

**Addressing key lunar  
science questions through  
state-of-the-art orbital  
investigations**

**LEAG CLOC-SAT\*,**

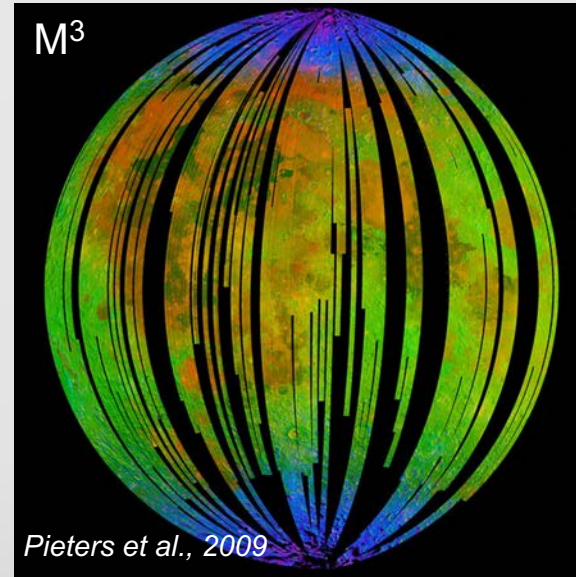
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# Outline

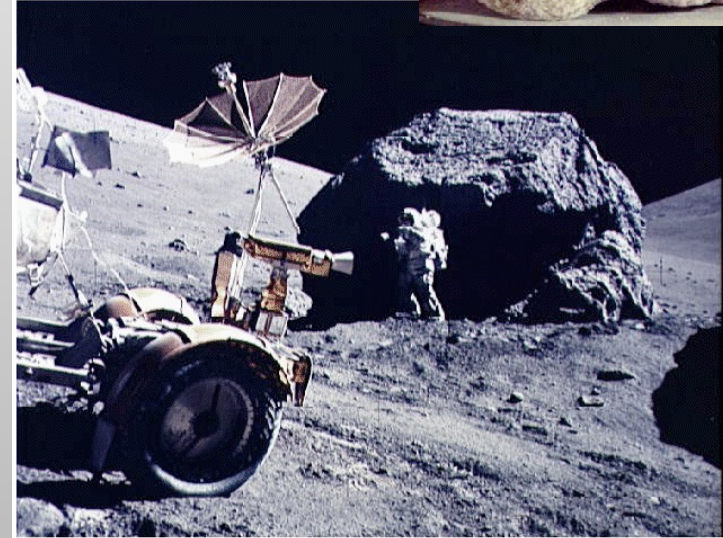
- Do we need more orbital data?
- Integration of orbital data with surface exploration (robotic & human) and sample return
- Compelling science questions for remote sensing
  - Some key references
  - Fundamental questions
- (New) New Views of the Moon



60025: anorthosite [NASA/photo S72-42187]



AS17-146-22294



# Do we need more orbital data?

- New Missions



Experiment Name
KPLO Gamma Ray Spectrometer (KGRS)
KPLO Magnetometer (KMAG)
Lunar Terrain Imager (LUTI)
ShadowCam
Wide-Angle Polarimetric Camera (PolCam)

Yes, or these missions would not be flying!

Key questions relating to water on the Moon!



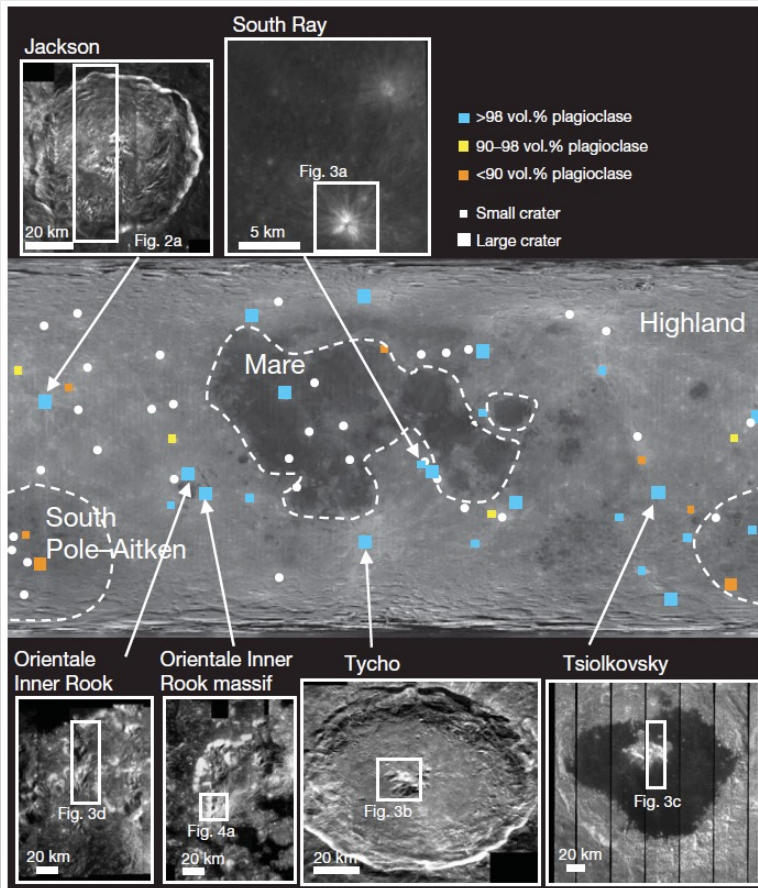
Credit: Lockheed Martin Space for Lunar Trailblazer

Advanced infrared sensors in orbit for spatial and temporal characterization of water and cold traps.



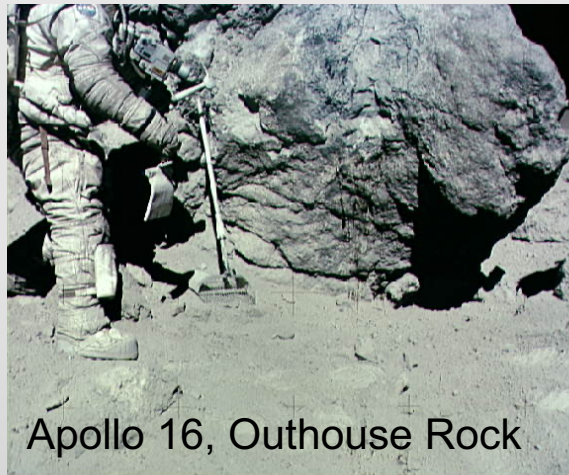
# Integration of orbital, surface, and sample data

## Remote Sensing

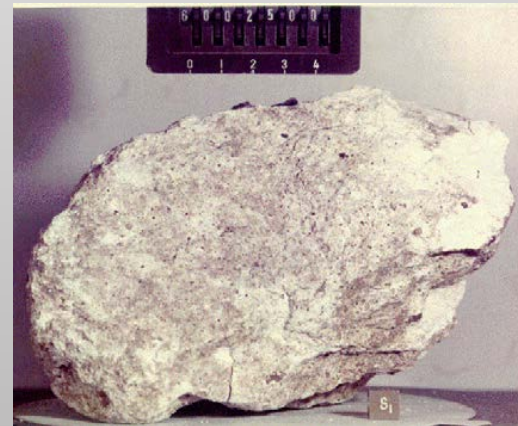


Ohtake et al., 2009, Nature

## Surface Investigations

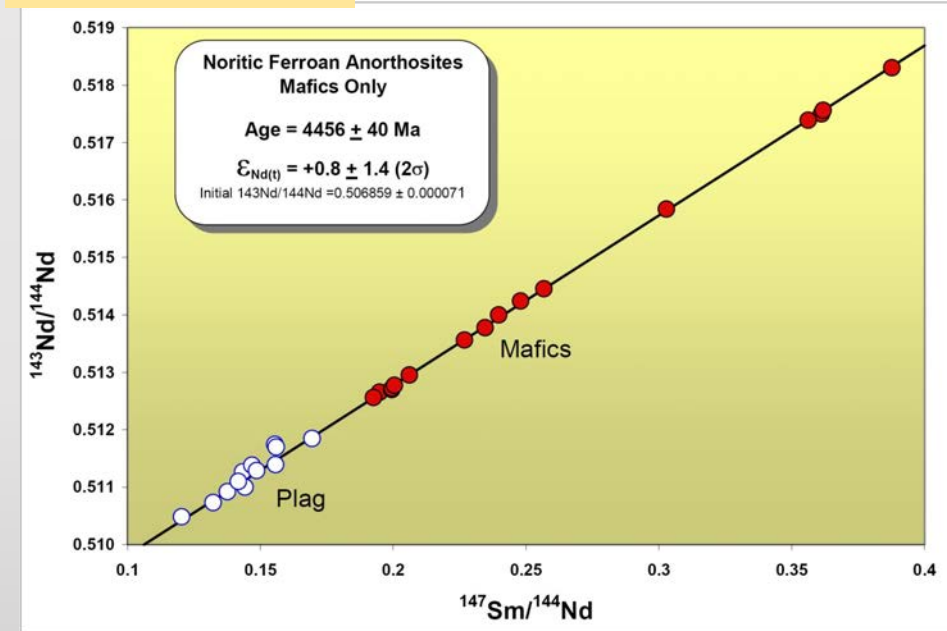


Apollo 16, Outhouse Rock



60025:  
anorthosite  
[NASA/photo  
S72-42187]

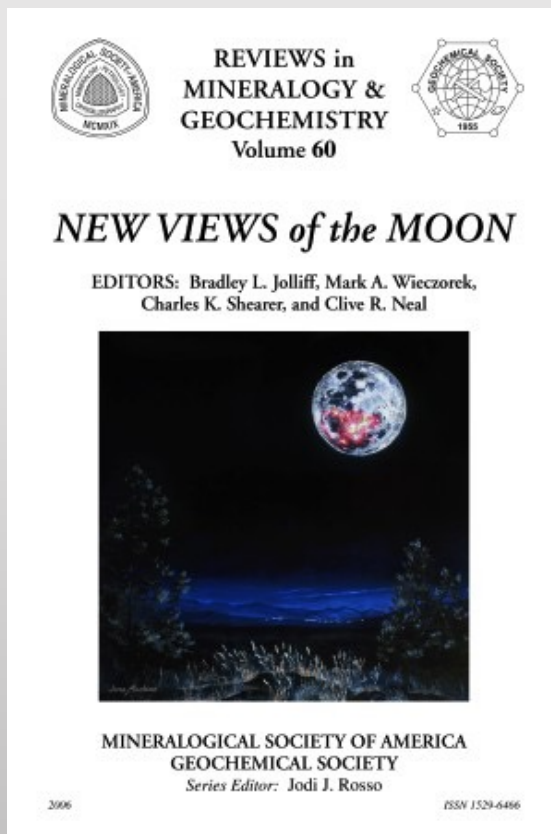
## Sample Data



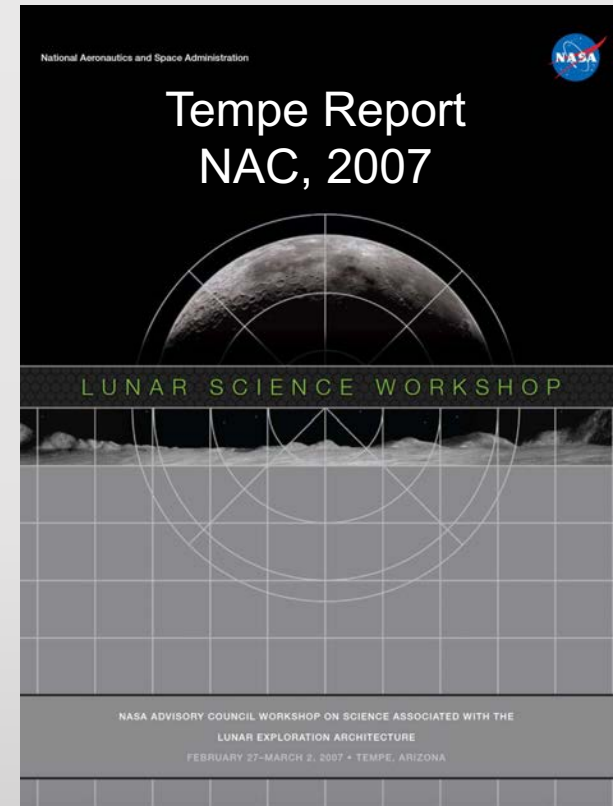
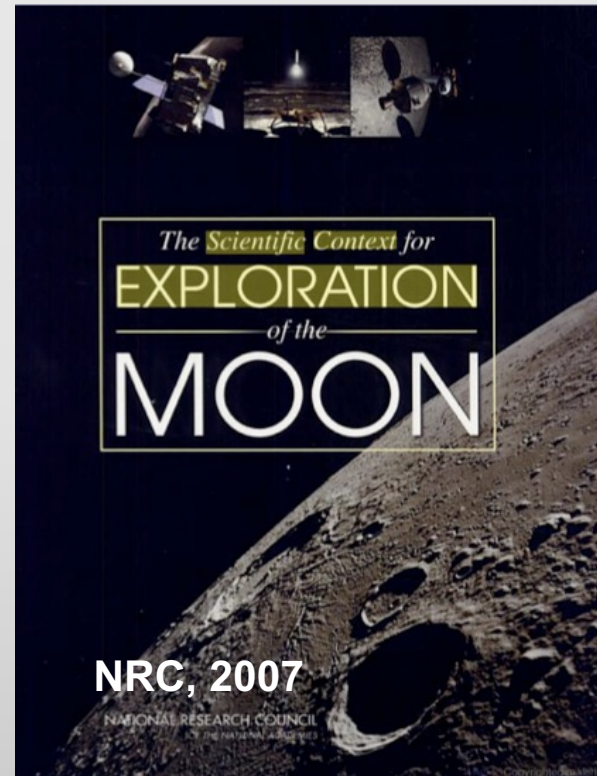
Cosmochemistry illustrated: based on Norman et al., 2003, Meteorit. Planet. Sci. 38, 645-661

- Distribution of anorthosite
- Characterization of anorthositic rocks
- Chronology of anorthositic crust

# References for scientific questions (a few of many)



NVM, 2006



**New Views of the Moon II  
(forthcoming)**

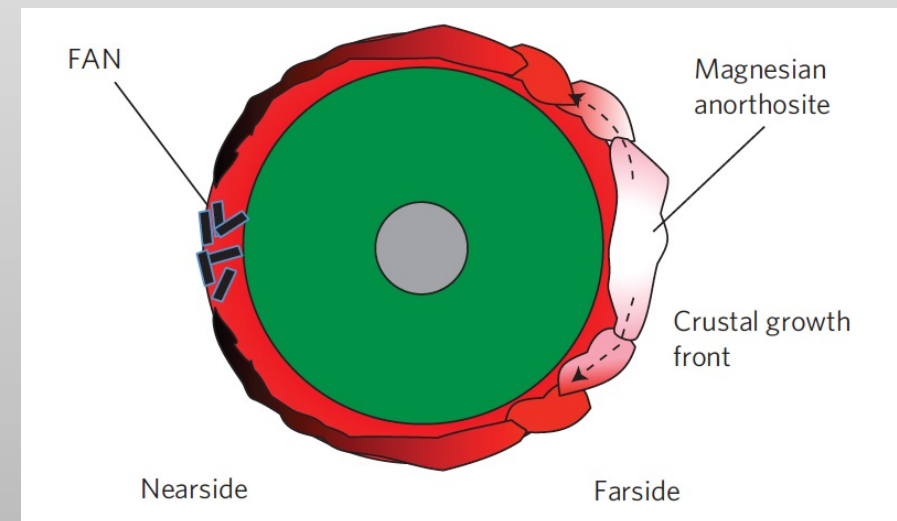
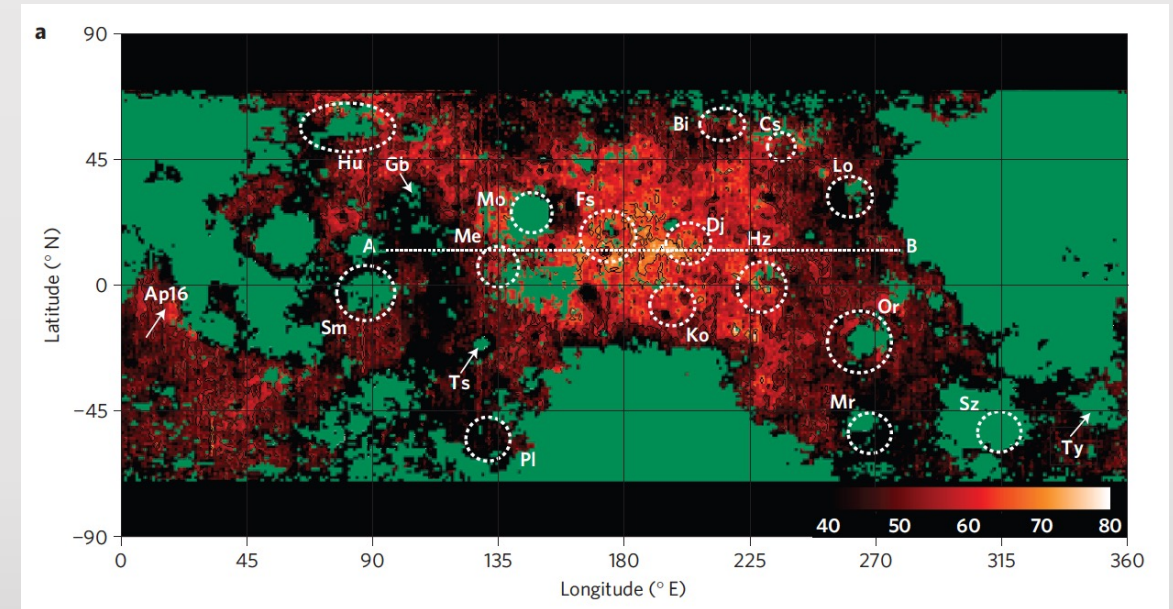
# Fundamental Questions

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- Origin and makeup of the lunar crust
  - Rock type diversity
  - Magma Ocean
- Formation and Evolution of the lunar interior
  - Cooling history
  - Volcanism
  - Tectonics
- Impact history of the Moon
  - Cataclysm at 3.9-4.0 Ga or not?
- Origin and history of Moon's magnetic field
- Characteristics of Moon's endogenous volatiles
  - Implications for giant impact origin
- Characteristics of Moon's exogenous volatiles
  - Solar wind implantation
  - Wet asteroids, comets
- Origin and characteristics of polar volatile deposits

# What is the composition of the farside anorthositic highlands crust?

- FAN? MAN? PAN?
- How representative is the Apollo 16 anorthositic highlands site?
- Are the farside highlands made of magnesian anorthosite?
- How representative are the lunar feldspathic meteorites?
- What are the implications for the extraction of the feldspathic crust from the lunar magma ocean?



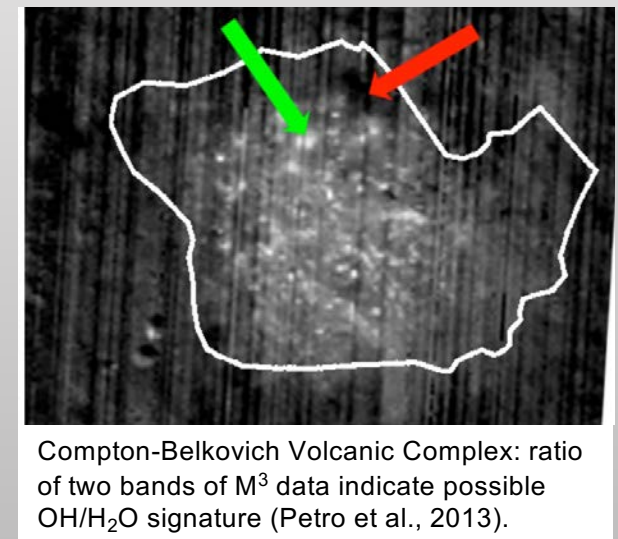
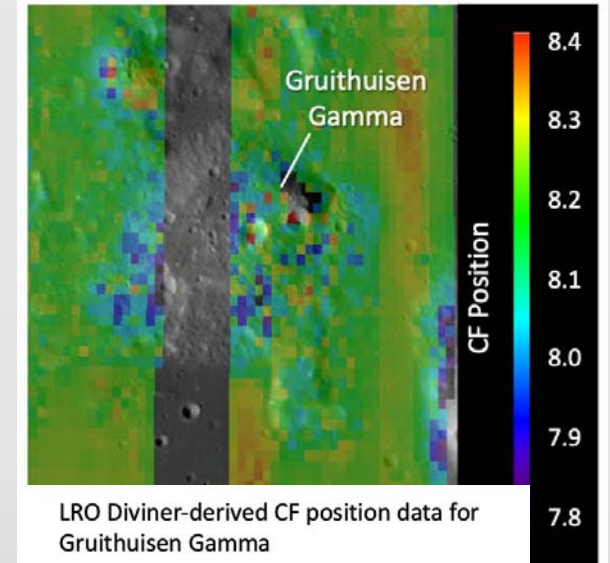
Ohtake et al.,  
*Nat. Geosci.*,  
2020





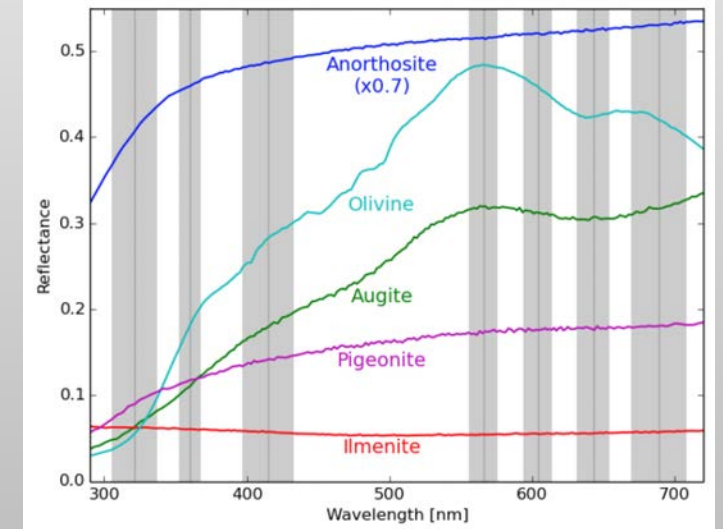
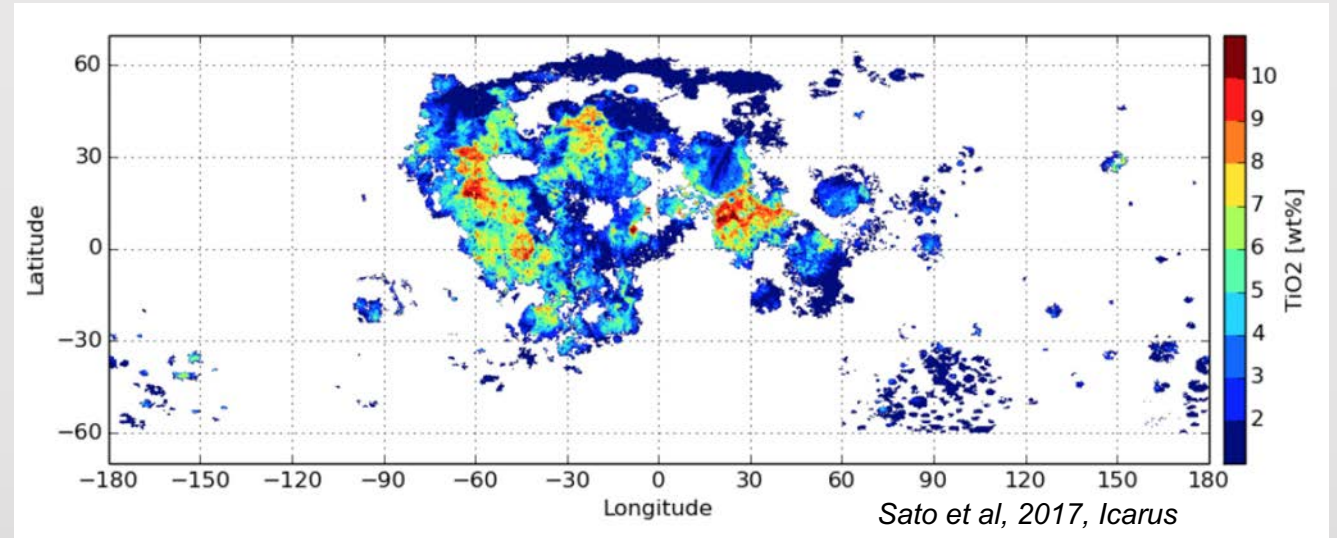
# What is the composition and origin of silicic volcanic (and intrusive?) rocks on the Moon?

- Are the Gruithuisen domes, Mairan domes, etc. rhyolitic? Or intermediate in composition?
- How did they form? If by basaltic underplating, what rock types were melted?
- What was the role (if any) of water?
- Did the Compton-Belkovich volcanic complex form in part by silicic pyroclastics? What volatiles were involved?
- What is the relationship (if any) between lunar silicic rocks and urKREEP?



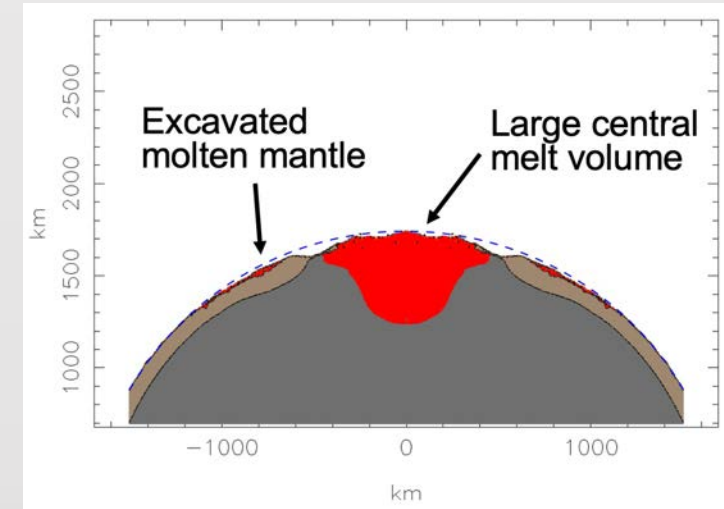
# What is the extent of compositional, geographic, and temporal variation of lunar basalts?

- Oldest basalts
  - How old?
  - Where are they?
  - What is their composition?
- Youngest basalts
  - How young?
  - What is their composition?
  - How did basaltic volcanism persist?
- What do the basalts reveal about their mantle sources and internal evolution of the Moon?
- What is the origin of the nearside-farside dichotomy?

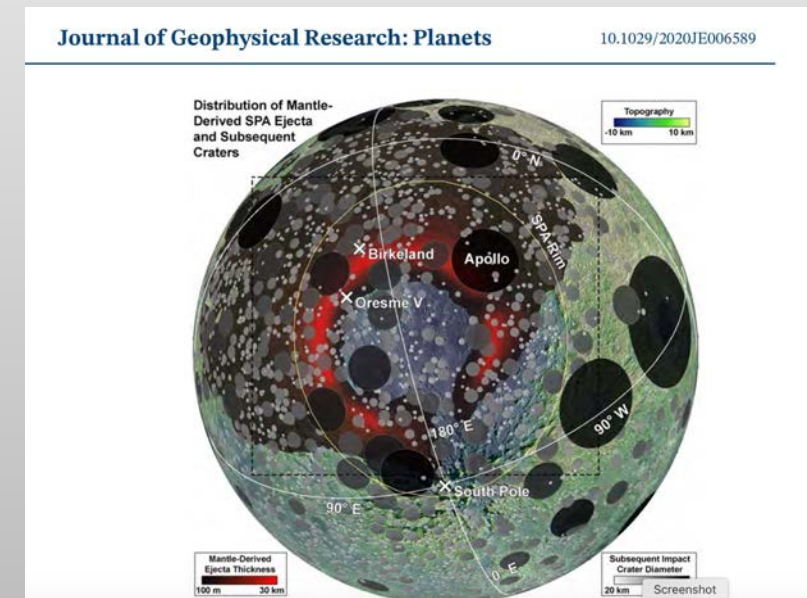


# South Pole-Aitken Basin

- How old is SPA and does it constrain the cataclysm?
- What is the composition and diversity of materials excavated by the basin?
- Are excavated materials from the lower crust or upper mantle, or both?
- What are the characteristics of the SPA impact-melt sea and is that material exposed today?



*From Melosh & Collins*



*Moriarty et al., 2021*



# Concluding Thoughts

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- Orbital data needs:
  - High resolution chemical composition (major, minor, trace elements, volatiles; XRS, GRS, NS)
  - High resolution mineralogy (NIR-MIR hyperspectral)
  - Global magnetic field
- Orbital data - not a precursor to surface exploration or sample return.. But is best done in concert with them.
- New findings in one arena lead to new questions in the others.