Science Rationale for South Pole-Aitken Basin Locations for Sample Return

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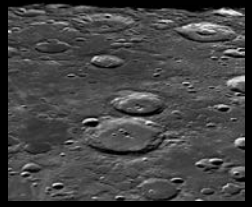
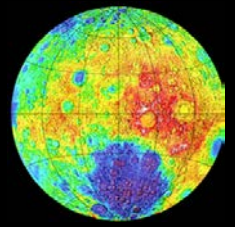
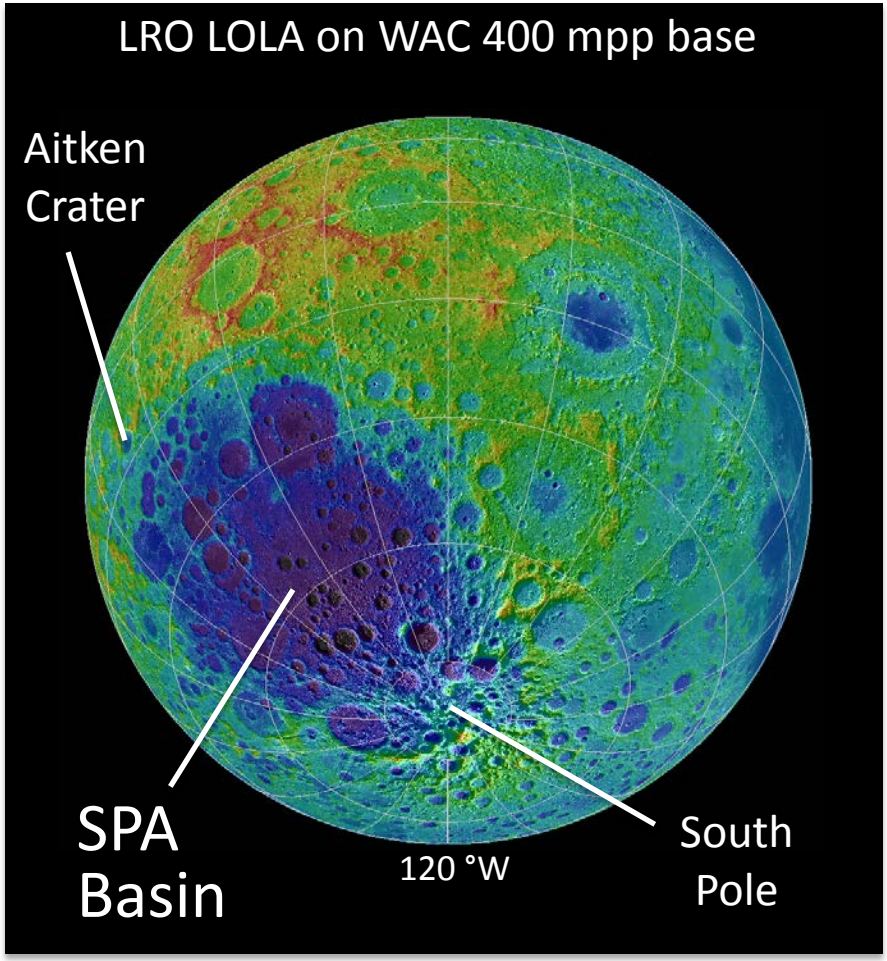
Background Image: SPA Basin Interior, LRO WAC, NASA/GSFC/ASU



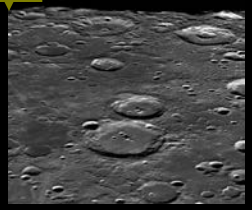
Outline



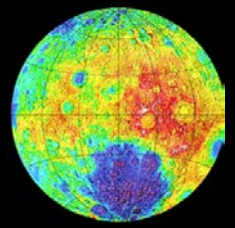
- Why SPA?
- Why Sample Return?
- Where to land in SPA?
- Process for Site Selection
- Benefits of SPA-SR



Combined LRO WAC Image mosaic and LOLA topography

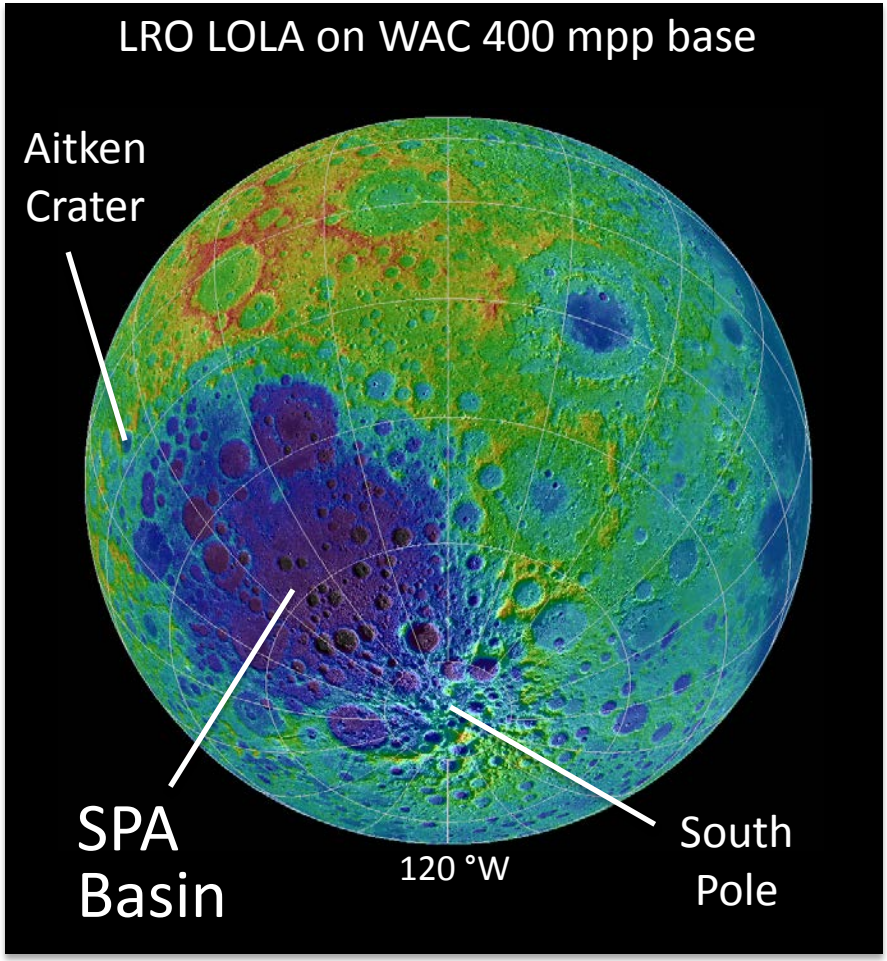


Priority



** *Priority*

- *Decadal Survey for Planetary Science (2011)*
- *Scientific Context for Exploration of the Moon*
- *Lunar Exploration Roadmap*
  - *Goal A (1,2,6,7,8)*
  - *Goal B (1)*
  - *Goal FF-A (6)*
  - *Goal FF-C (1,3,4)*



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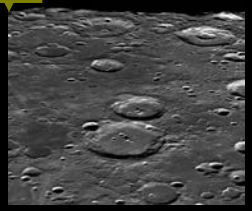
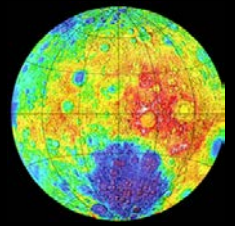
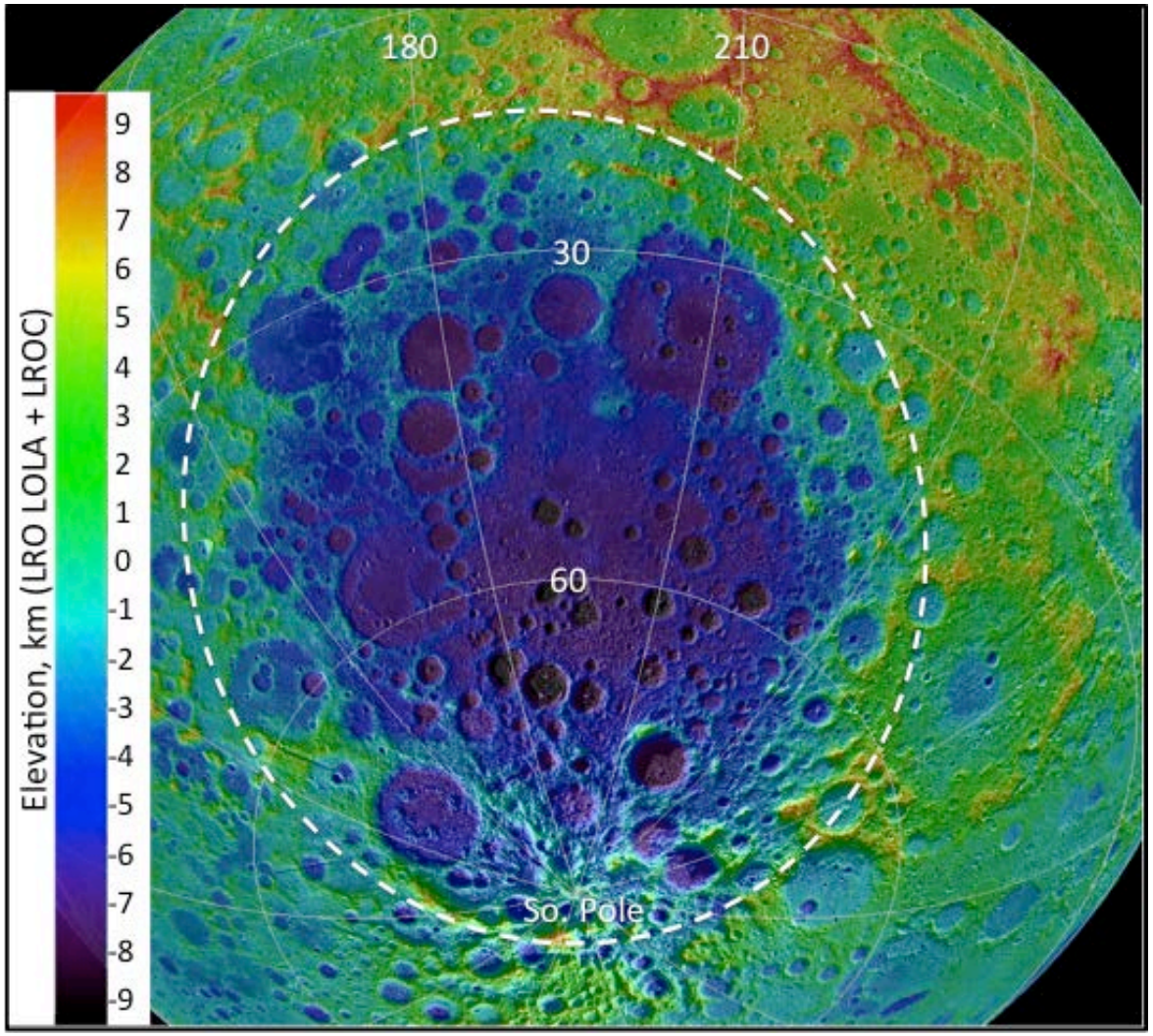


Why SPA Basin?



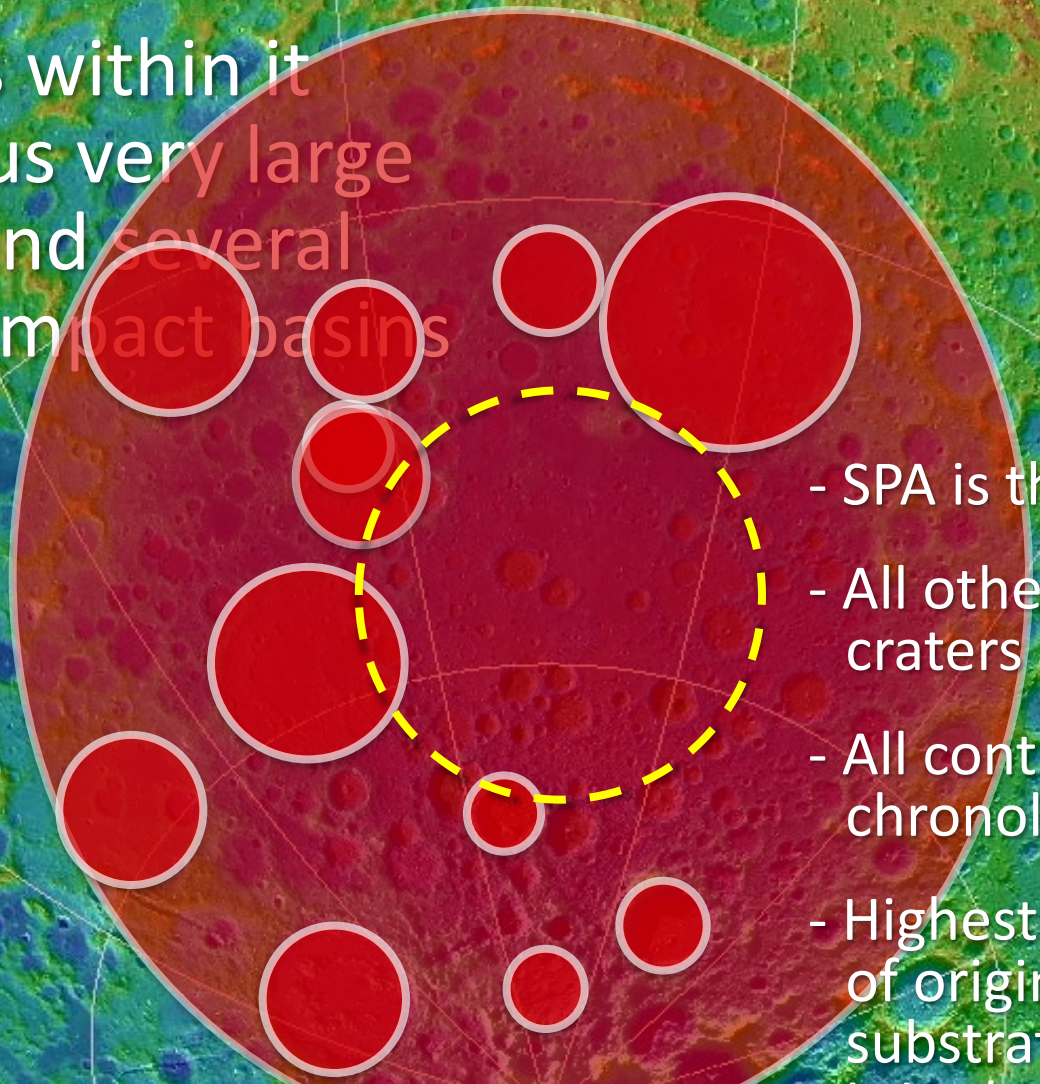
- Largest and oldest of the clearly recognizable impact basins on the Moon
  - SPA event completely resurfaced this part of the Moon and reset ages over an enormous area.
  - As such, SPA anchors the lunar heavy impact chronology.



LRO WAC base with LOLA and GLD100 DTM
Scholten et al., 2012

SPA Basin Chronology

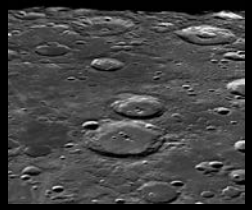
- Contains within it numerous very large craters and several smaller impact basins



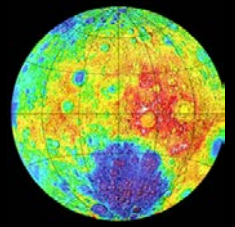
- SPA is the "bookend."
- All other basins and craters are younger.
- All contribute to SPA chronology.
- Highest concentration of original SPA substrate materials is in the center.

LRO LOLA
Laser Altimeter
NASA/GSFC/ASU/MIT

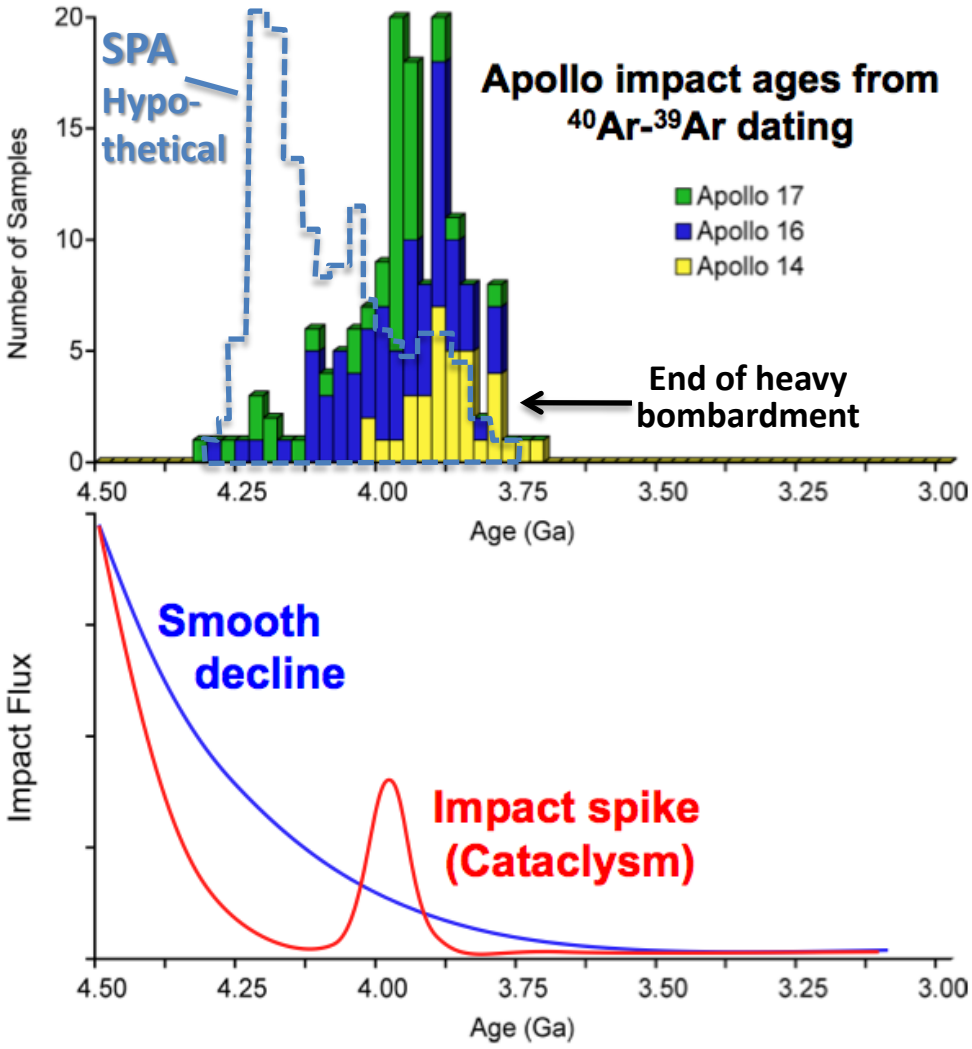
Jolliff et al., LEAG

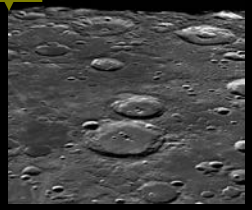


Analysis of many samples is required

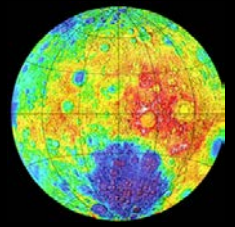


- Statistical approach is needed - by obtaining many isotopic ages - to identify the age of SPA and ages of post-SPA impacts.
- What does this histogram look like for the SPA chronology?
- Do not need to know which individual basins & craters are dated, just the distribution and spread of ages.

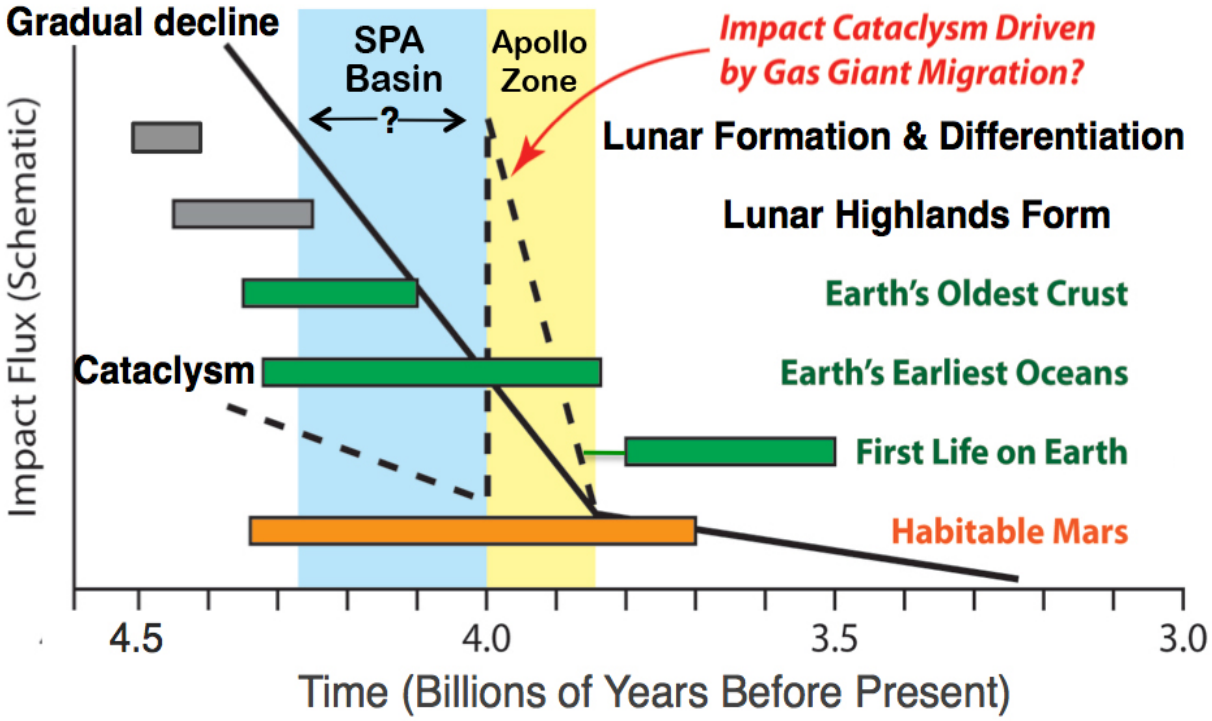




SPA as a Window into the Early Solar System Environment



- SPA-SR science builds on chronology and chemistry from Apollo, but..
  - the cataclysm test cannot be done solely with Apollo samples; **SPA samples are required.**

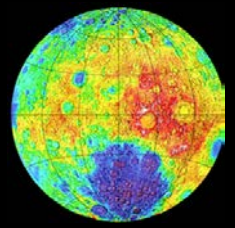


Gradual decline: older age for SPA, no support for gas giant migration

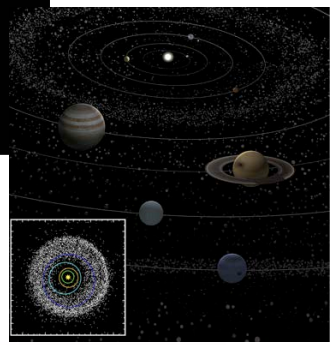
Cataclysm: younger age for SPA, support for gas giant migration

To understand early Solar System environment, we must acquire new samples from the oldest and largest of the well preserved impact basins, SPA, which reset ages over a large part of the Moon when it formed.

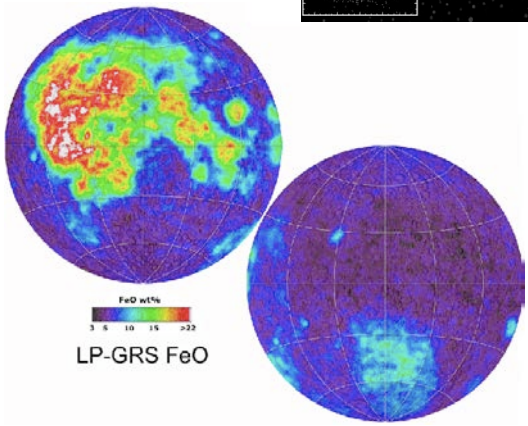
What can we learn?



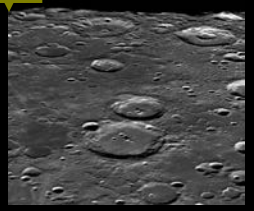
- Was there a cataclysmic impact bombardment in the early Solar System?
  - Onset and duration?
  - Record is bound in the rocks of the South Pole-Aitken impact basin.



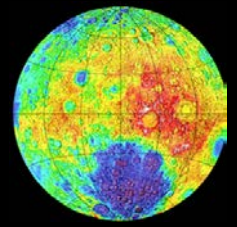
- *What were the effects of such bombardment on planets and moons in the Solar System?*
- How do planets differentiate to produce global scale asymmetries such as:
  - Crustal dichotomy (thickness, composition, volcanics)
  - Large-scale geochemical, volcanic, and magmatic provinces

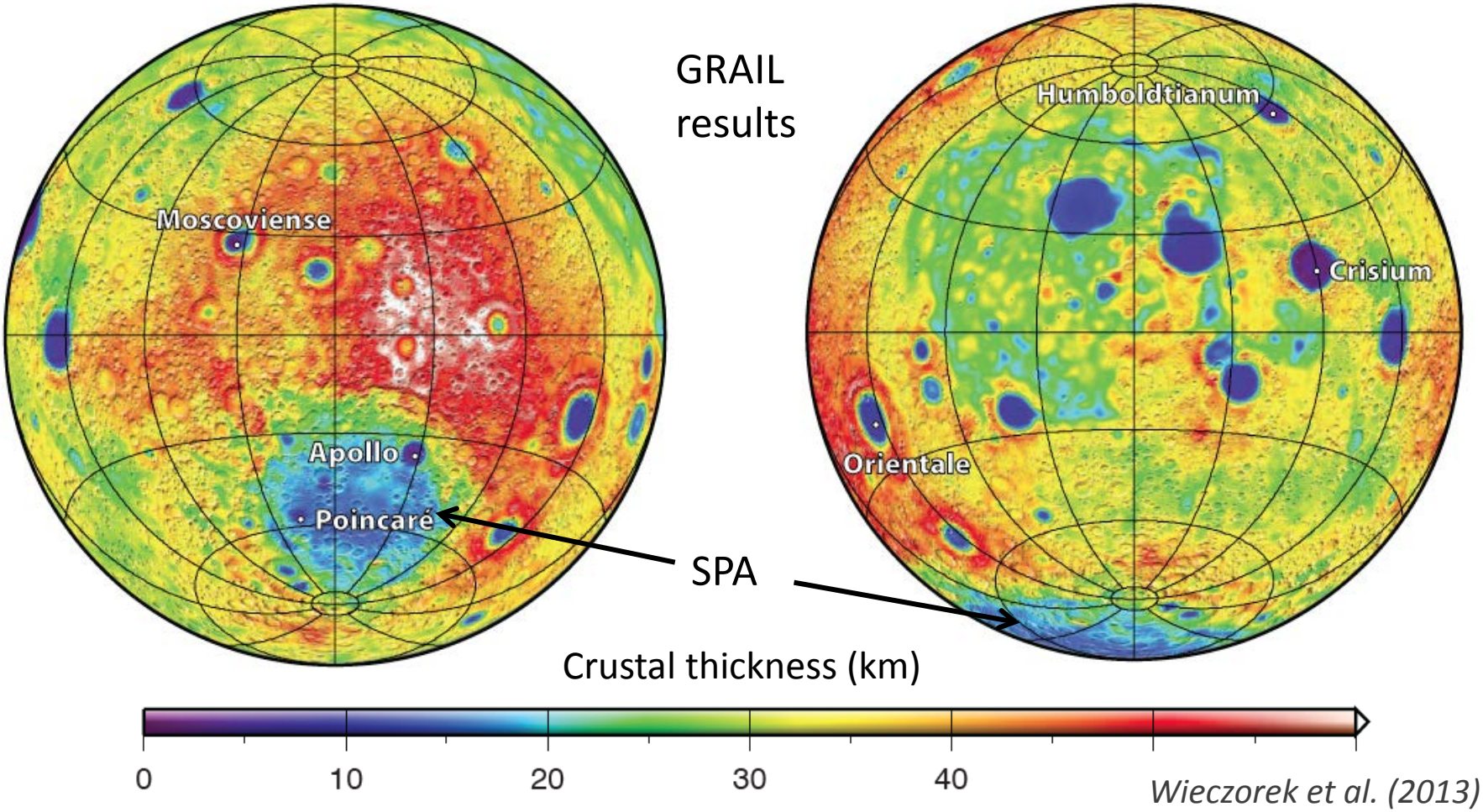


Moon's South Pole-Aitken Basin preserves a record of early Solar System events.



Crustal Thickness

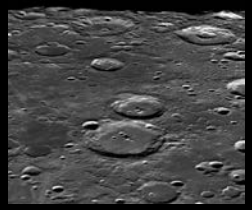




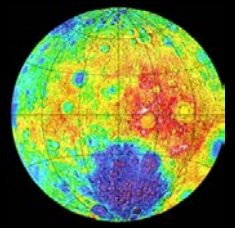
Wieczorek et al. (2013)

- SPA crust 15-20 km thick → interpreted as <u>differentiated impact melt</u>

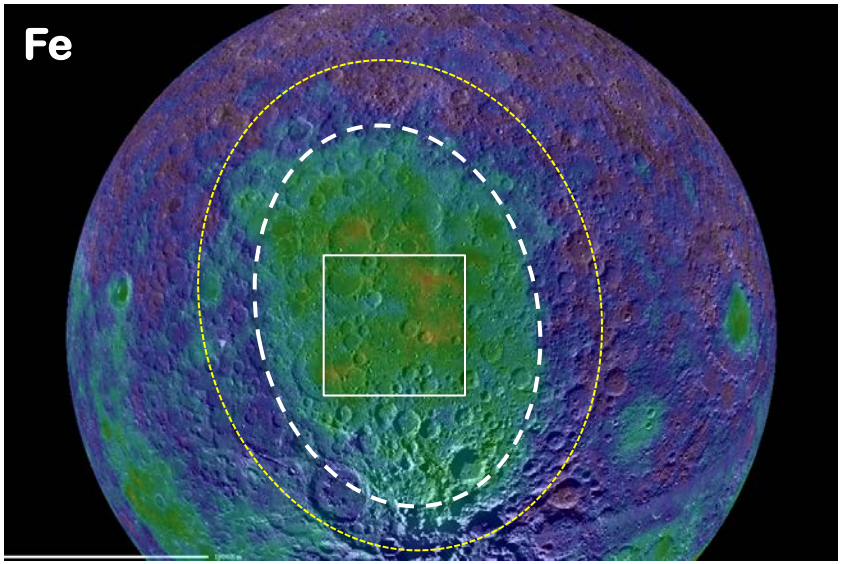
(Potter et al., 2012, Icarus; Vaughan & Head, 2013, PSS; Hurwitz & Kring, 2013, 2014 JGR)

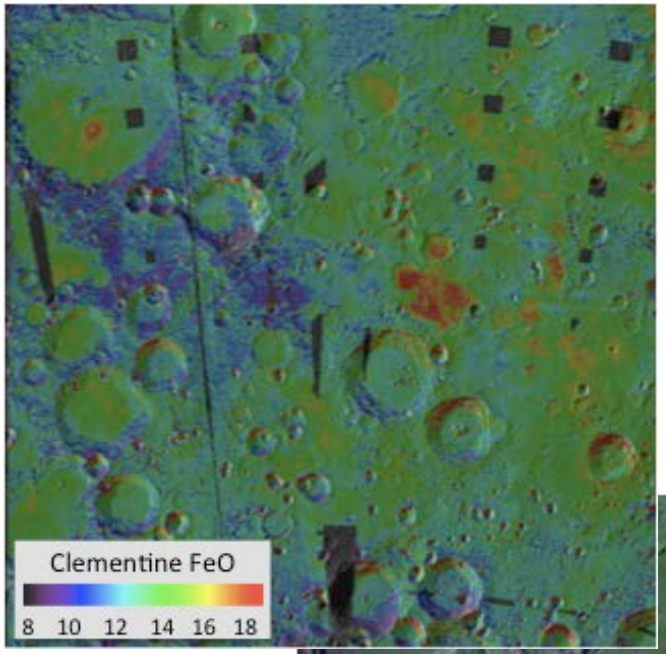


Geochemistry, FeO



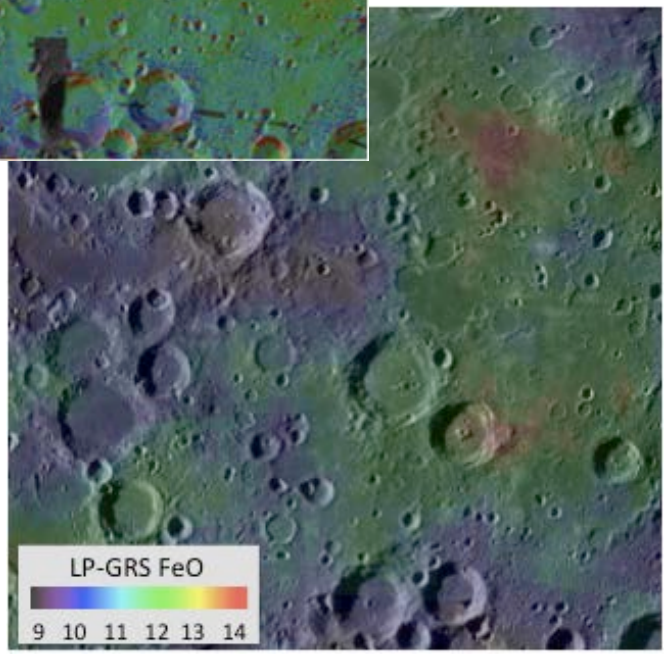
- LP-GRS and Clementine-derived FeO values relatively high in the basin interior:
  - 8-18% FeO
  - basalt, cryptomare, and impact-melt components difficult to distinguish
  - *samples are needed to sort this out.*

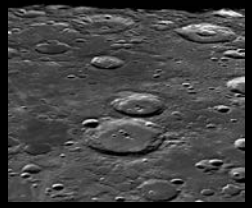




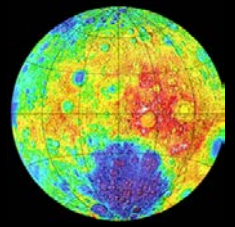
Basin Interior

Values need reconciliation

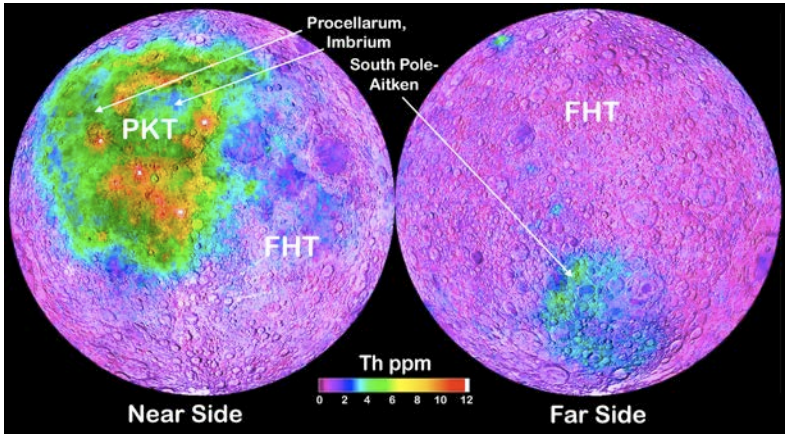


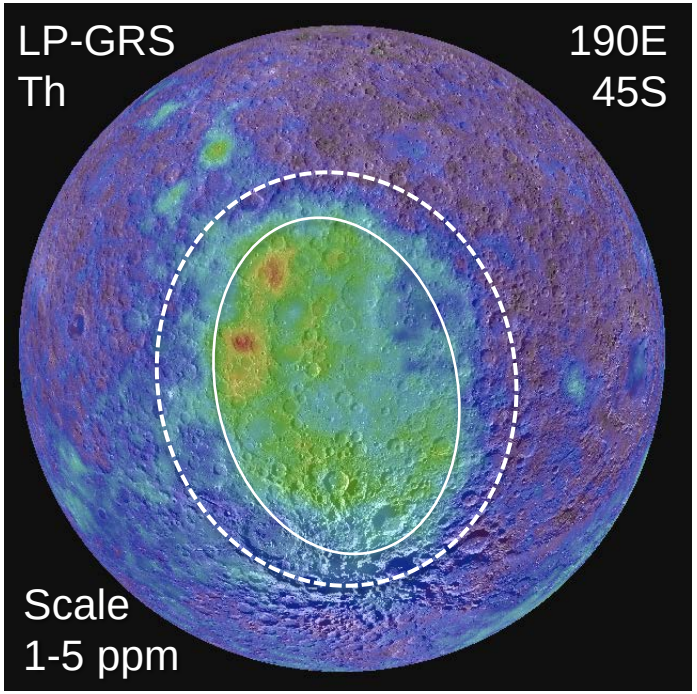


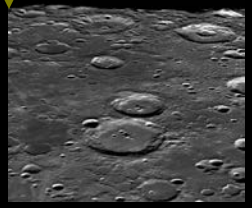
Geochemistry, Th (LP-GRS)



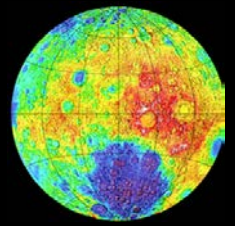
- **Thorium distribution**
  - Modest enhancement in basin interior, 2-3 ppm
  - Localized concentrations in northwest
  - Is background Th content related to SPA melt sheet?
  - Are thorium-rich materials of SPA similar to KREEP from near side?
  - Evidence for multiple Th-rich components?



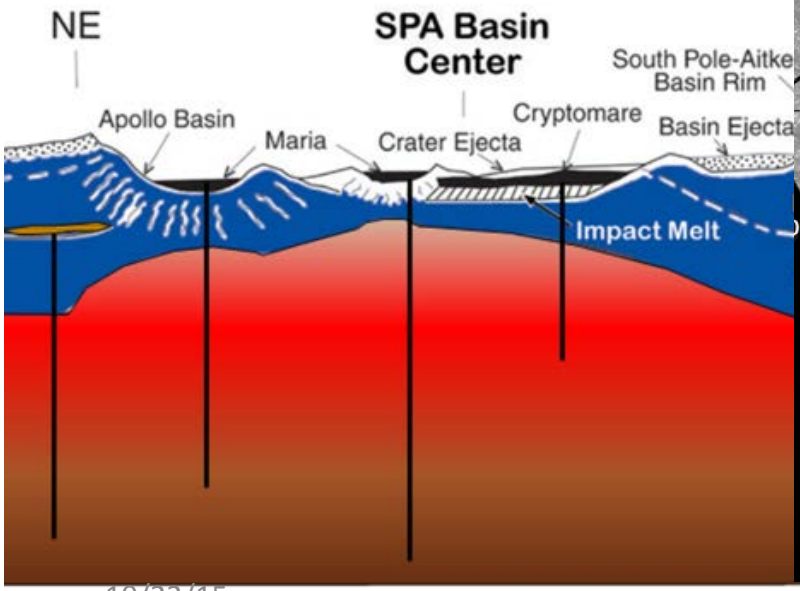


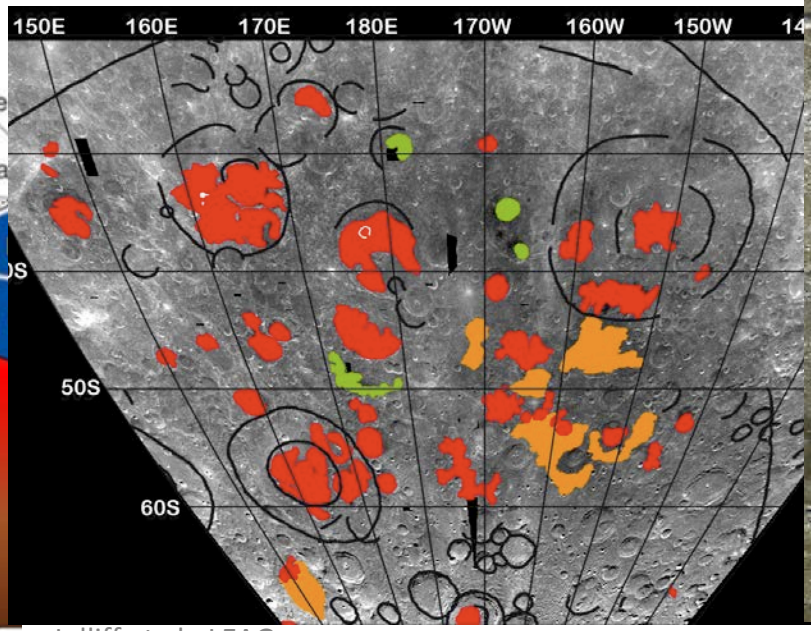


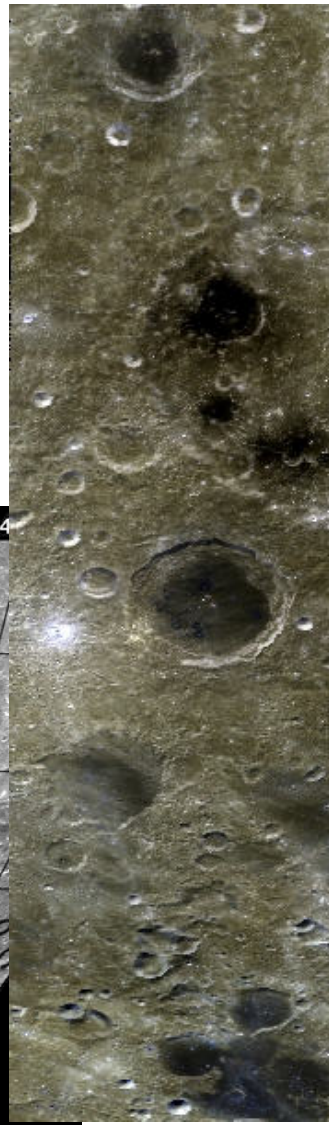
Basaltic Volcanism

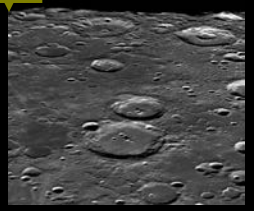


- Chronology and composition of basaltic volcanic rocks
  - sampling sub-SPA mantle and testing models for origin and differentiation of the Moon
  - timing and thermal evolution

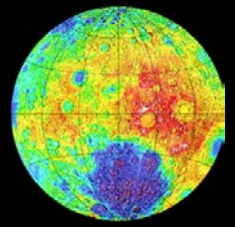








Magnetic Signatures



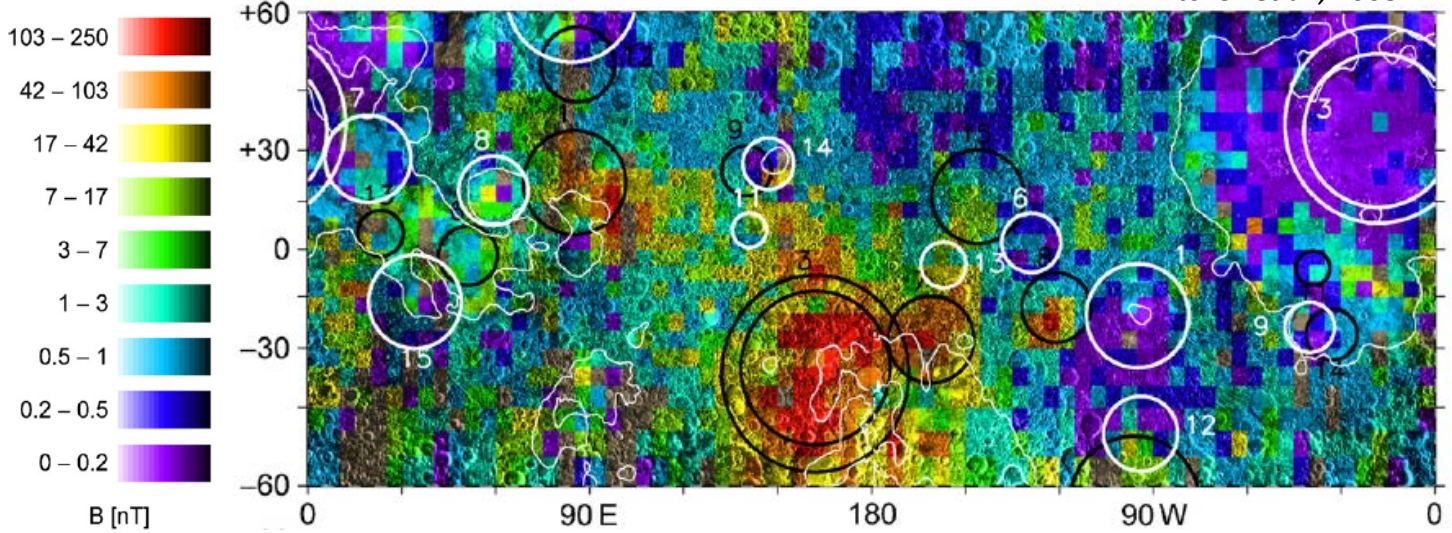
Surface crustal magnetic field intensity from *Mitchell et al., 2008*

What is the origin of the high intensity in SPA?

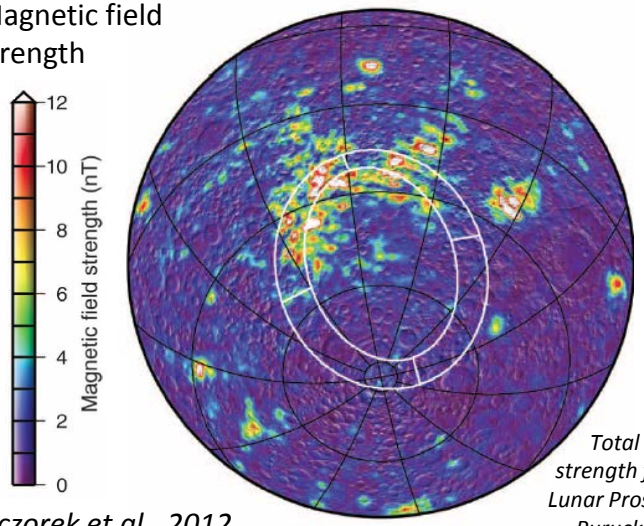
Antipodal deposits from Imbrium and Serenitatis?

Or… Remnants of the SPA impactor as inferred by *Wieczorek et al., 2012*?

Mitchell et al., 2008

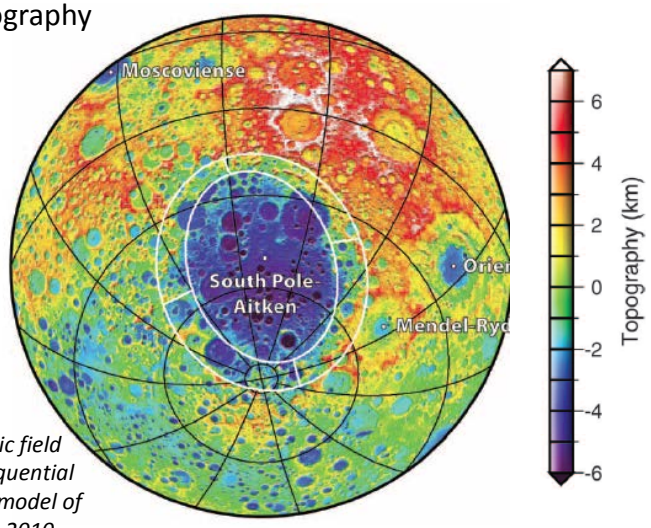


Magnetic field strength

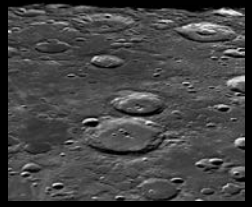


Wieczorek et al., 2012

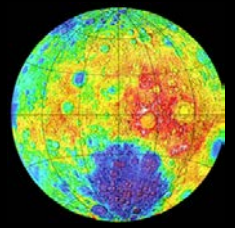
Topography



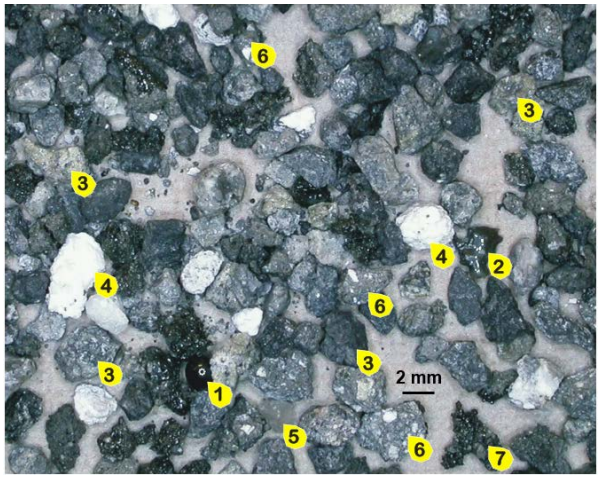
Total magnetic field strength from sequential Lunar Prospector model of Purucker et al., 2010



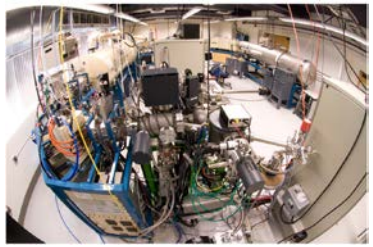
Again, Why Sample Return?

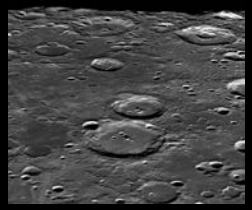


- Samples represent a complex mixture of lithologies
  - Many individual rock fragments are themselves complex breccias
  - Must investigate petrography, chemistry, isotopes, etc.
- Leverage best analytical capabilities on Earth with the returned samples
- Increase science yield of sample by sieving and collection of 1 kg or more of rock fragments

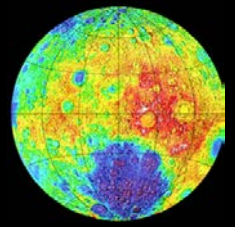


Lithologic variations in soil

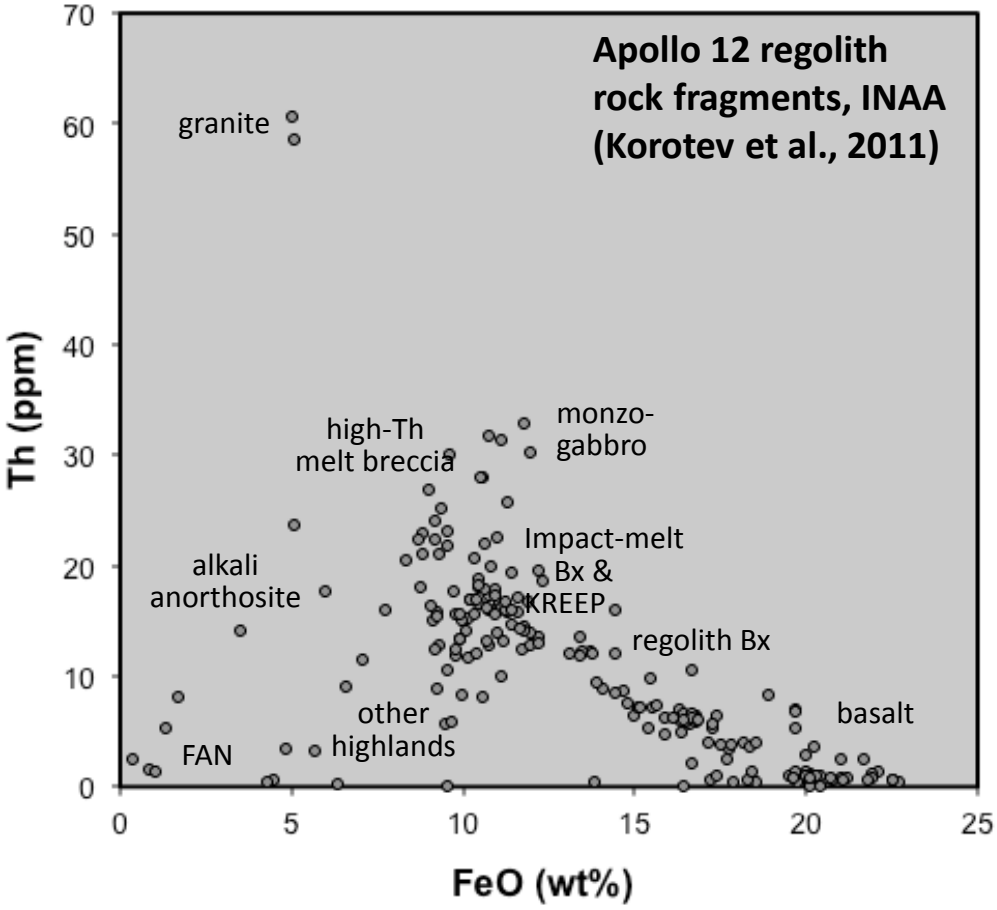


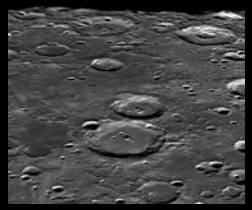


How: In-situ Sample Collection

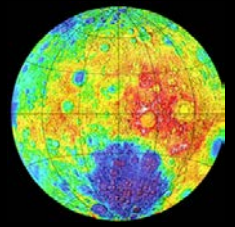


- Approach based on Apollo-based knowledge of regolith rock fragment diversity
- Take advantage of impact mixing
  - precise location of landing site is not critical
  - can select safest landing site and accomplish science objectives

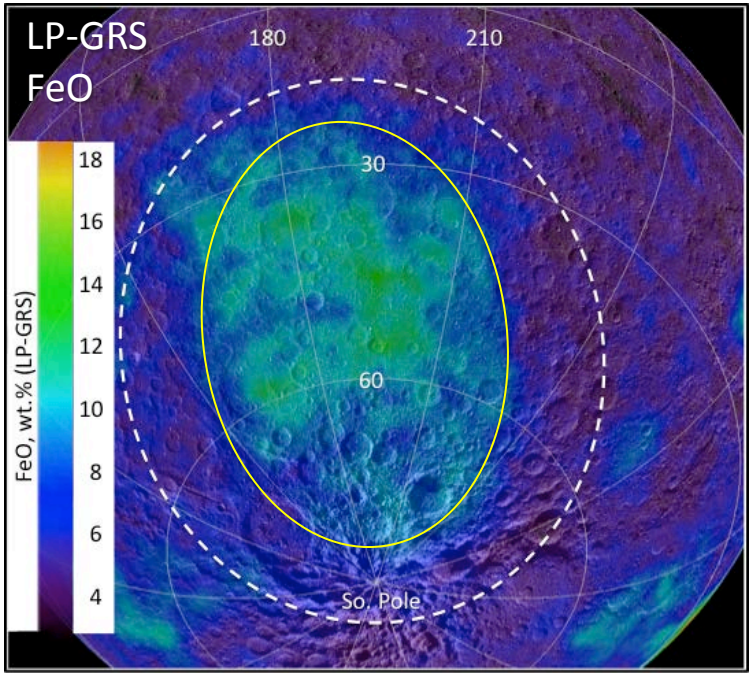


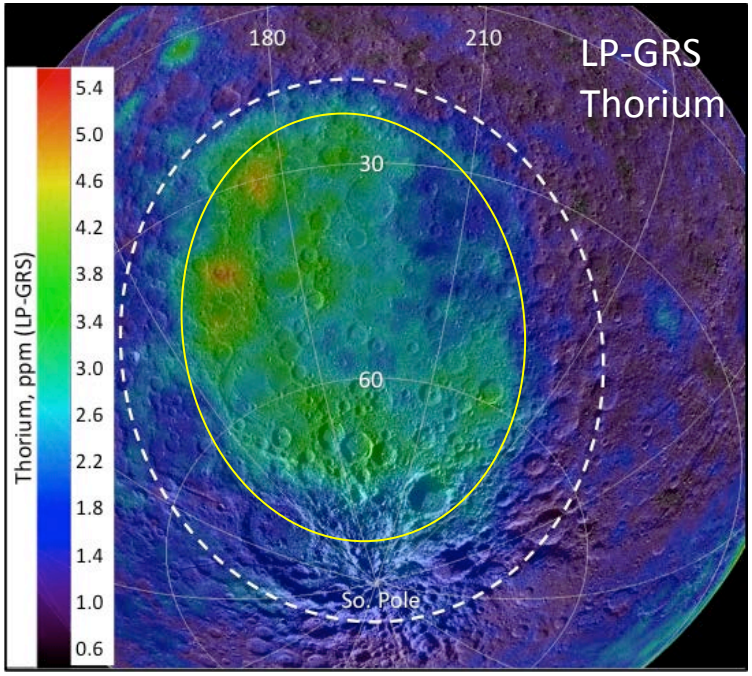


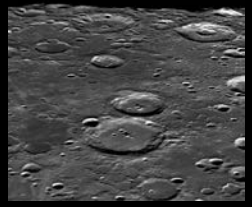
Where to Land?



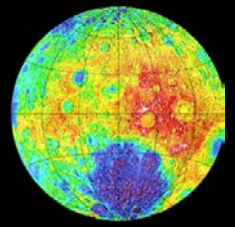
- **Sample within the Basin as defined by broad compositional signature corresponding to SPA interior.**
  - LP-GRS & other compositional data
  - Keep to the interior of the basin, ~ 1200 km across (E-W)





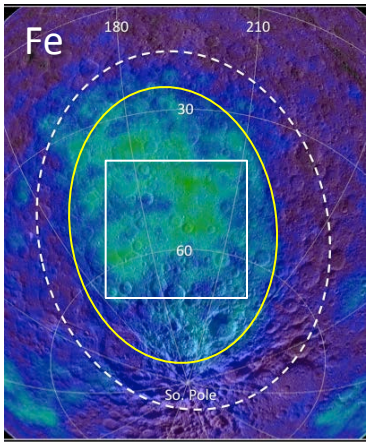


Where to Land?



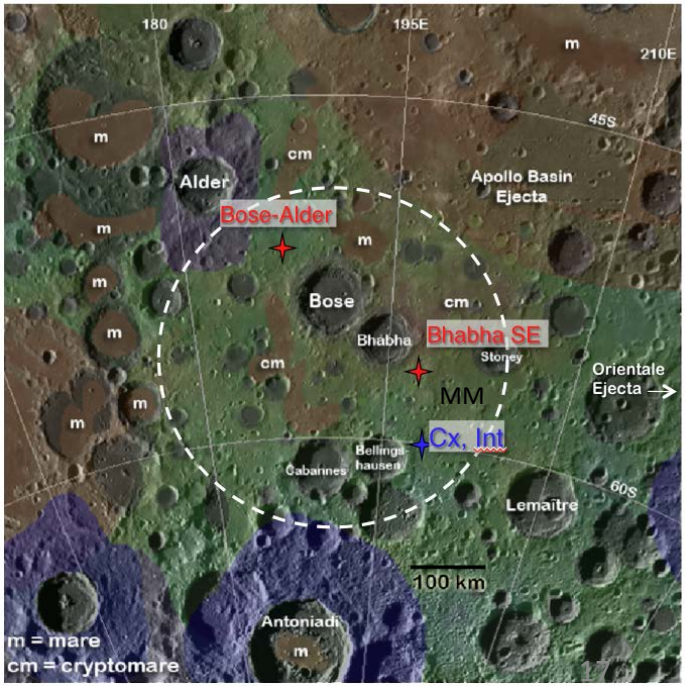
- **Sample within the SPA Basin as defined by broad compositional signature corresponding to SPA interior.**

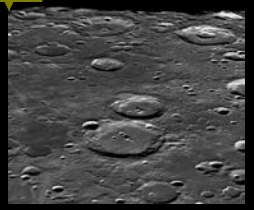
- **Many safe landing ellipses within this area**
- **Proximity to basalt (mare and 'cryptomare')**
  - Sample basalt fragments delivered by impacts; volcanic glass.
- **Most of the areas shown in green → correspond to intercrater plains.**
  - Mostly low-lying, level, and ~smooth terrain
- **Data needed for scientific site selection and landing site safety are available (LRO).**
- **Hold workshops prior to mission to select and prioritize landing sites.**



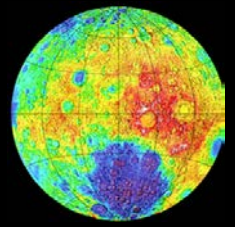
LP-GRS

Geology on LRO WAC base





Major Advances that SPA sample return would provide in Planetary Science

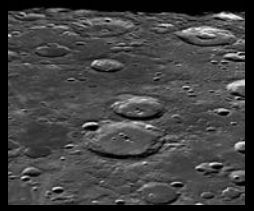


- Will change thinking about **dynamics of the Solar System and the key importance of cataclysmic events**
  - Advances beyond current models for late, heavy bombardment
- Will revolutionize understanding of the **effects of giant impacts on the development of terrestrial planets**
  - Nails down giant impact flux, applicable to other planets & moons
  - Improves knowledge of early environments / habitability
- **Will provide evidence and chronological anchors for a major event in the inner Solar System**
  - Will fill time gap in our understanding of evolution of the inner Solar System from 4.5 to 4.0 billion years ago
- **How terrestrial planets evolve with time**
  - Crust-mantle differentiation, causes of global asymmetry, links between distribution of heat-producing elements and thermal history

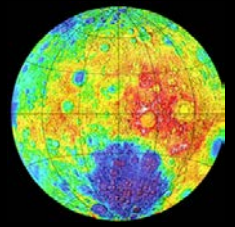
Thank You!!

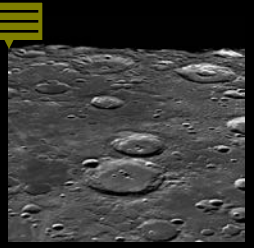
Acknowledgements:
MoonRise Science Team,
LRO and LROC Teams
NASA

LROC QuickMap: NASA/GSFC/ASU

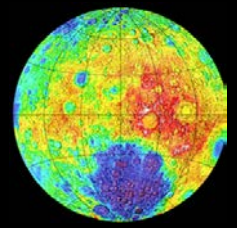


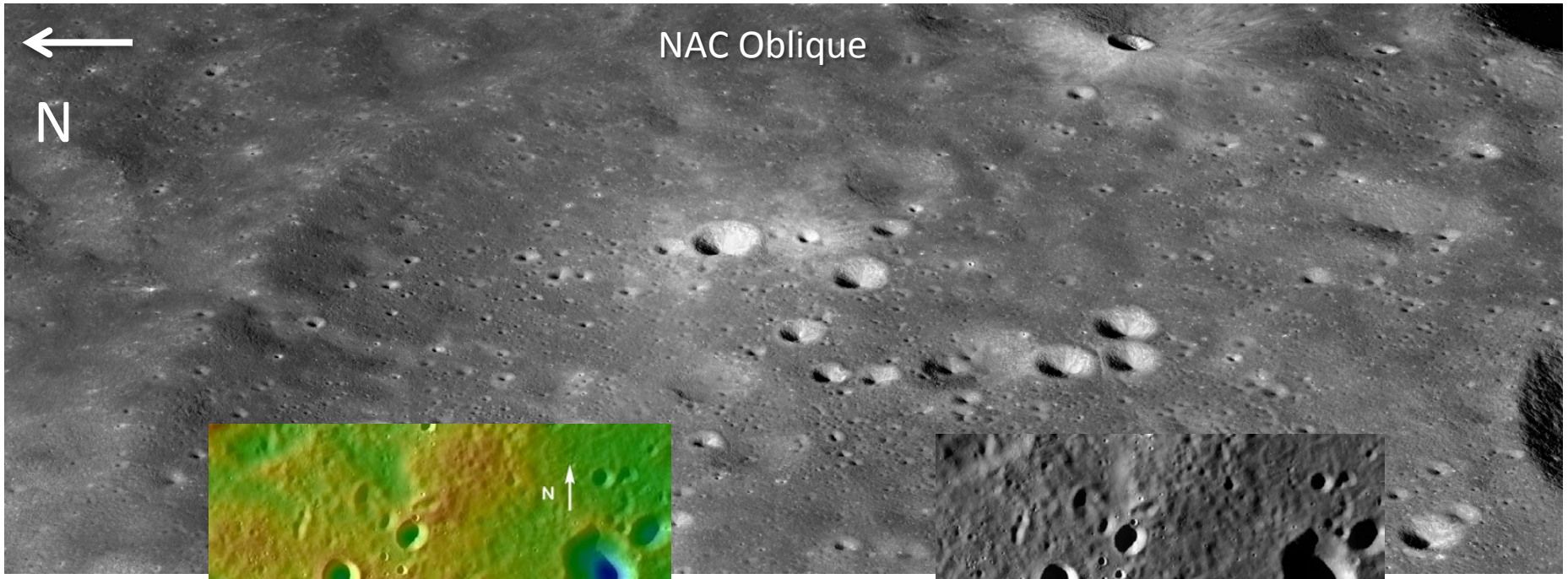
Backup

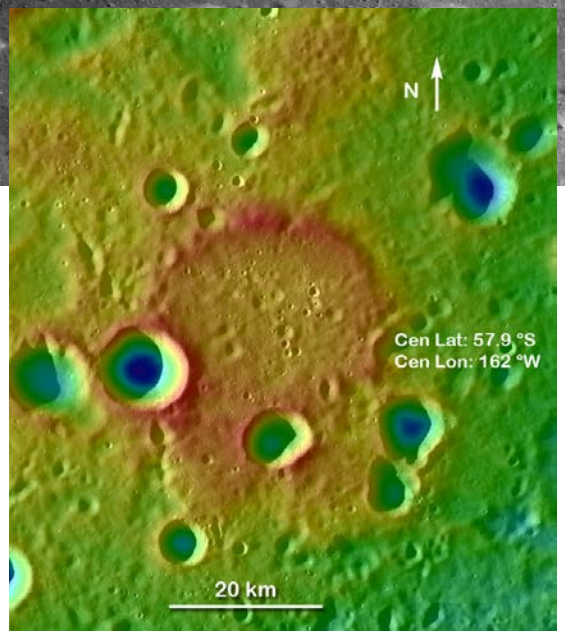




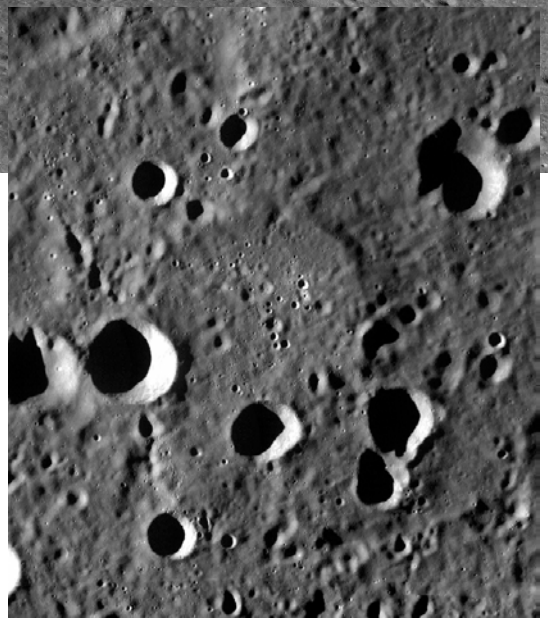
Near the Center of the Basin…







"Mafic Mound"



See recent paper by Moriarty and Pieters, *GRL* 42