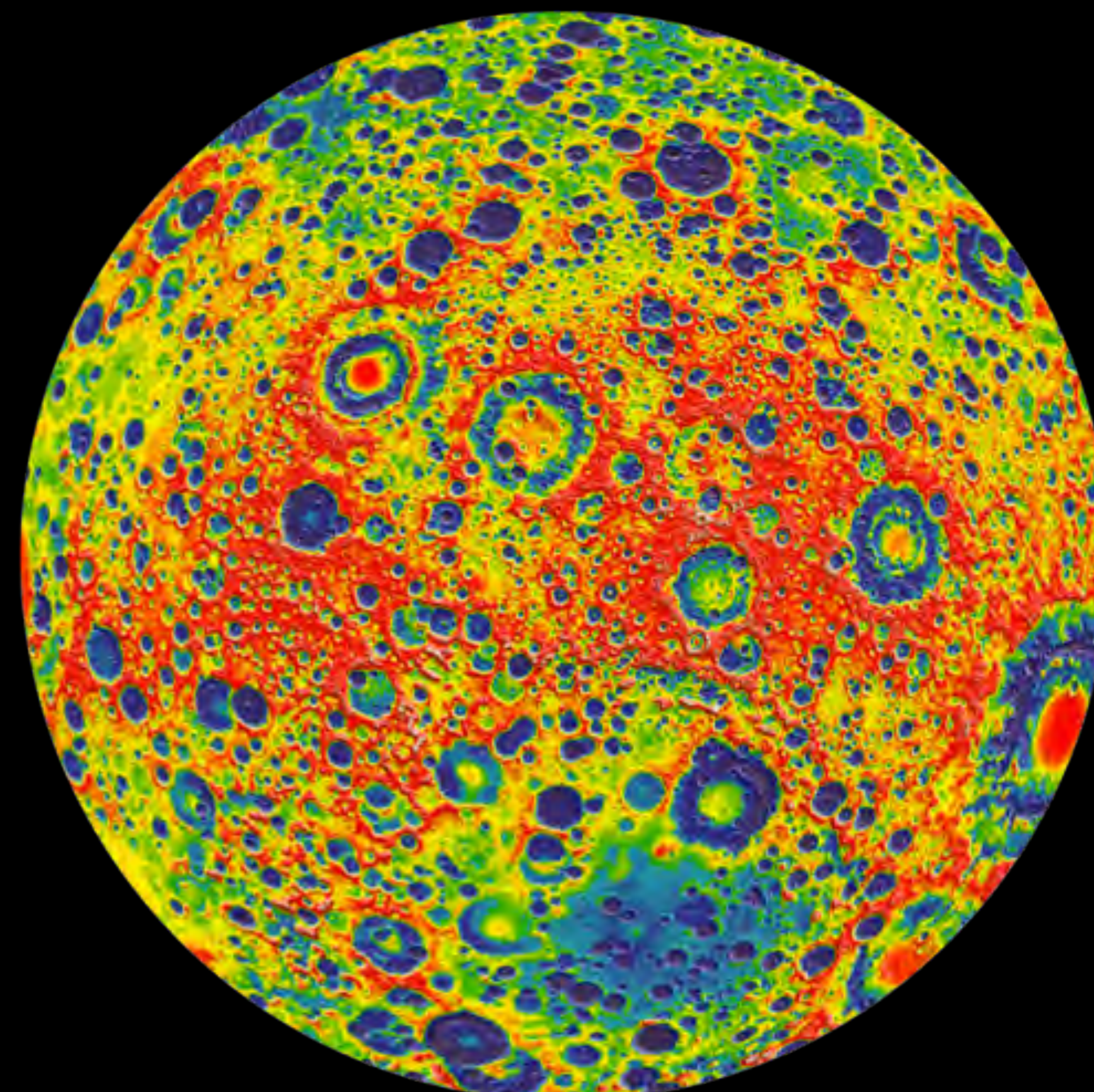


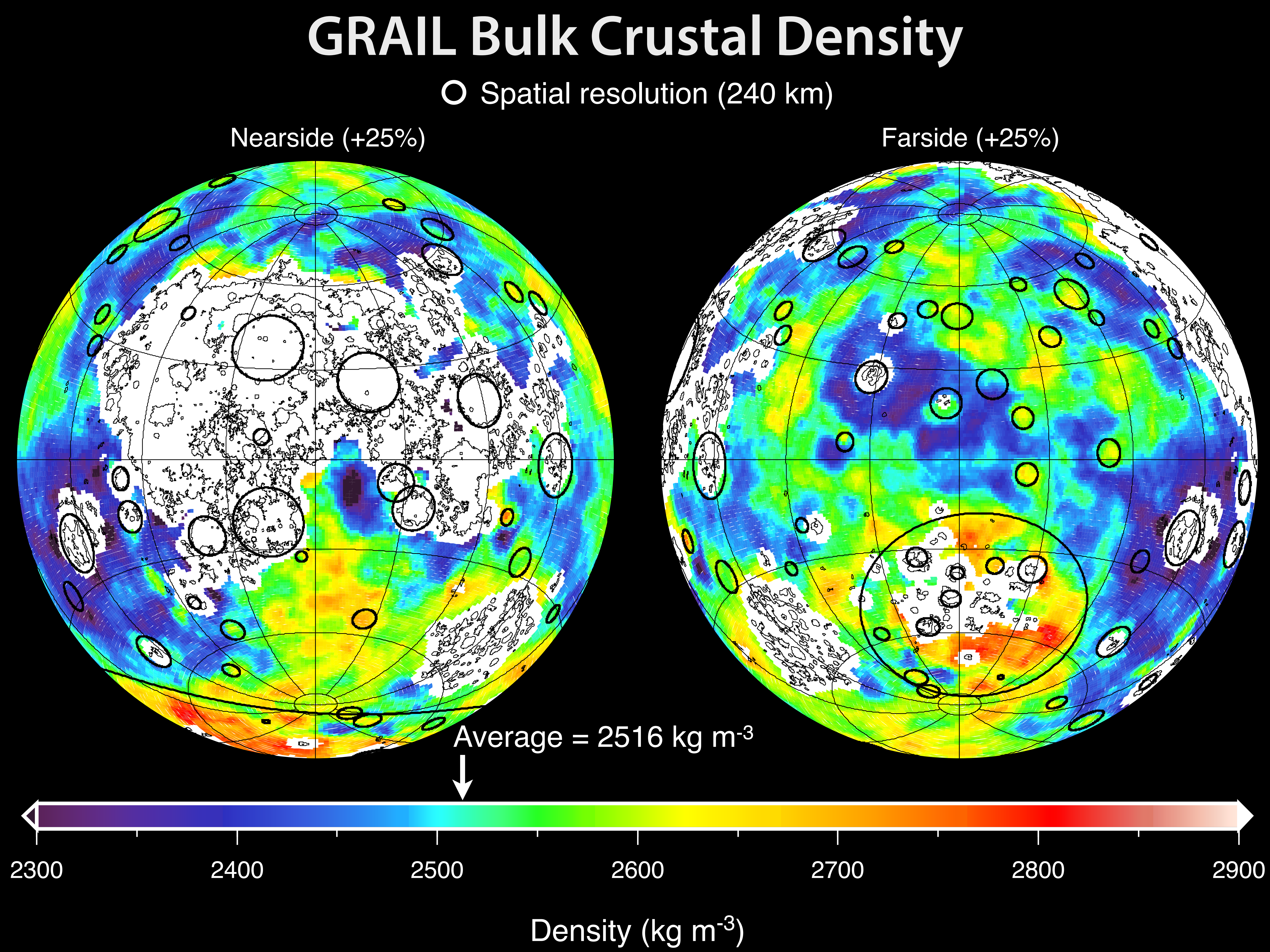
LOLA topography & GRAIL gravity
(Centered over farside)

Topography

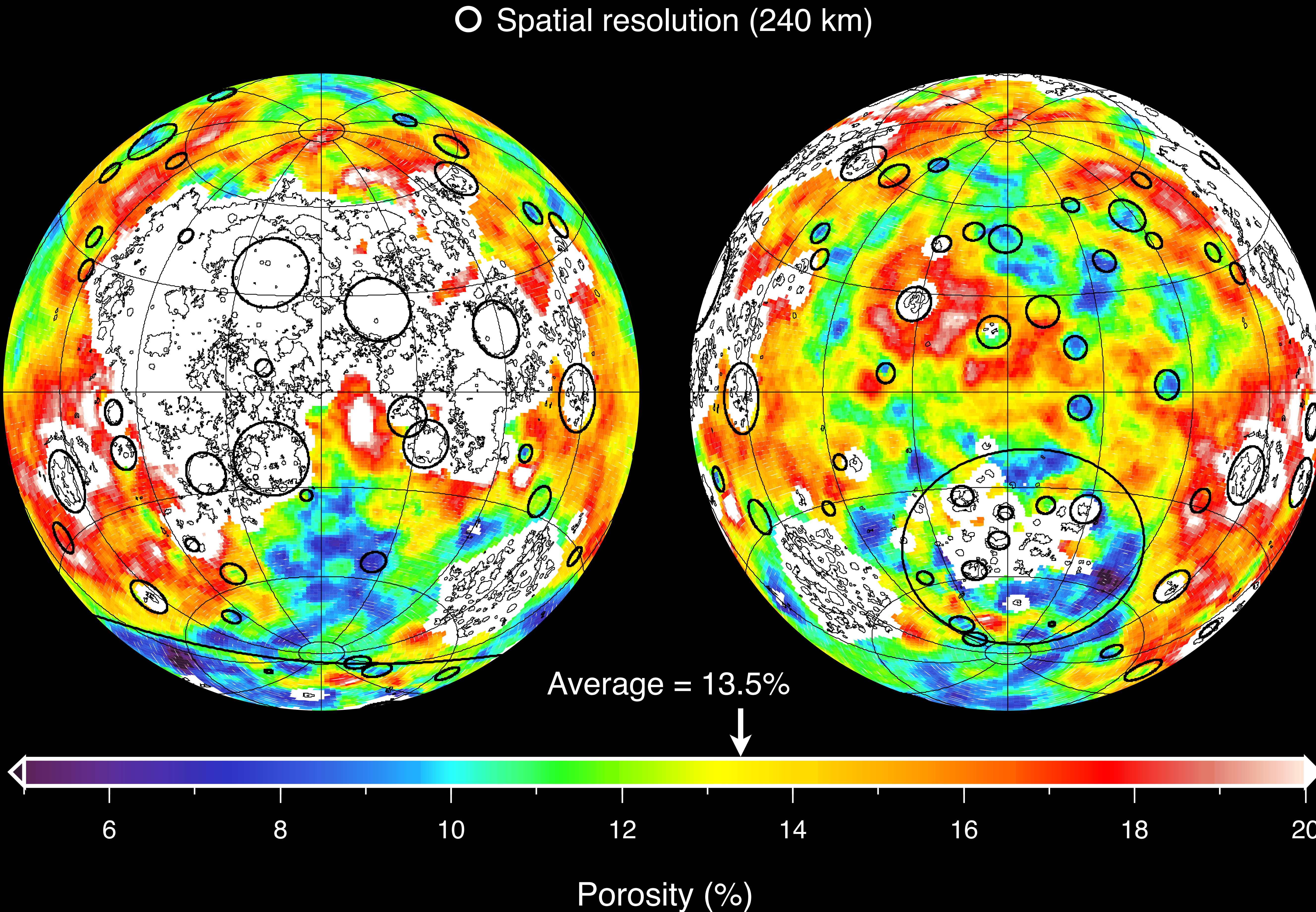


Free-air gravity

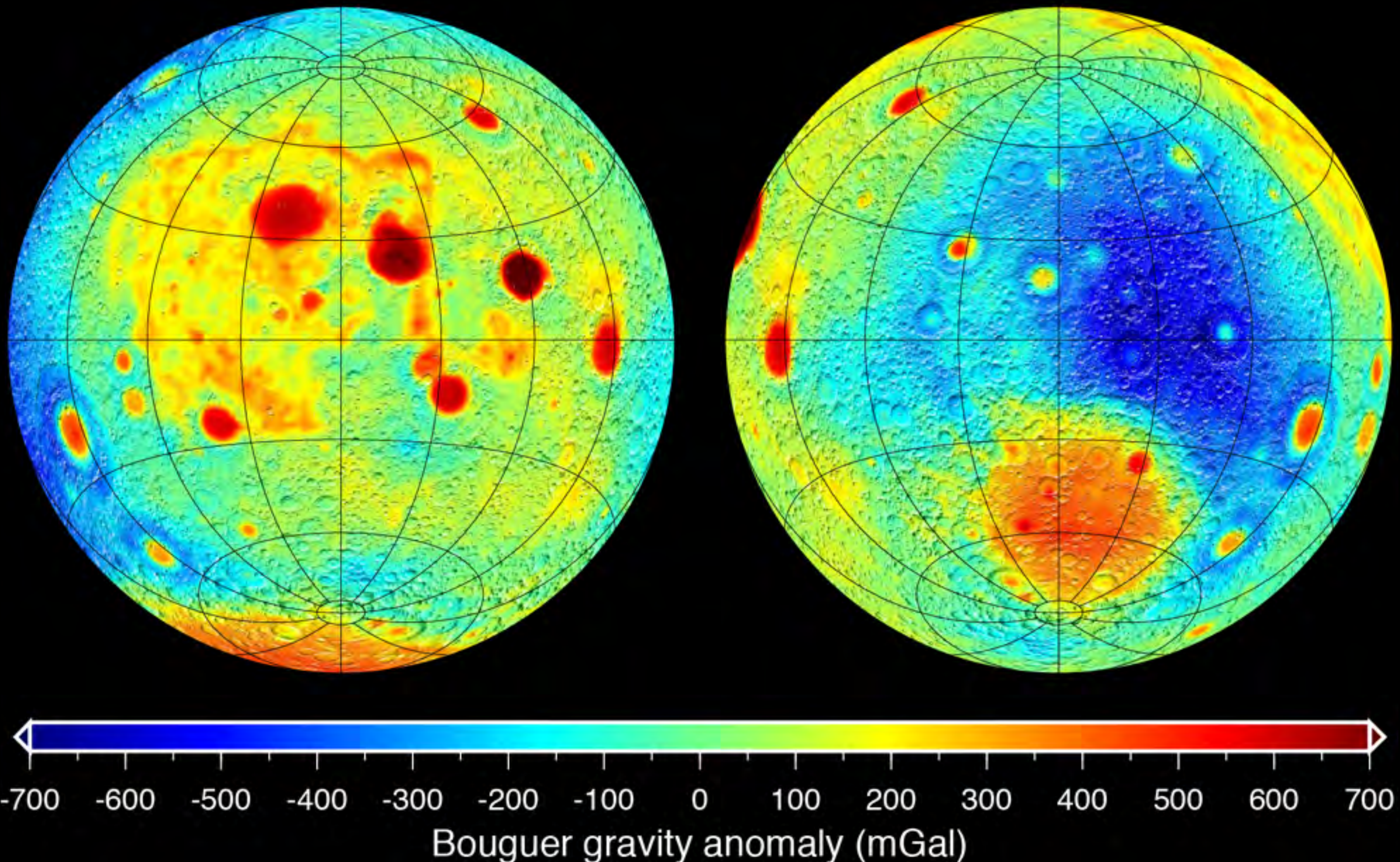



GRAIL Bulk Crustal Density
Spatial resolution (240 km)
Nearside (+25%)
Farside (+25%)
Average = 2516 kg m-3
2300
2400
2500
2600
2700
2800
2900
Density (kg m-3)

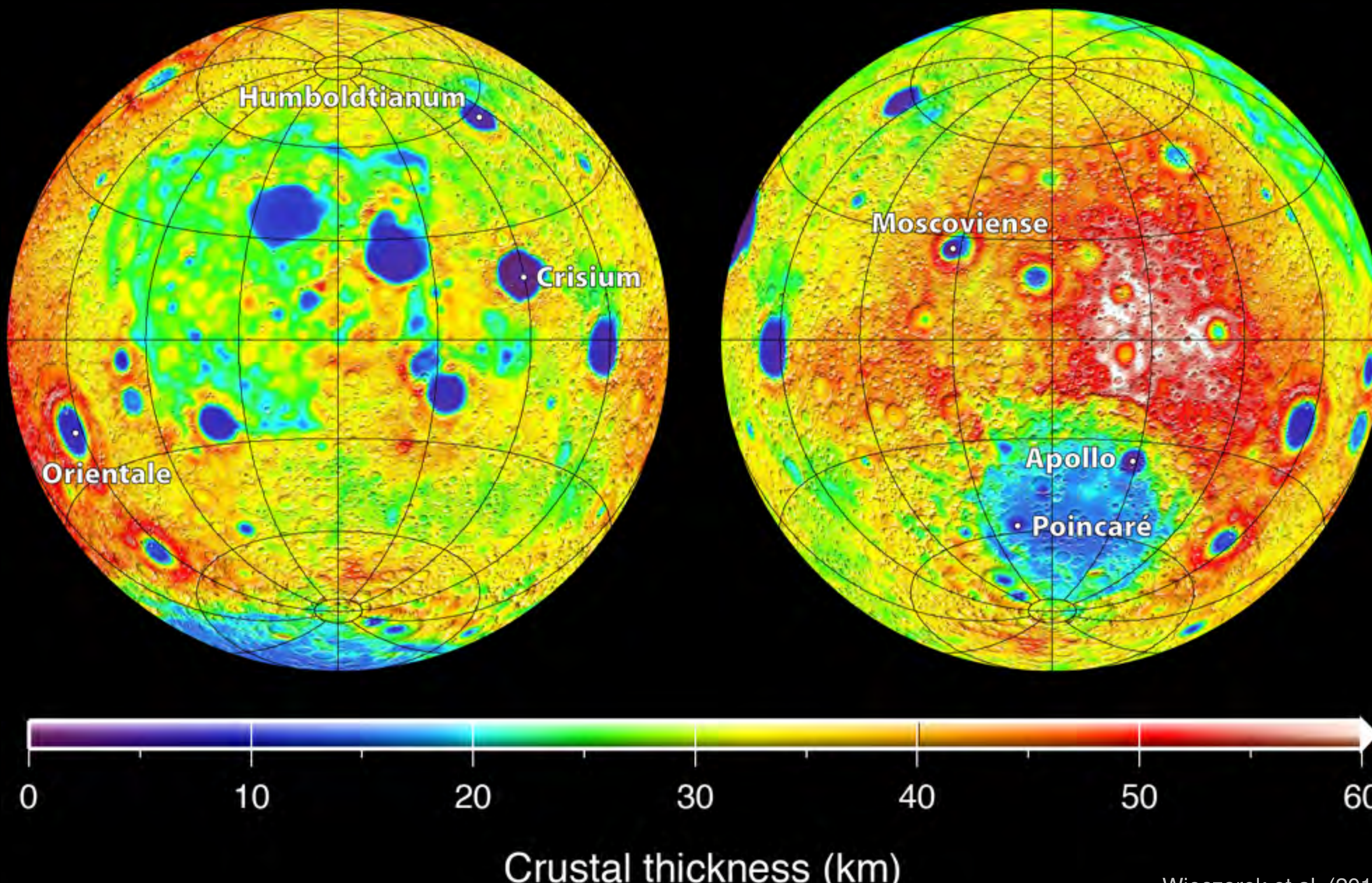
GRAIL Porosity



Bouguer gravity anomaly

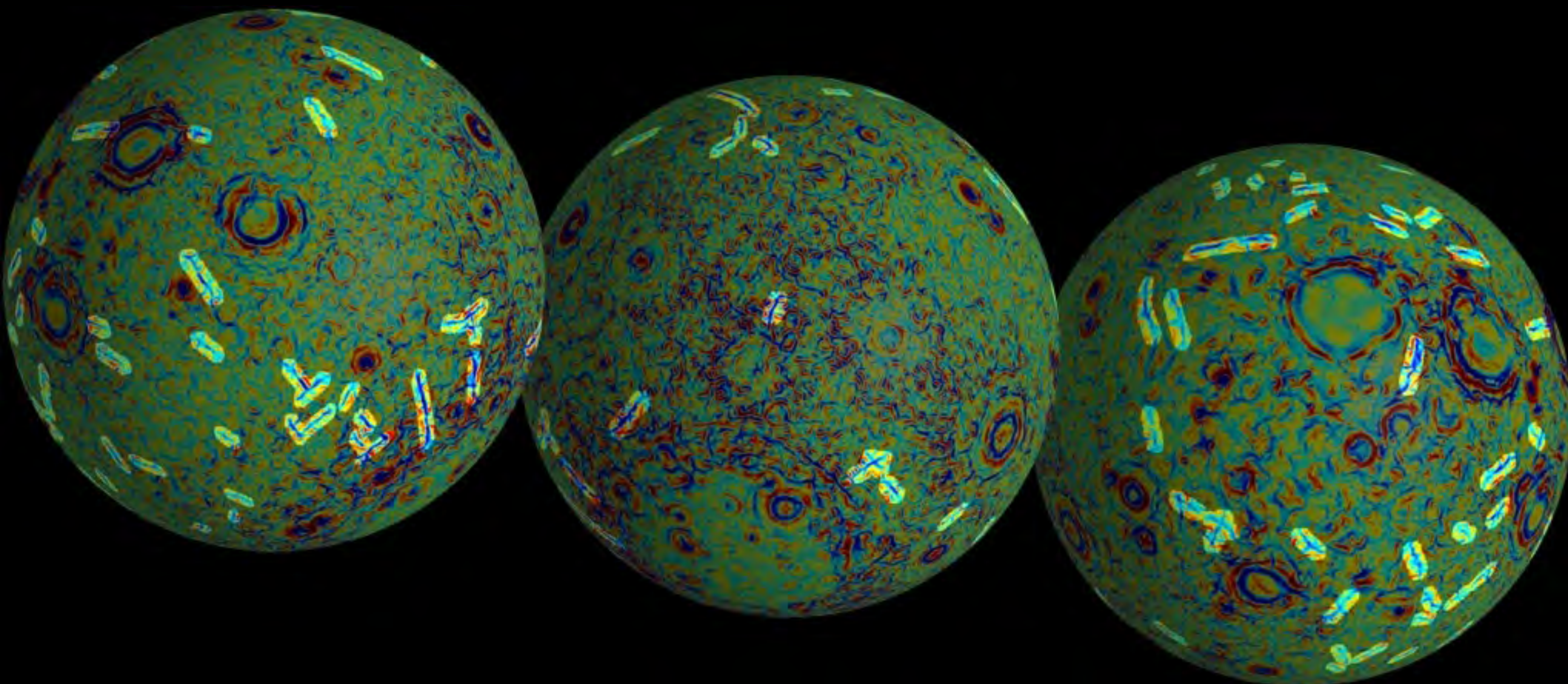


GRAIL Crustal Thickness



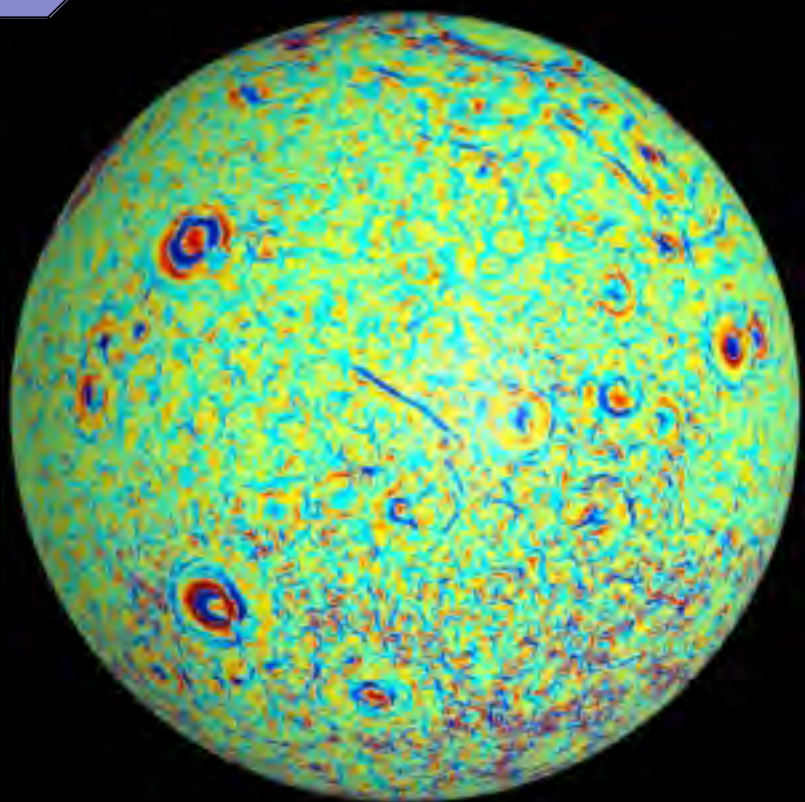
Wieczorek et al. (2013)

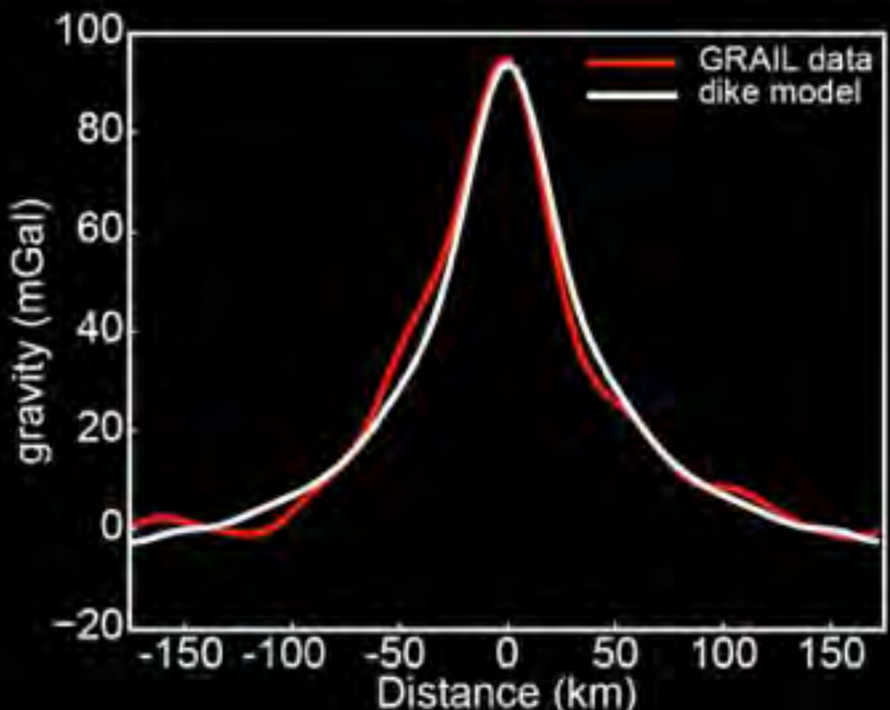
Subsurface linear density anomalies from GRAIL horizontal gravity gradients



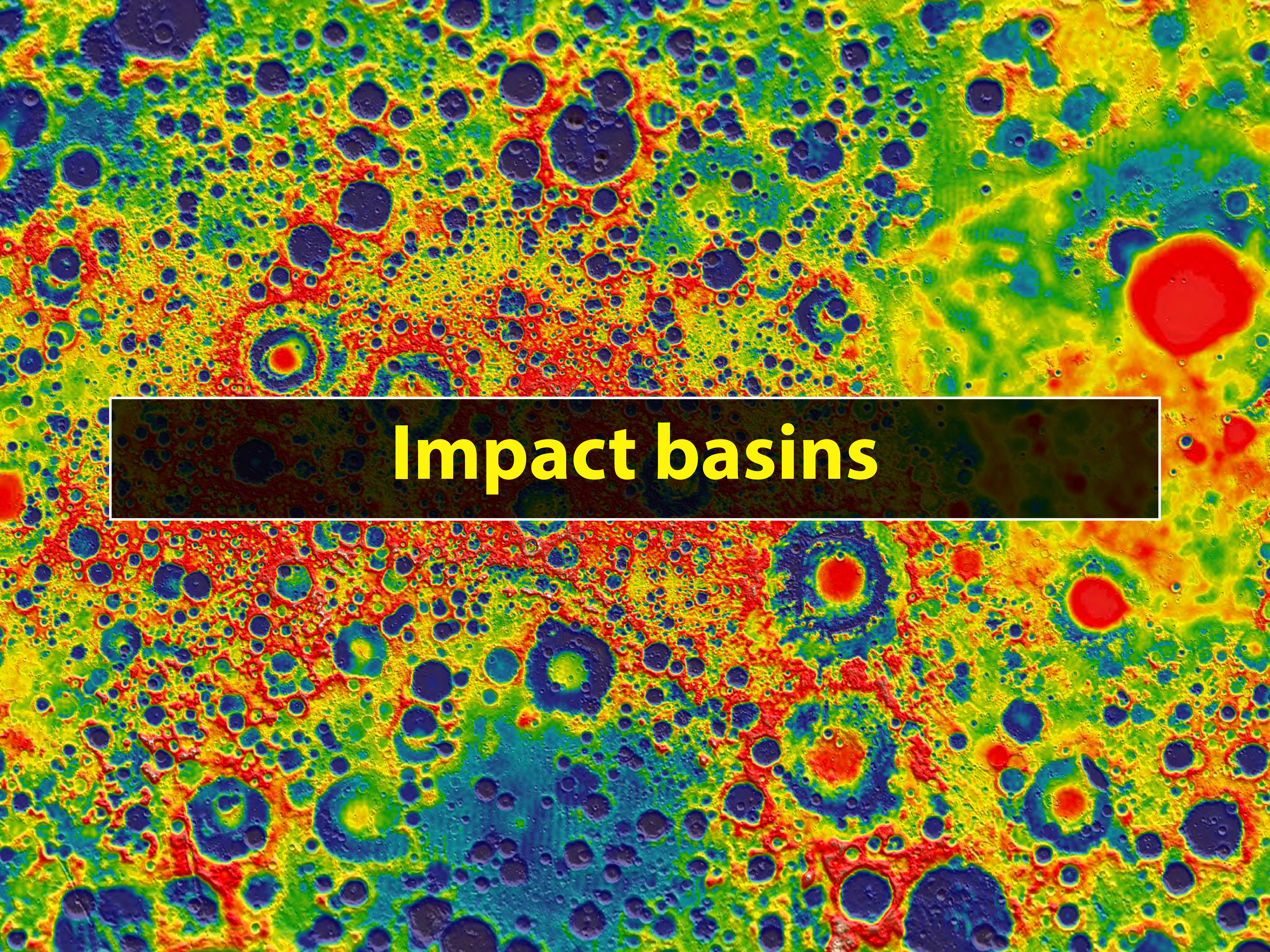
Andrews-Hanna et al. (2013)

Giant linear subsurface dikes



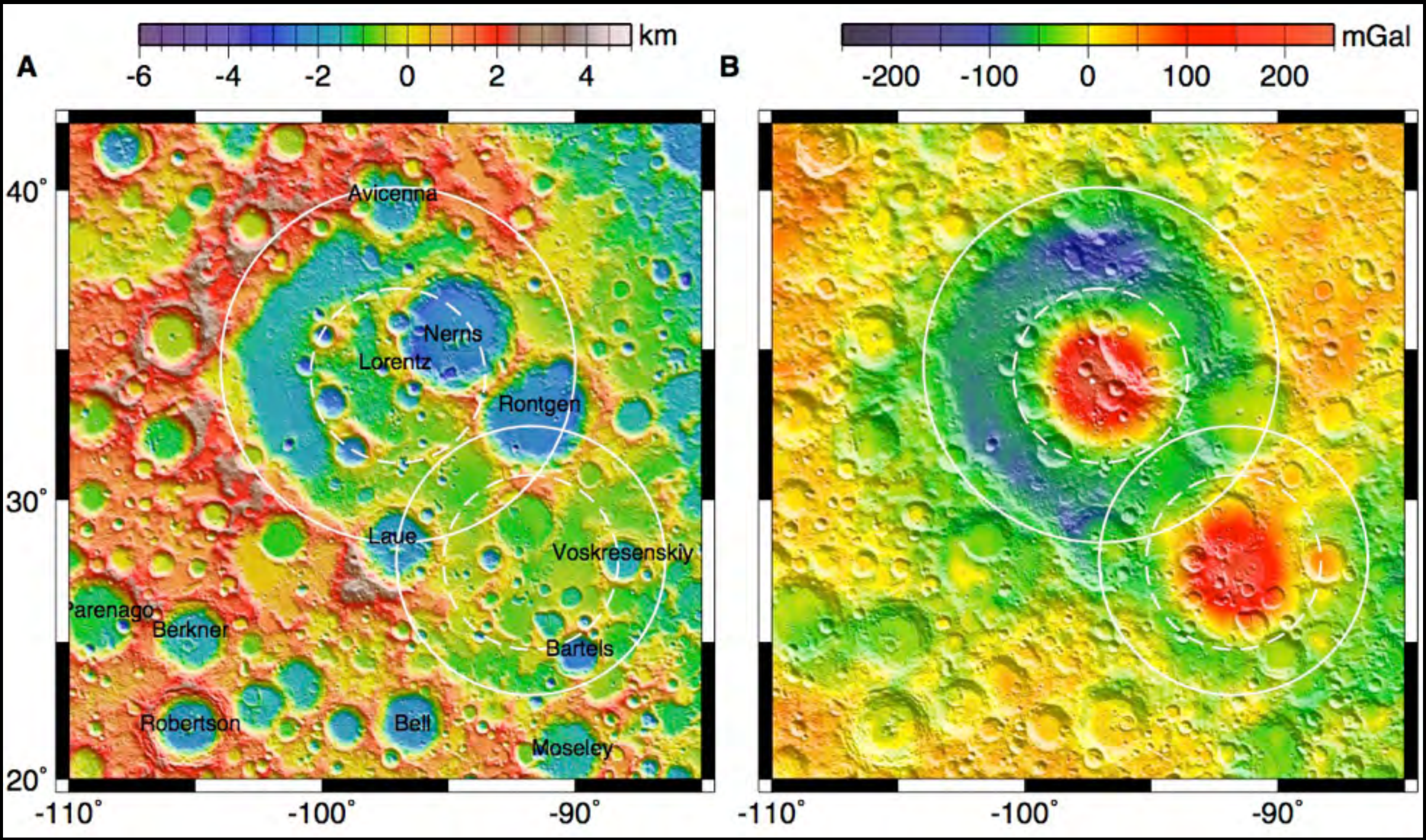


Andrews-Hanna et al. (2013)


Impact basins

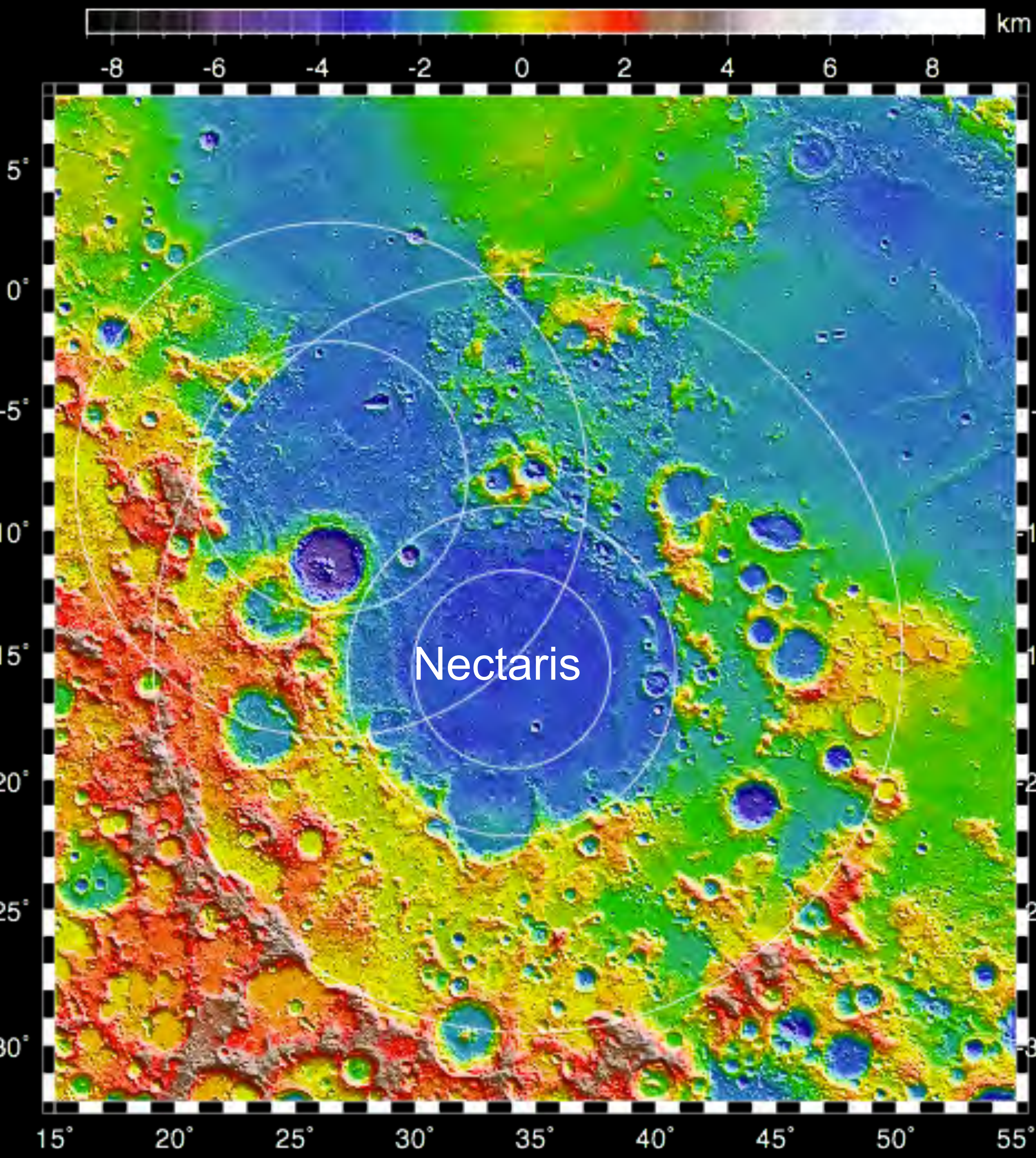
Lorentz and the highly degraded Bartels-Voskresensky basins

Topography | **Bouguer gravity**

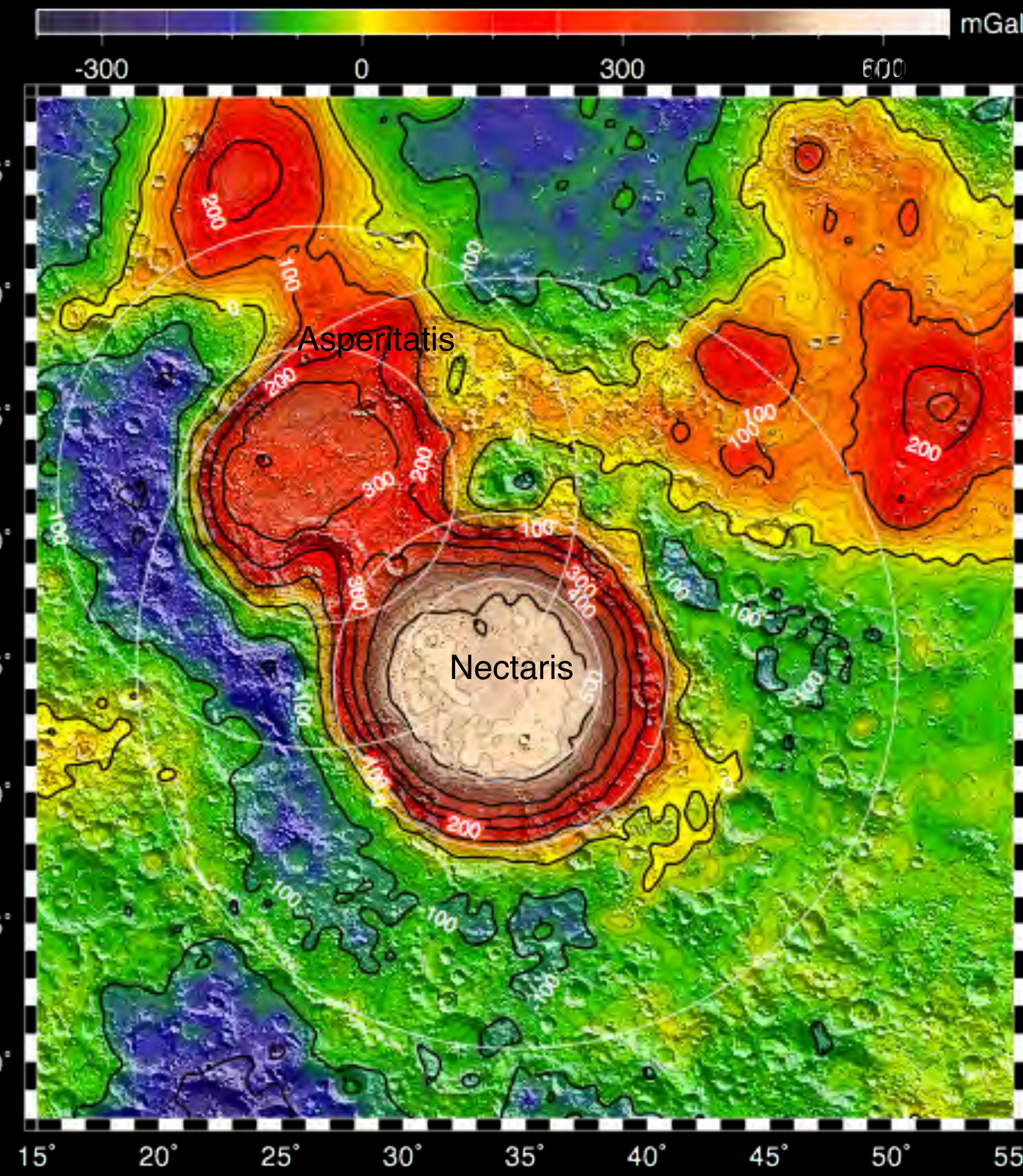


Discovery of the previously undetected basin Asperitatis

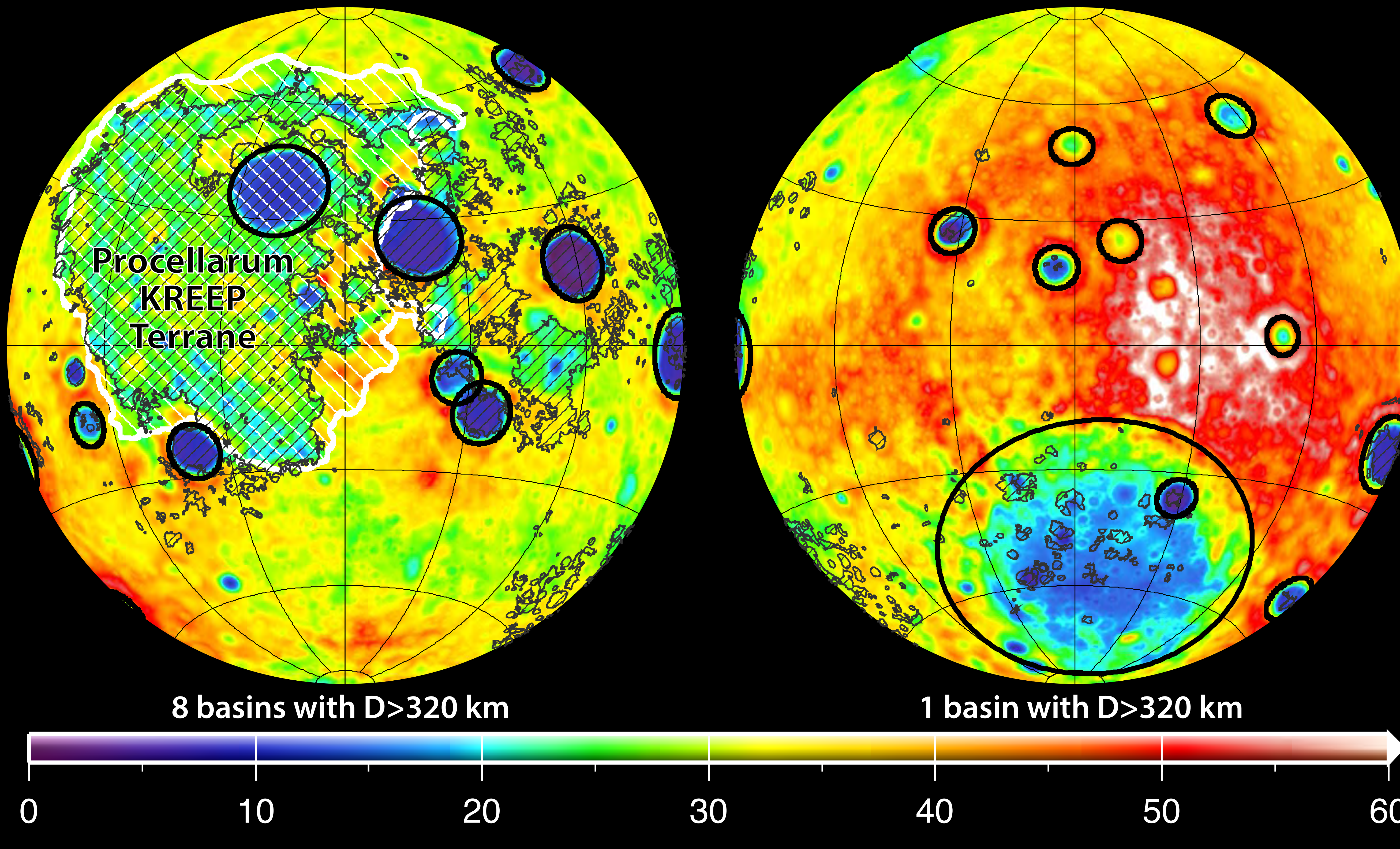
Topography



Bouguer gravity

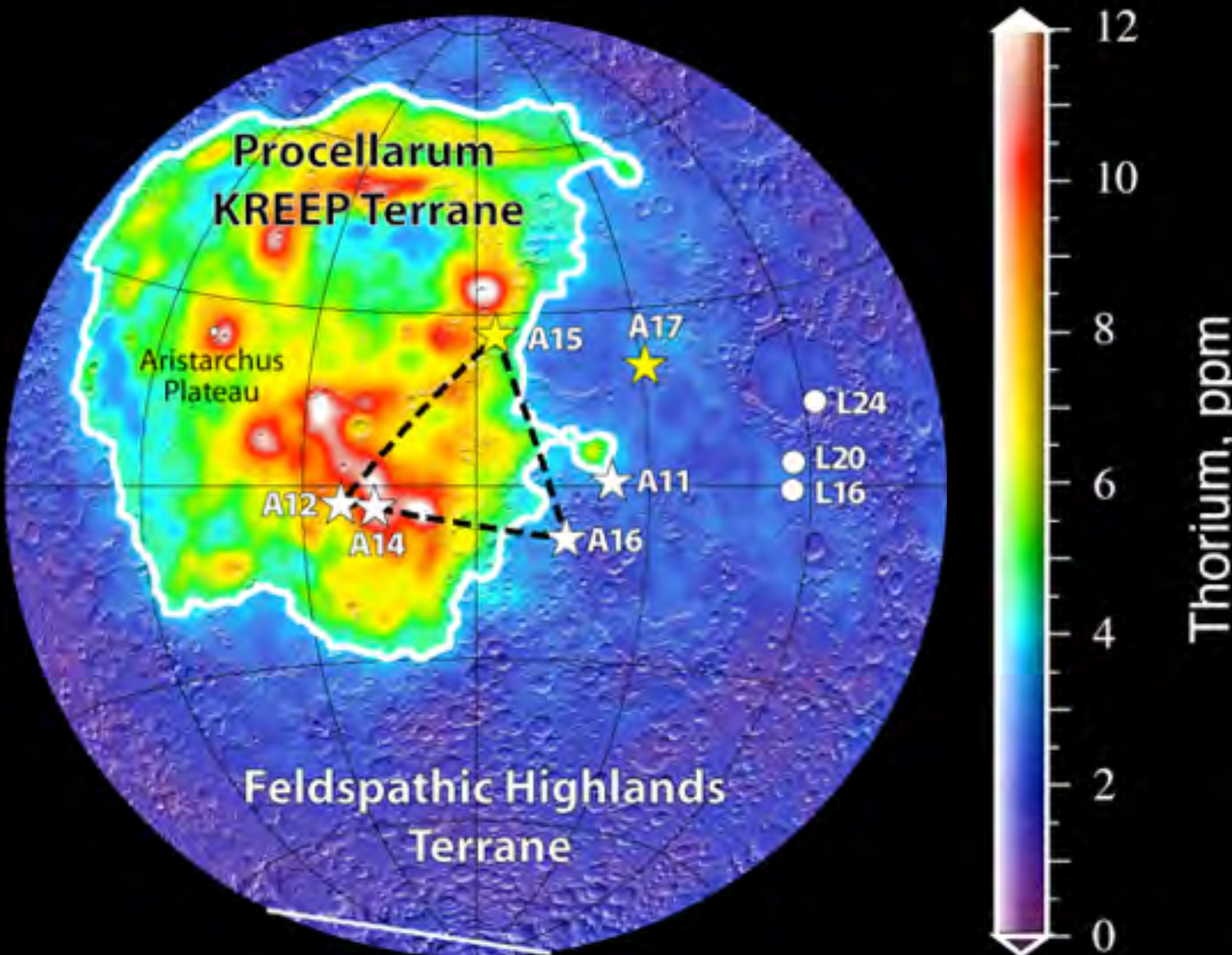


There are more large impact basins on the nearside than the farside

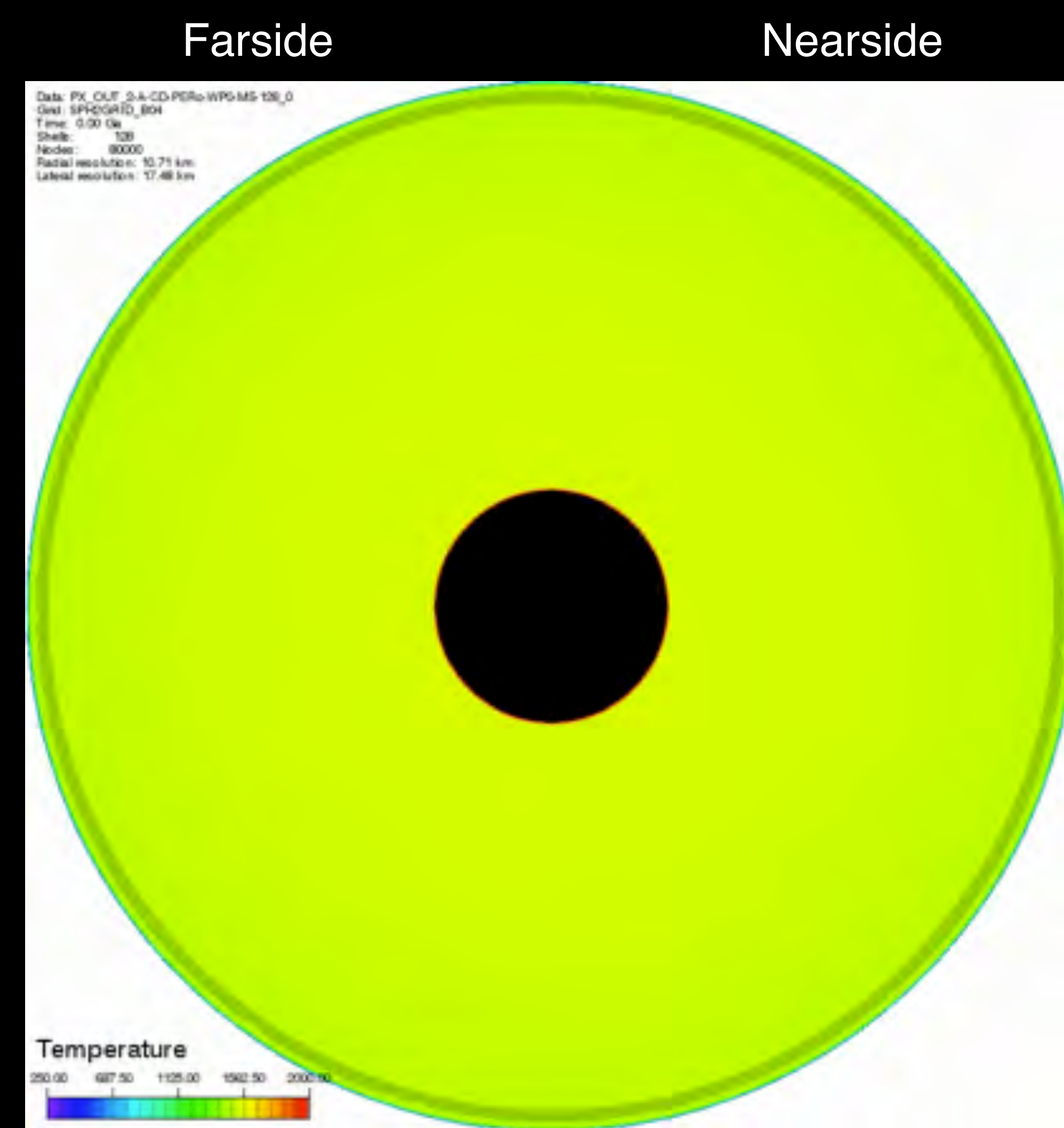


Miljkovic et al. (2013)

The nearside of the Moon is hotter than the farside



Abundance of radioactive elements as measured by the Lunar Prospector gamma-ray spectrometer

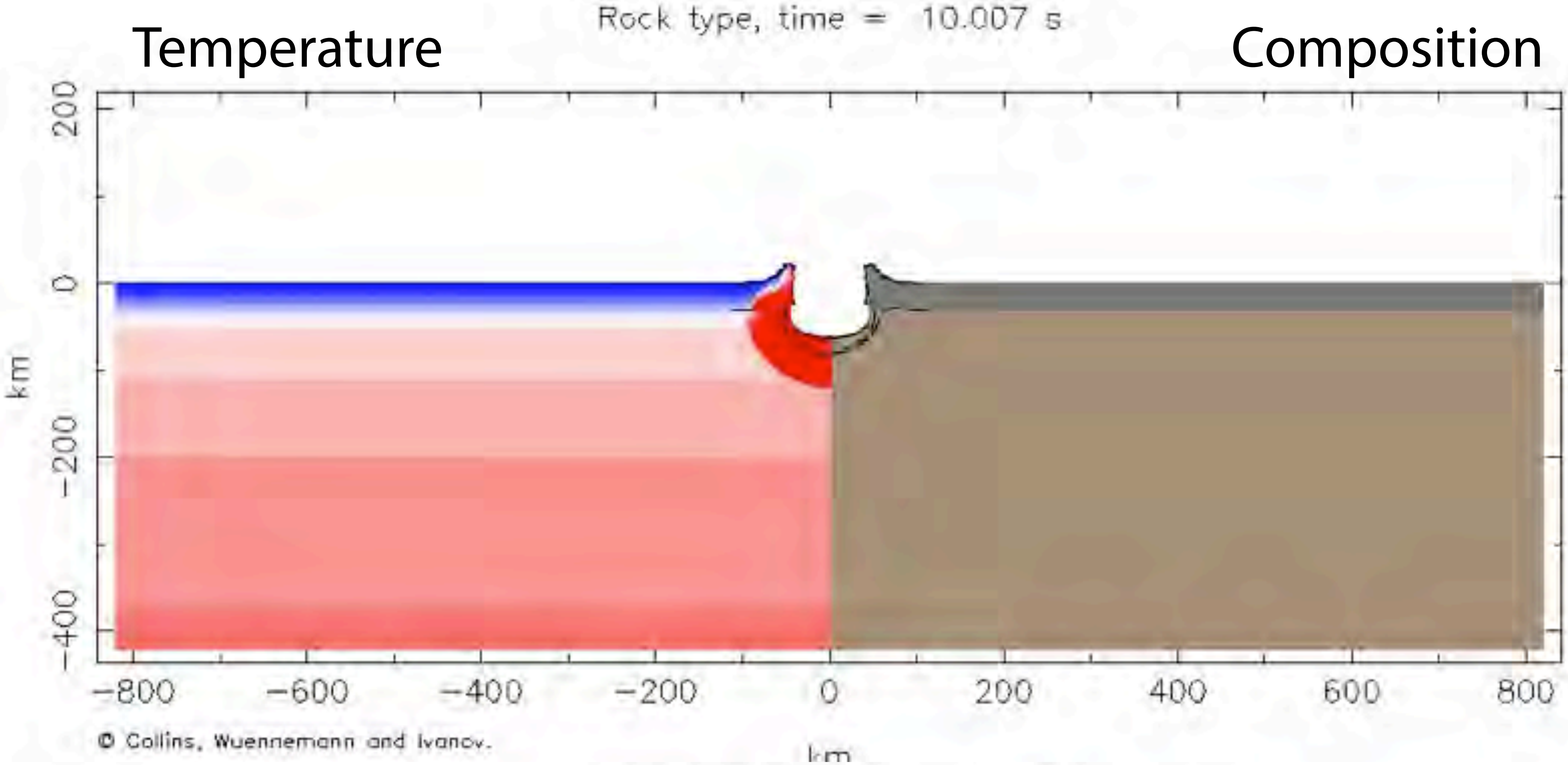


Laneuville et al. (2013)

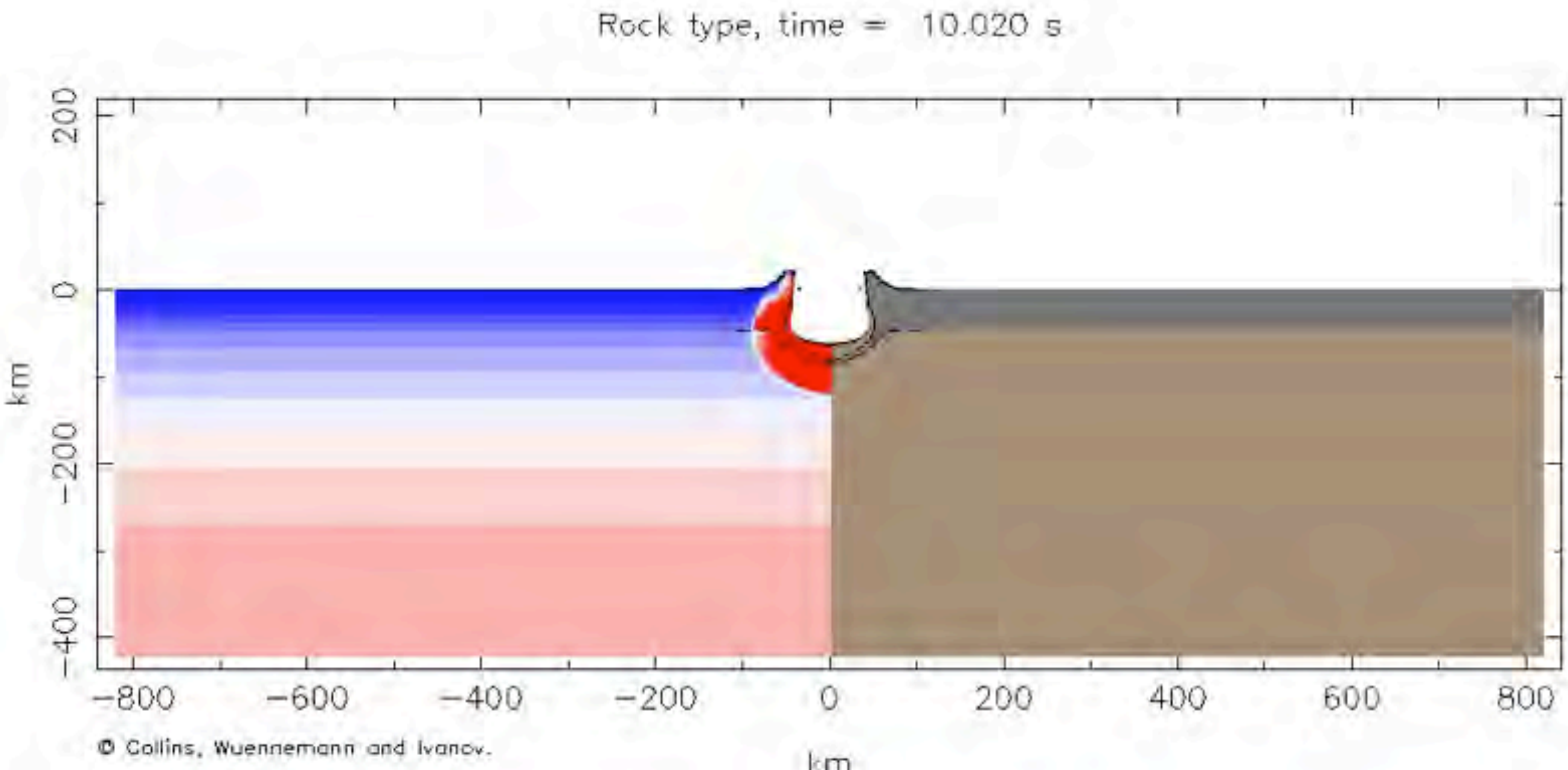
Simulated thermal evolution of the Moon

Temperature

Composition

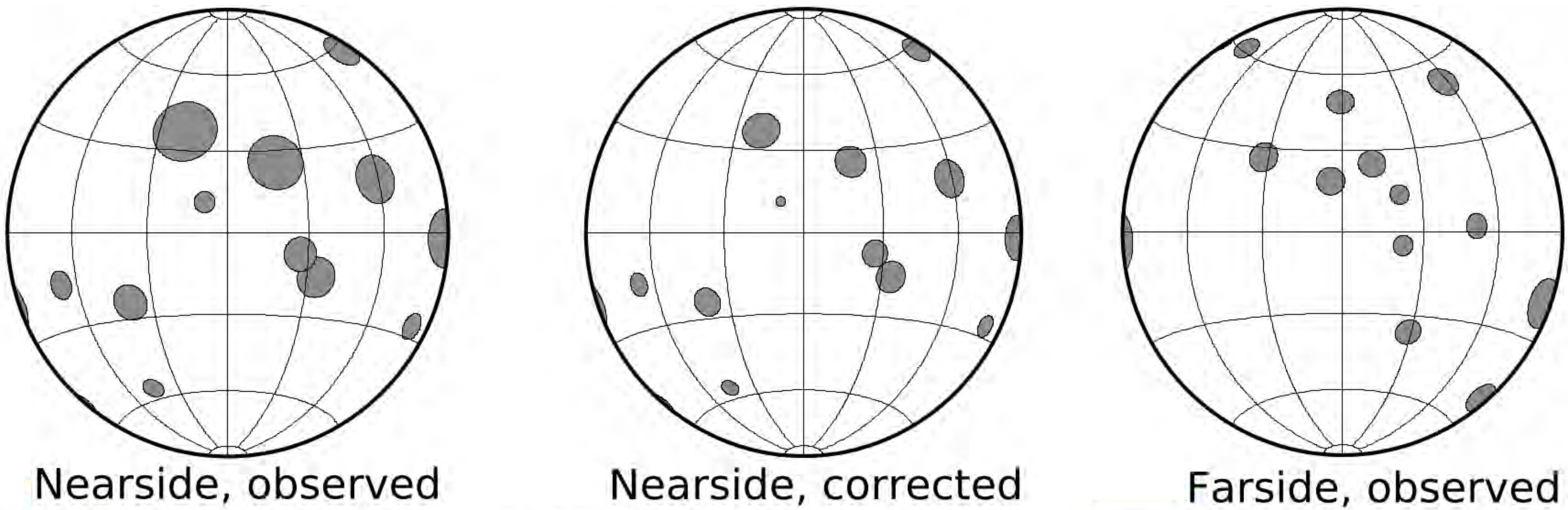


Impact onto a hot thin crust on the nearside of the Moon.



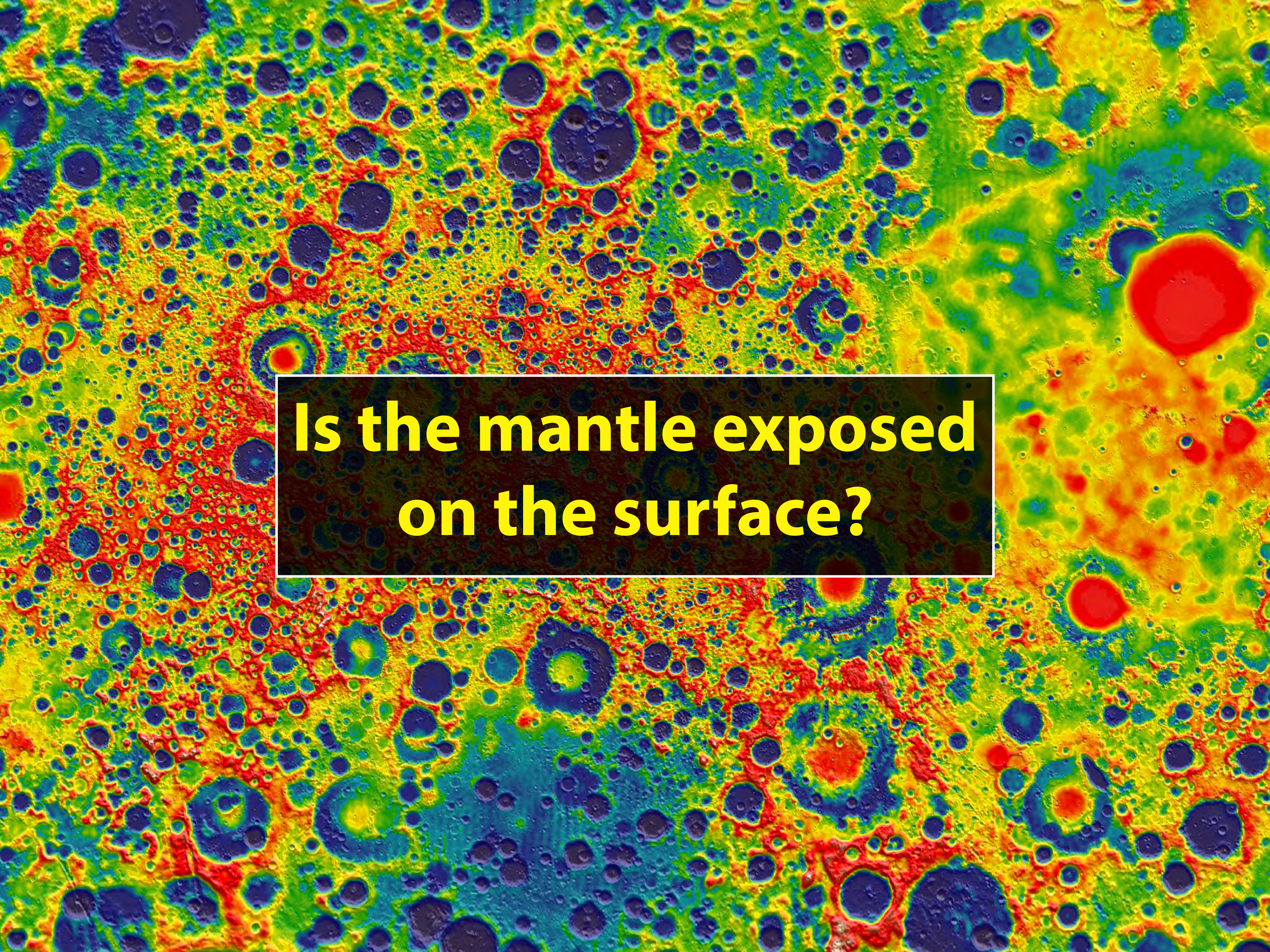
Impact onto a cold thick crust on the farside of the Moon.

Hydrocode simulations show that basins can be twice as big when they form in a weak hot target.

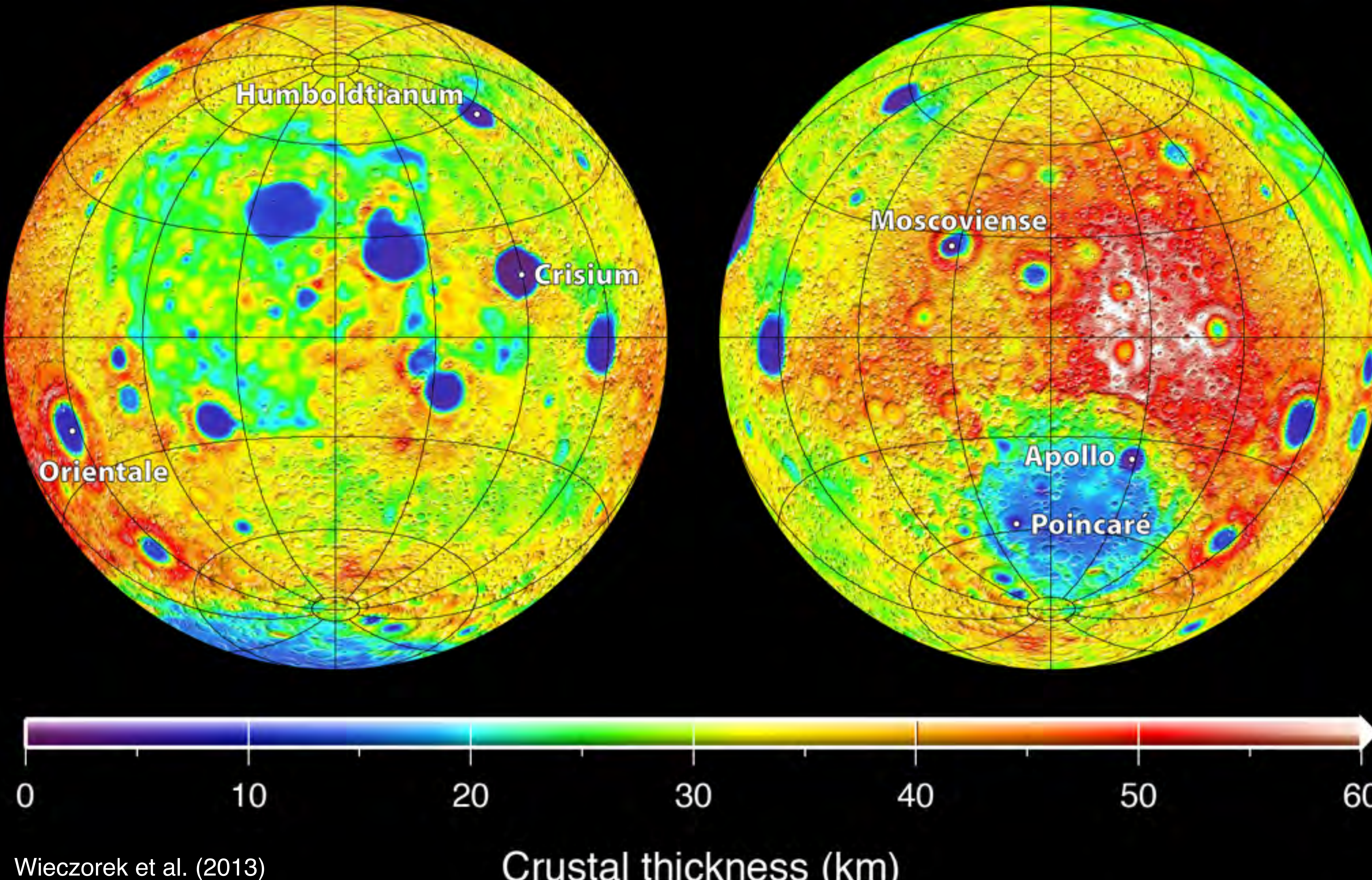


When the sizes of nearside basins are corrected for temperature effects, the nearside and farside look the same.

Miljkovic et al. (2013)


Is the mantle exposed
on the surface?

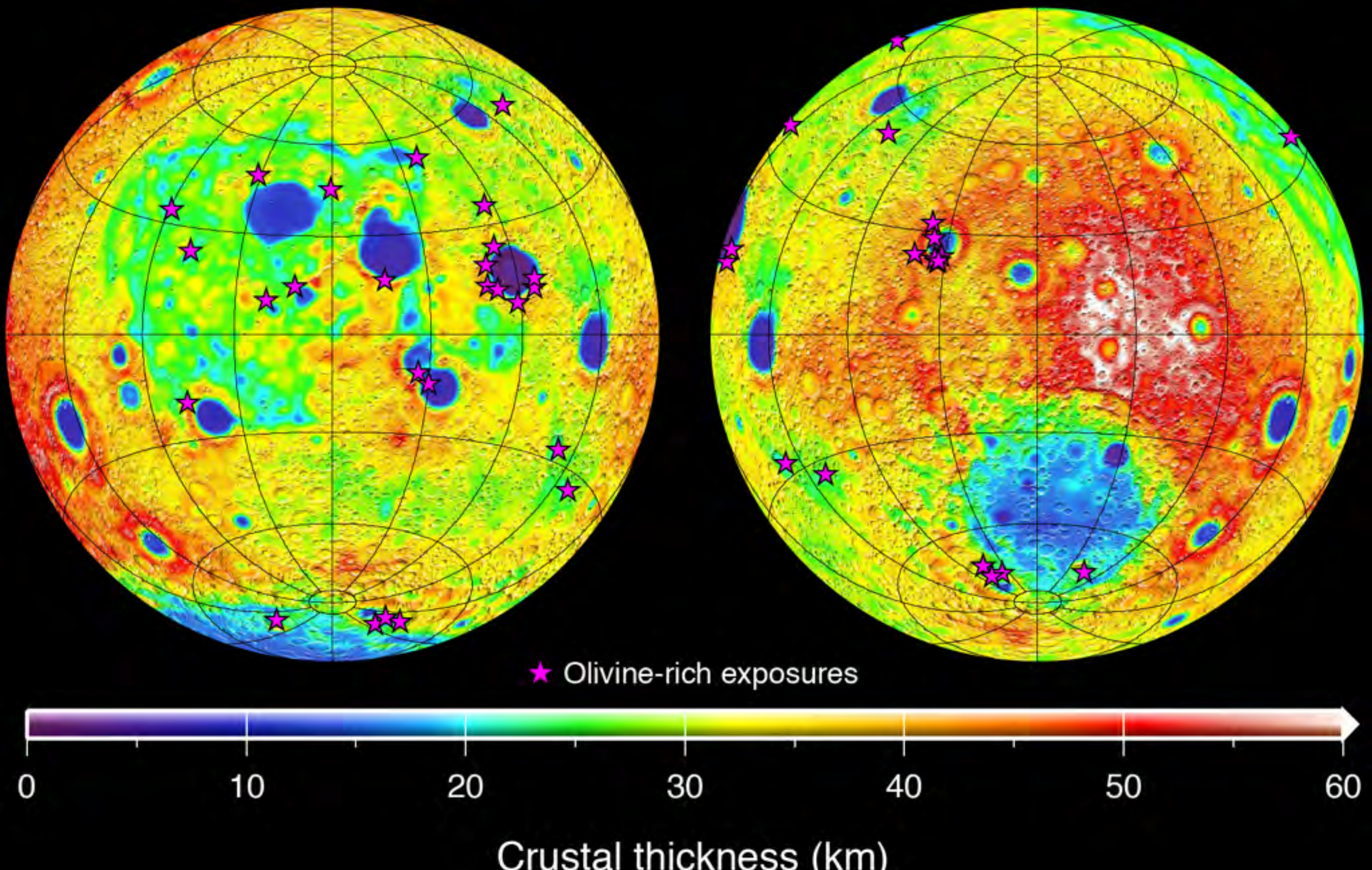
GRAIL Crustal Thickness



Wieczorek et al. (2013)

Exposures of olivine-rich (mantle?) materials

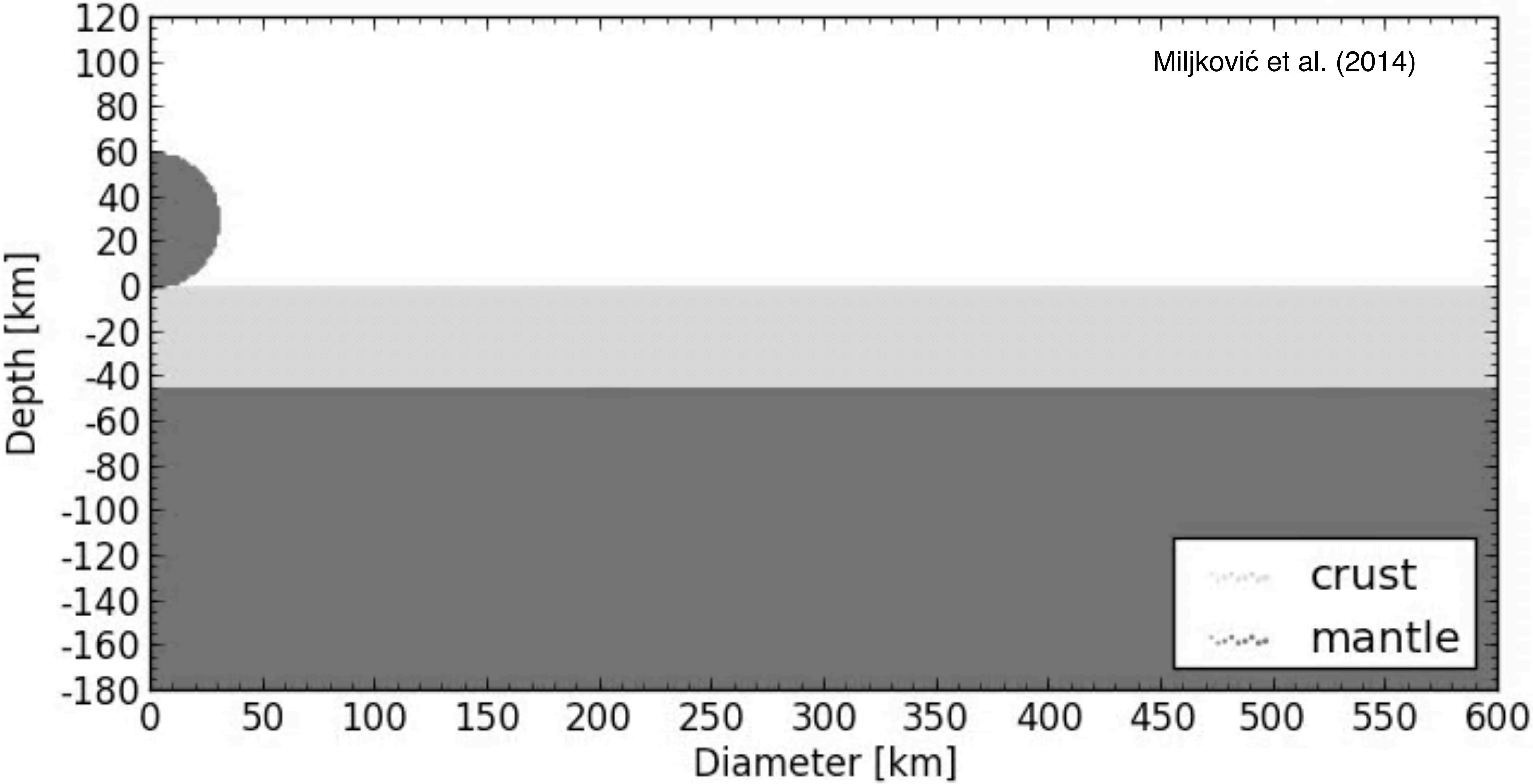
(Yamamoto et al., 2010)



Mantle excavation by impact basins

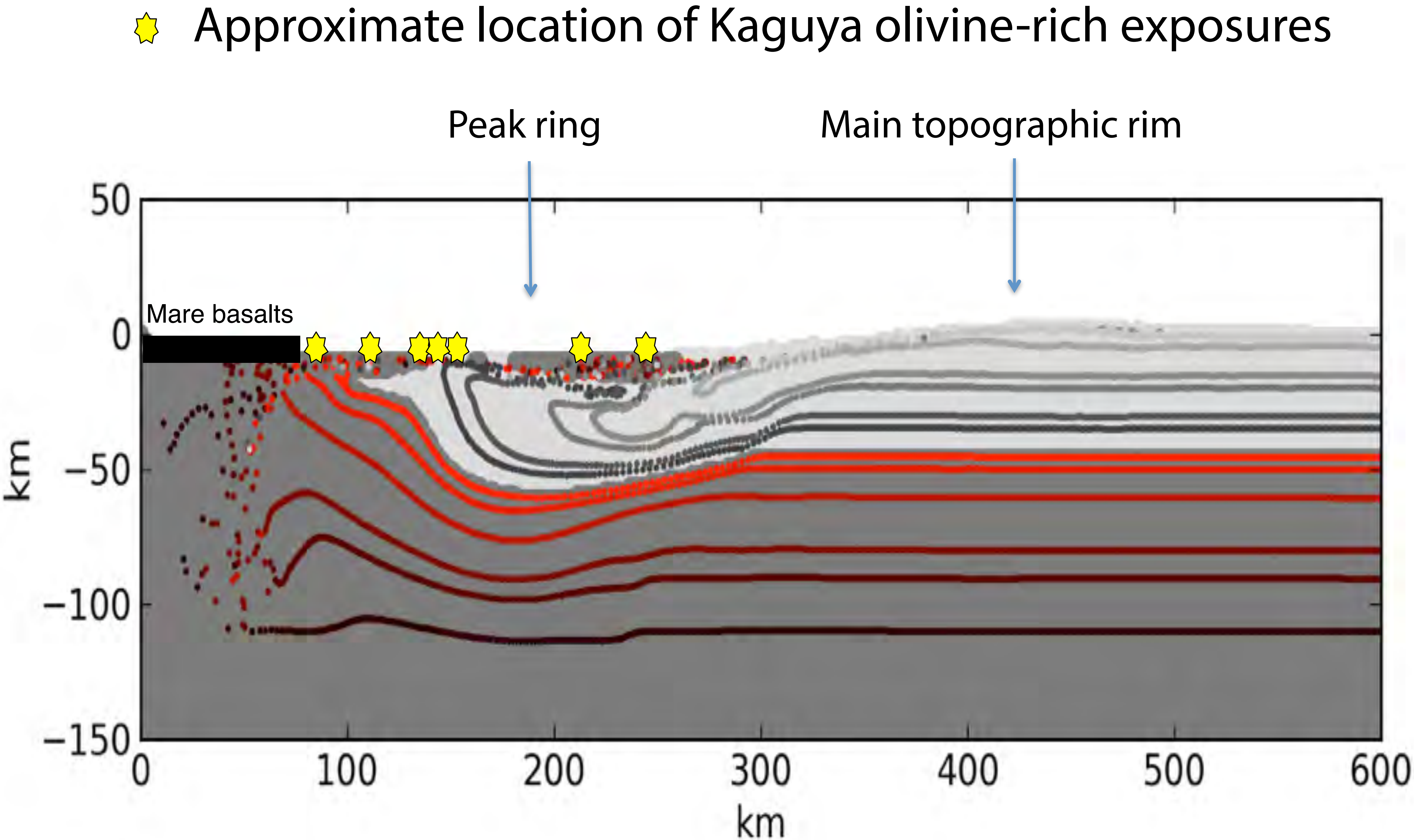
Numerical impact simulation into basalt crust overlaying dunite mantle by a 60 km impactor at 17 km/s vertical impact.

"Moscoviense," first 2 hours following impact ($D_{transient}$ = 185 km)



“Moscoviense”

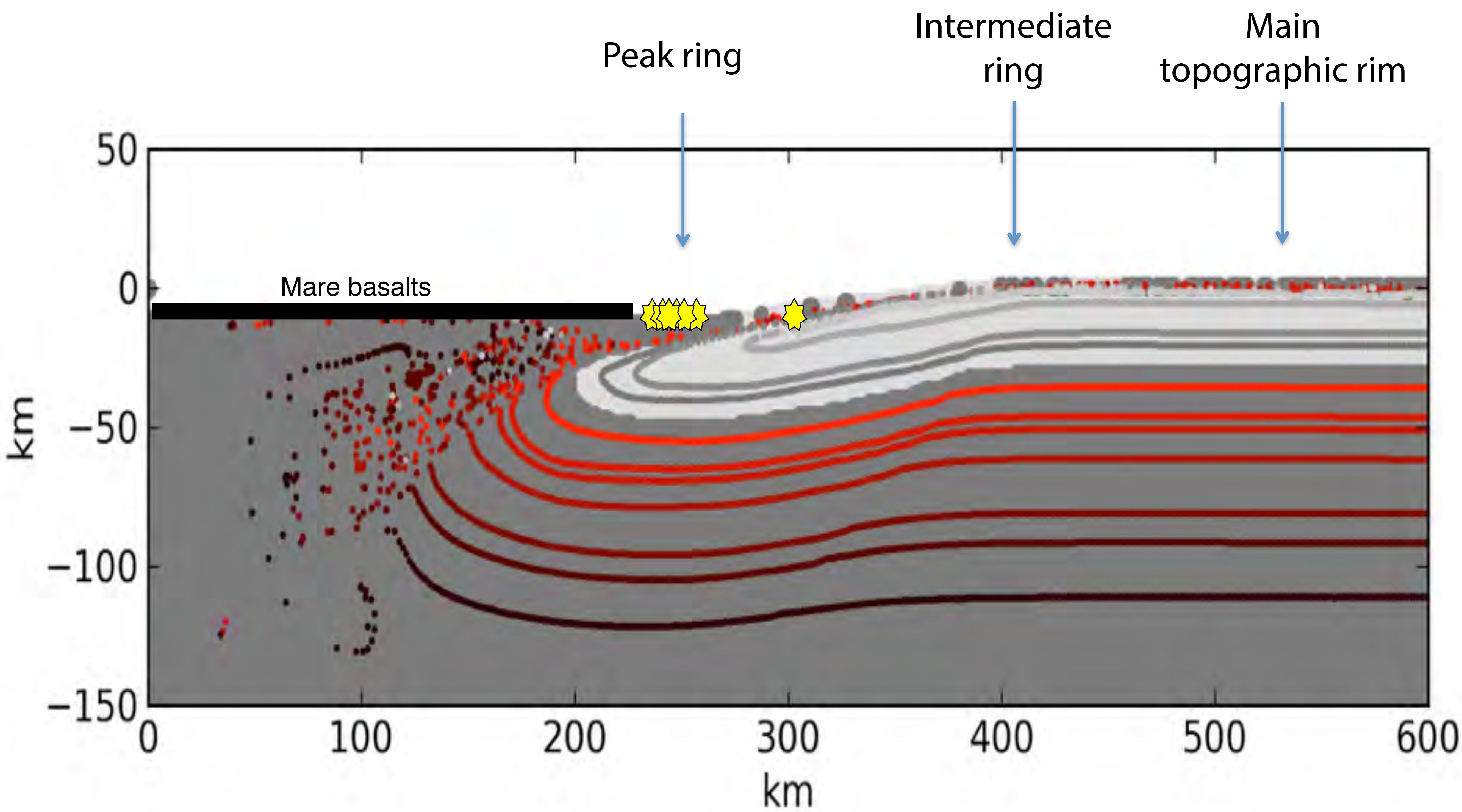
(Cold and thick farside crust)



"Crisium"

(Hot and thin nearside crust)

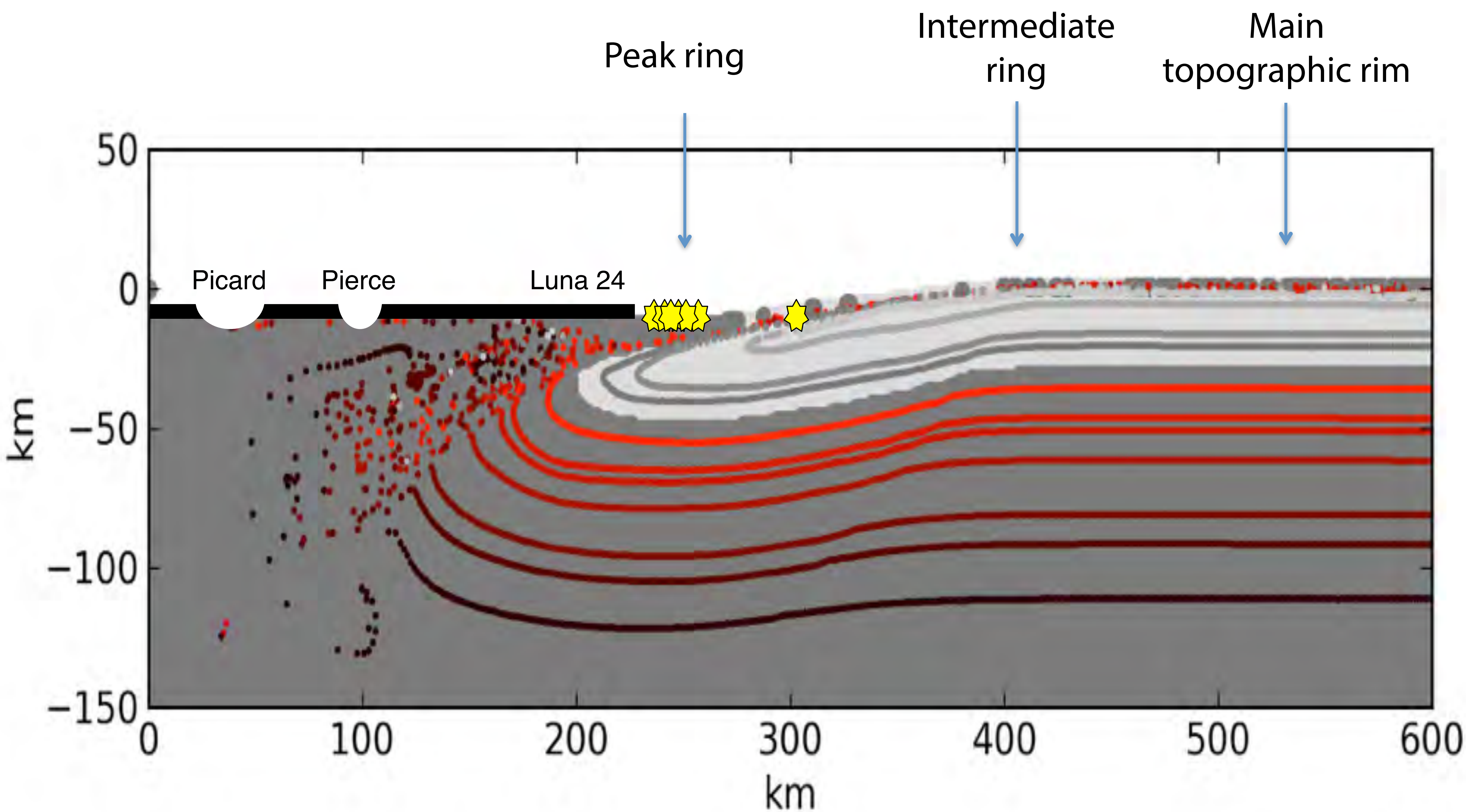
Approximate location of Kaguya olivine-rich exposures



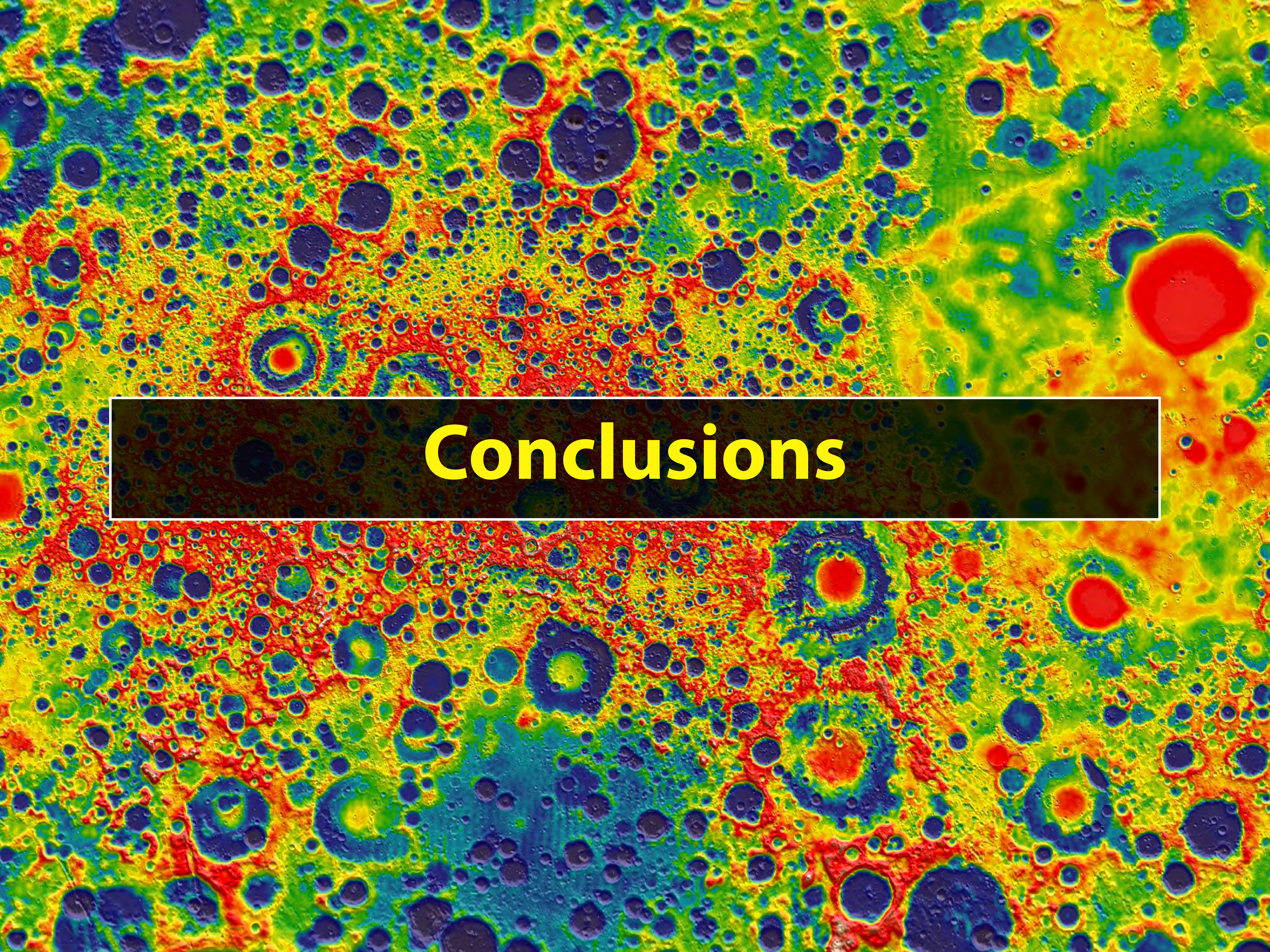
"Crisium"

(Hot and thin nearside crust)

Approximate location of Kaguya olivine-rich exposures



Conclusions



GRAIL MoonKam flyover of Orientale

NASA's GRAIL mission took this flyover video above the Mare Orientale basin of Earth's moon. It was collected by the MoonKAM aboard GRAIL's Ebb spacecraft on April 7 and 8, 2012.