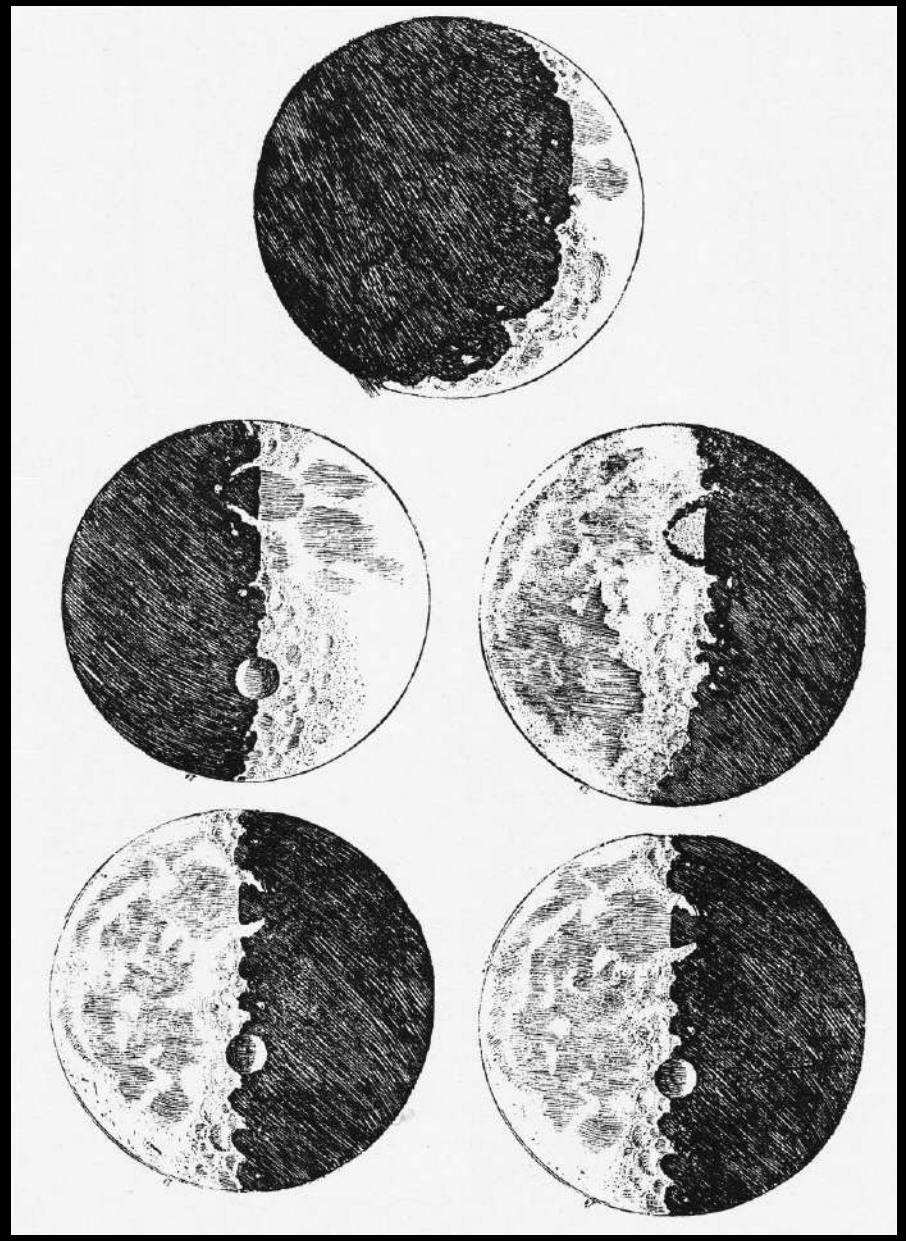
Moon Joy!

What We Learn When We Go To The Moon

Amanda Stadermann

Science on Tap / September 1, 2026

Earthrise, Apollo 8 astronaut William Anders



Galileo, 1610

Overview

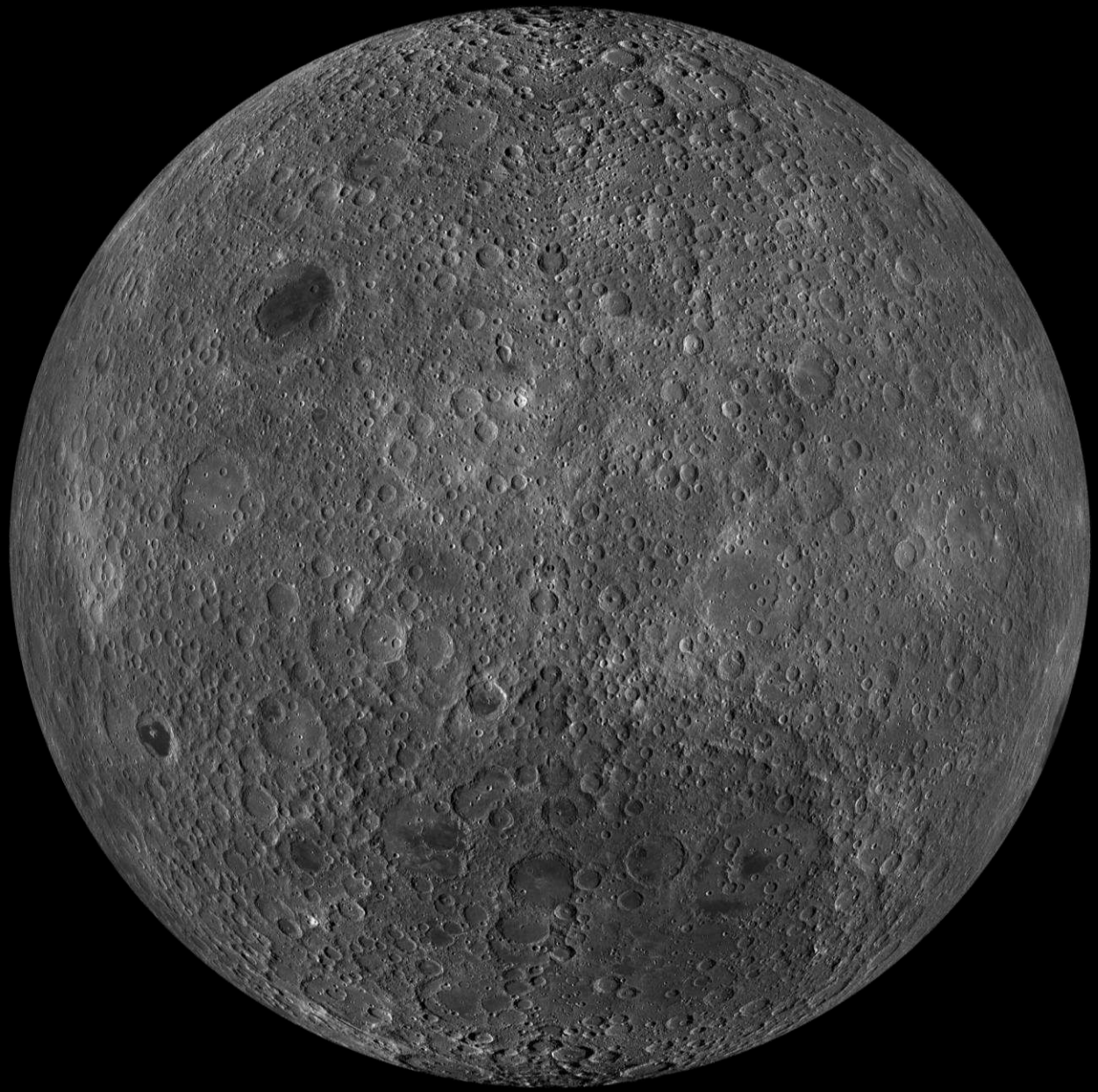
I. Brief history of lunar science and exploration

II. What we've learned **and are still learning** about the Moon

III. How past lessons are guiding future lunar missions

Lunar Nearside

Lunar Farside



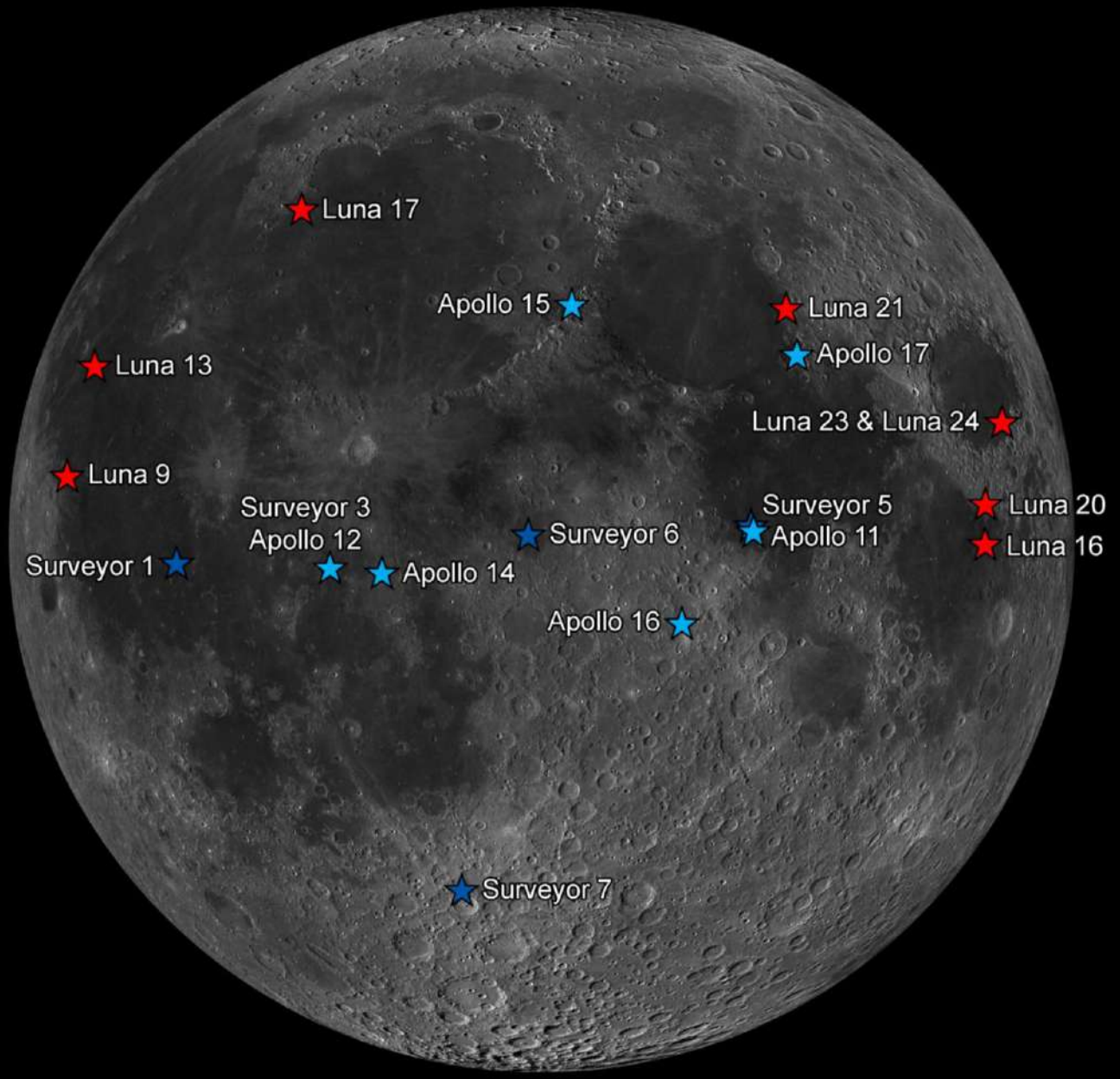
LROC QuickMap quickmap.lroc.im-ldi.com

Lunar Nearside

Pre-Space Race

- Are the craters volcanic or meteoritic?
  - Controversy also on Earth
- How did the Moon form?
  - Impact? Co-accretion? Capture? Rotational fission?
- The Moon is old
  - Records parts of Solar System history now largely lost on Earth

LROC QuickMap quickmap.lroc.im-ldi.com



Early Space Race Missions

- Flybys: Luna 3 (Oct 1959)
- Intentional hard landings: Luna 2 (Sept 1959), Ranger 7 (Jul 1964+)
- Orbiters: Luna 10+ (Mar 1966+), Lunar Orbiter 1+ (Aug 1966+)
- Luna 9 (Feb 1966) followed by Surveyor 1 (June 1966)

★ Luna (USSR)

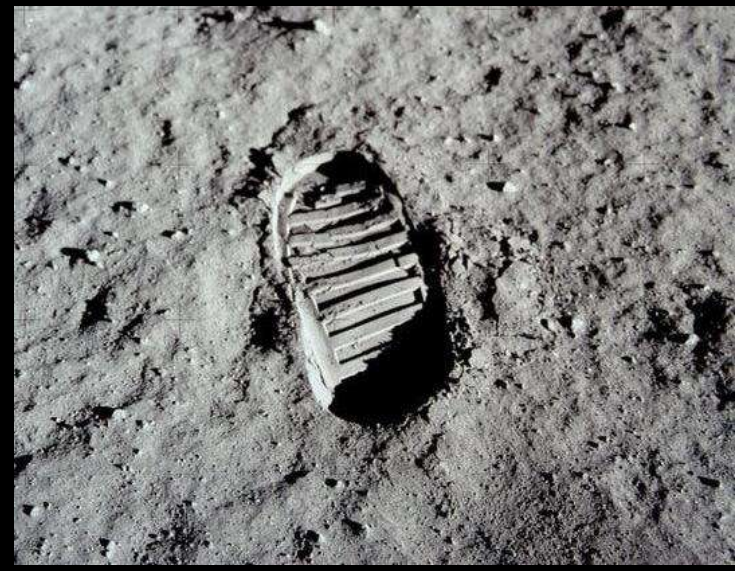
★ Surveyor (USA)

★ Apollo (USA)

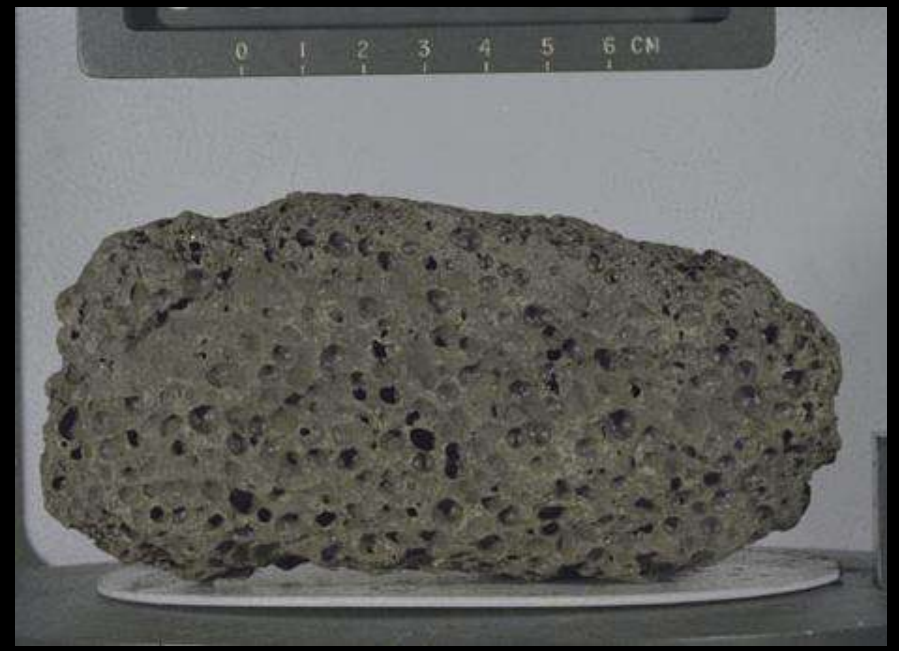
LROC QuickMap quickmap.lroc.im-ldi.com

Importance of People in Science

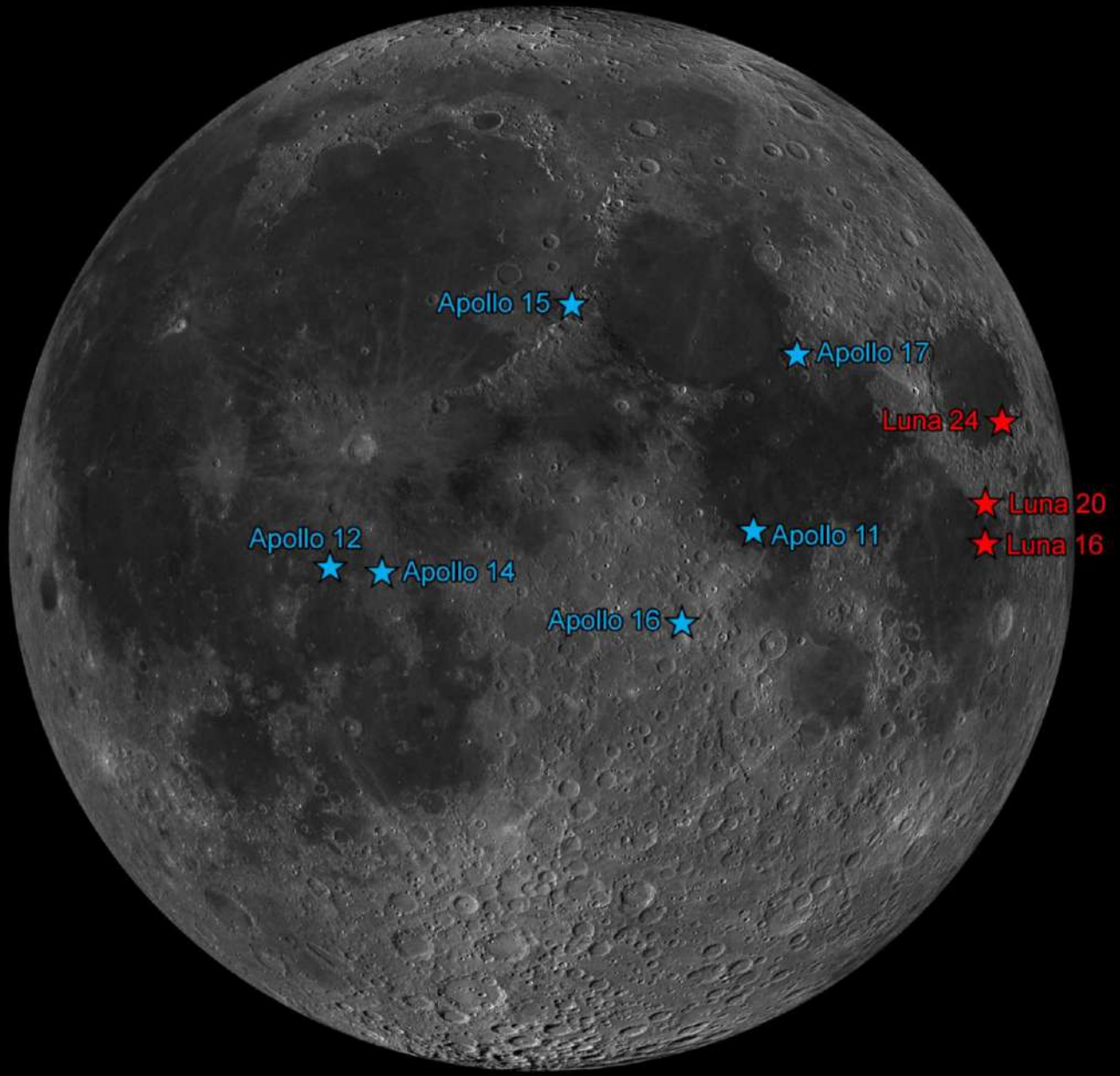
- **Field observations are key to understanding geology**
- Initial observations of lunar surface by Neil Armstrong before and after first step
  - Talked about how deep his boot print went into the ground
- Apollo 15 astronaut David Scott pretended to have an issue with the seatbelt to pick up 15016



Armstrong's Bootprint



15016 "Seatbelt Rock"

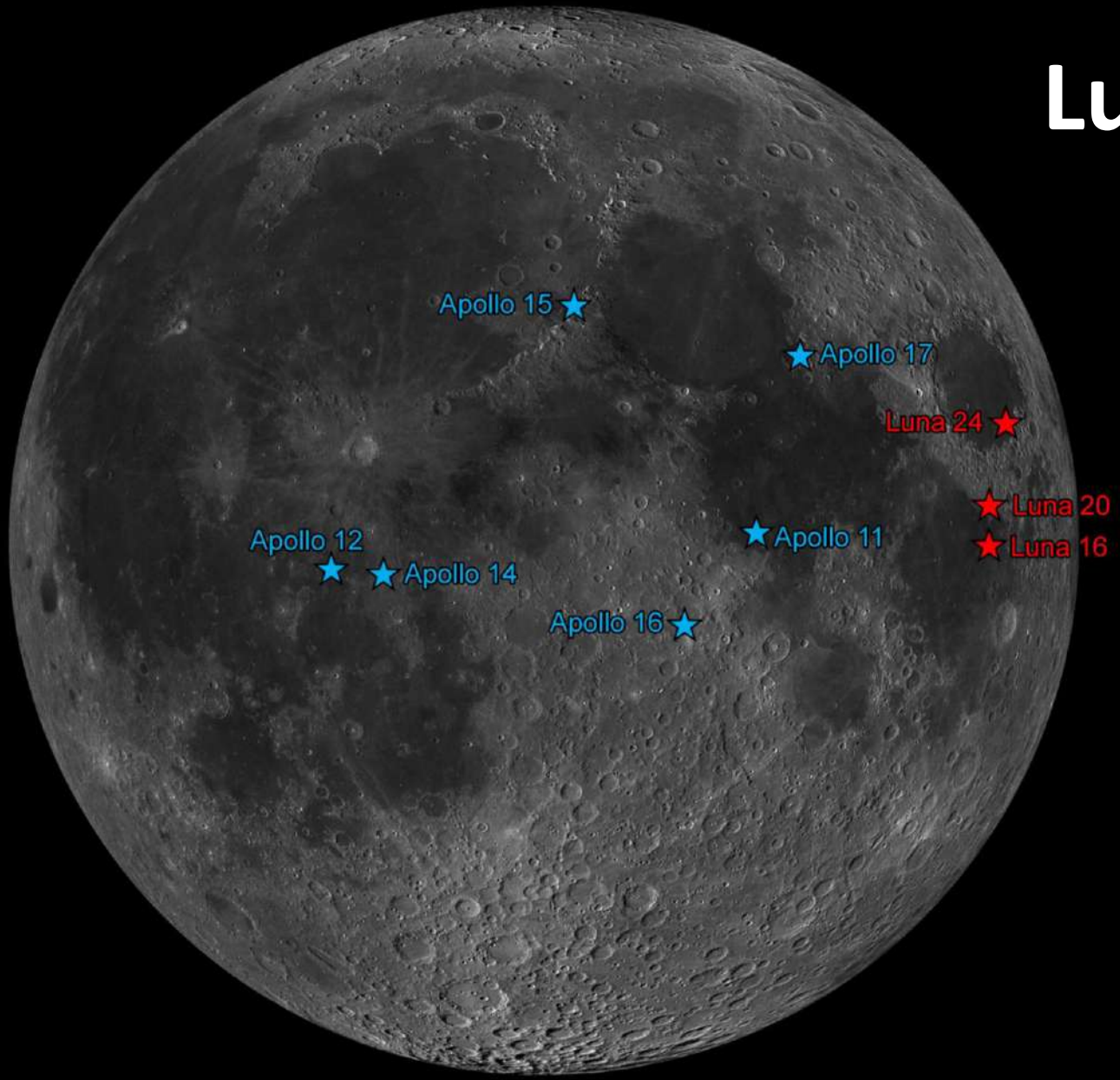


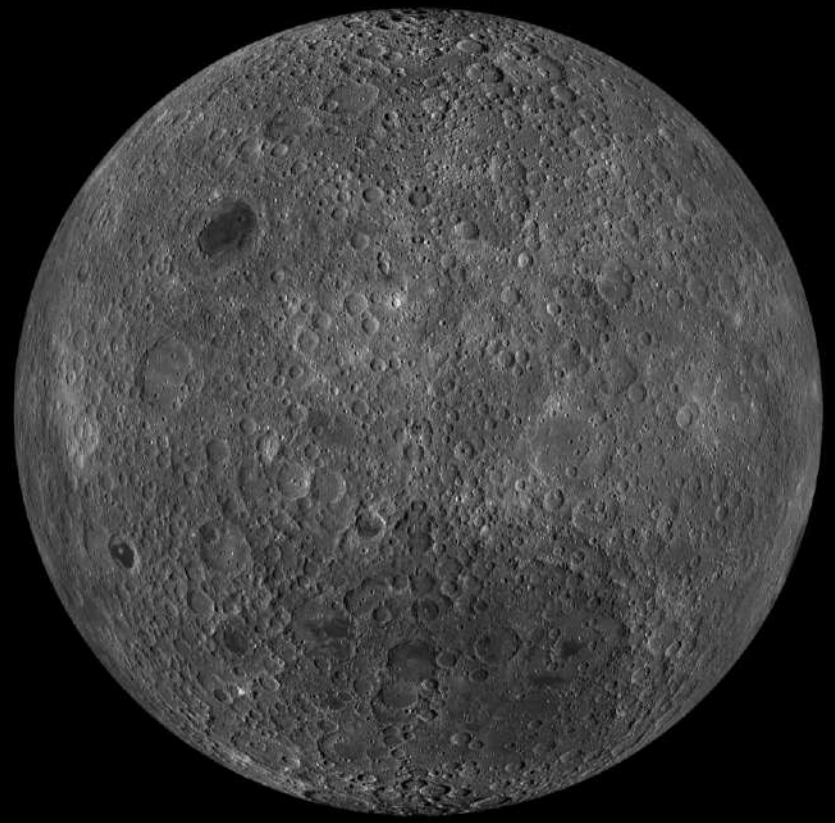
Moon Rocks in 20th Century

Apollo 11	21.55 kg
Apollo 12	34.30 kg
Luna 16	0.10 kg
Apollo 14	42.80 kg
Apollo 15	76.70 kg
Luna 20	0.05 kg
Apollo 16	95.20 kg
Apollo 17	110.40 kg
Luna 24	0.17 kg

Lunar Meteorites

- Apollo & Luna samples: 843 lbs
- Lunar meteorites: 4400+ lbs



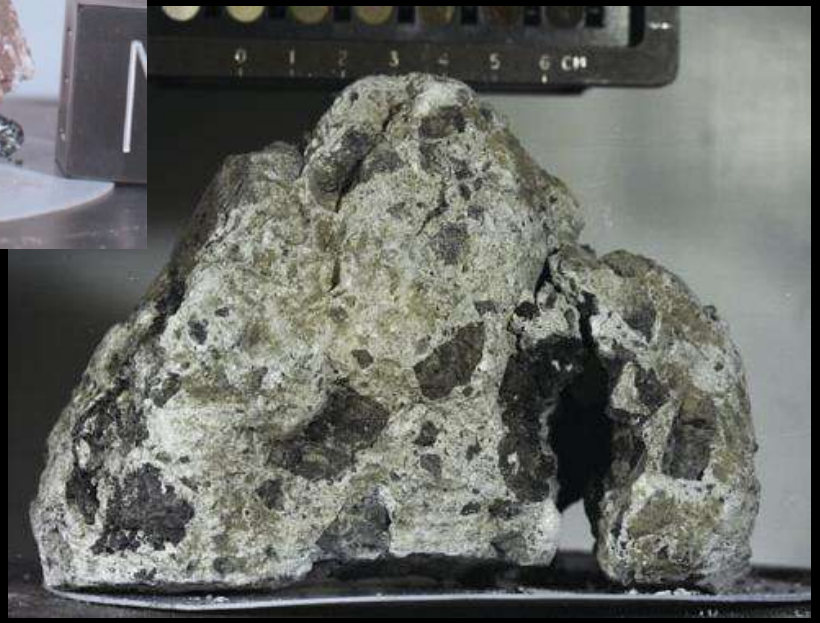


Types of Lunar Rocks

- Highlands rocks (ferroan anorthosites, Mg-suite)
- Volcanic rocks (mare basalts and glasses)
- Impactites (breccias, contai clasts of above)
- Regolith (soil)

15556: mare basalt

15415: ferroan anorthosite



67015: fragmental breccia

Apollo Photo Database

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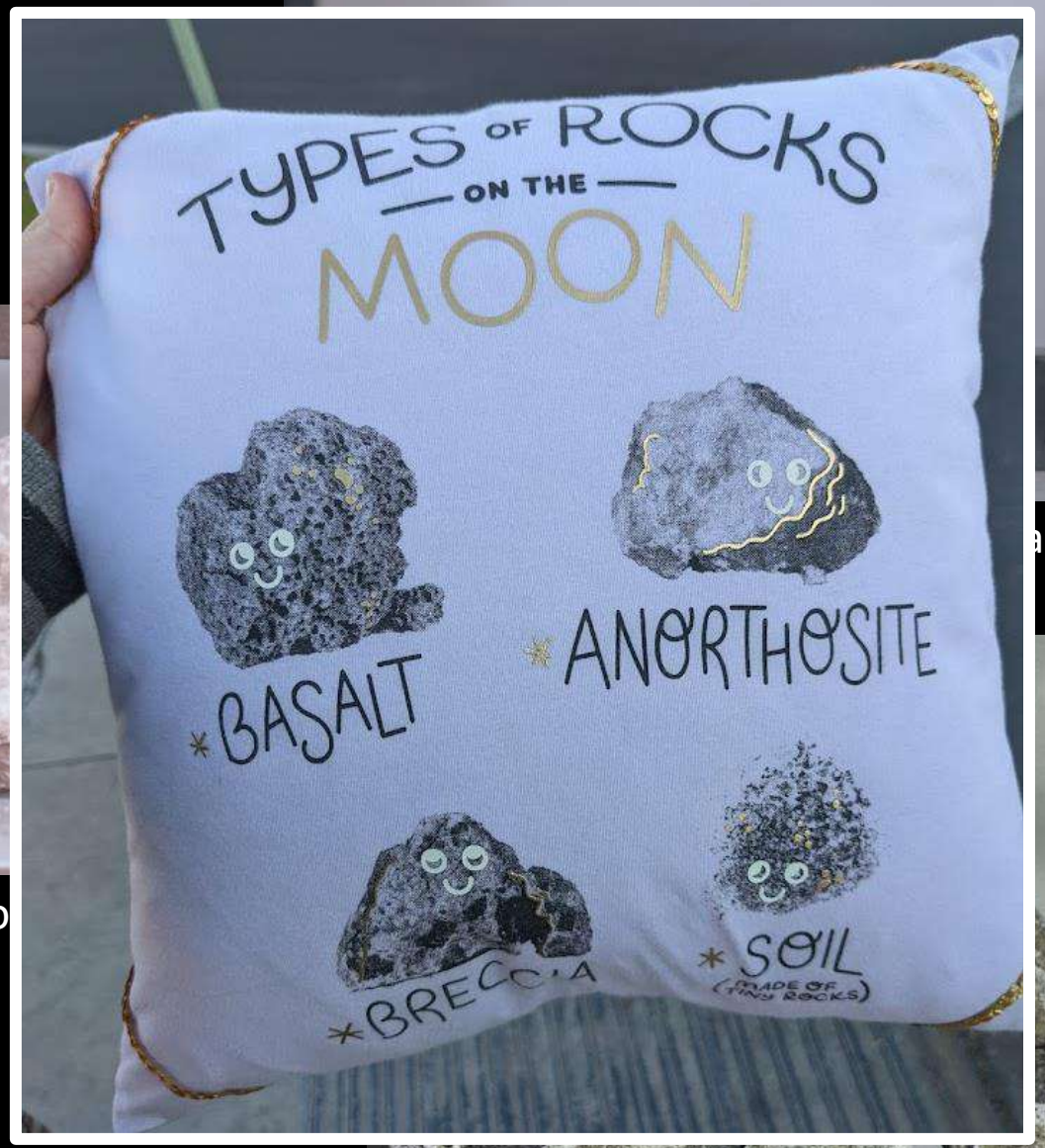
15415: ferro



asalt

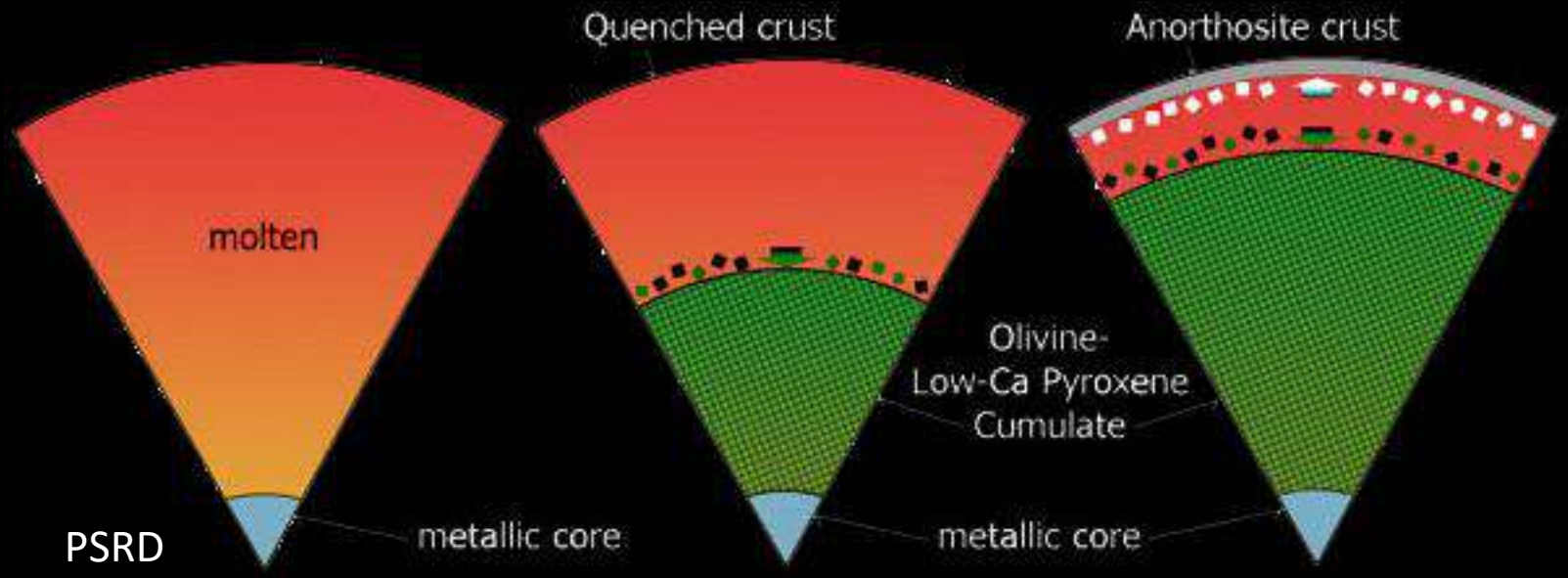
67015: fragmental breccia

Apollo Photo Database

We Learned: the Moon formed in a Giant Impact with Earth

The Moon is **very dry** – all the volatiles (like water) left early

Had to be mostly or entirely molten when it formed



PSRD

“Magma Ocean”

15415: ferroan anorthosite

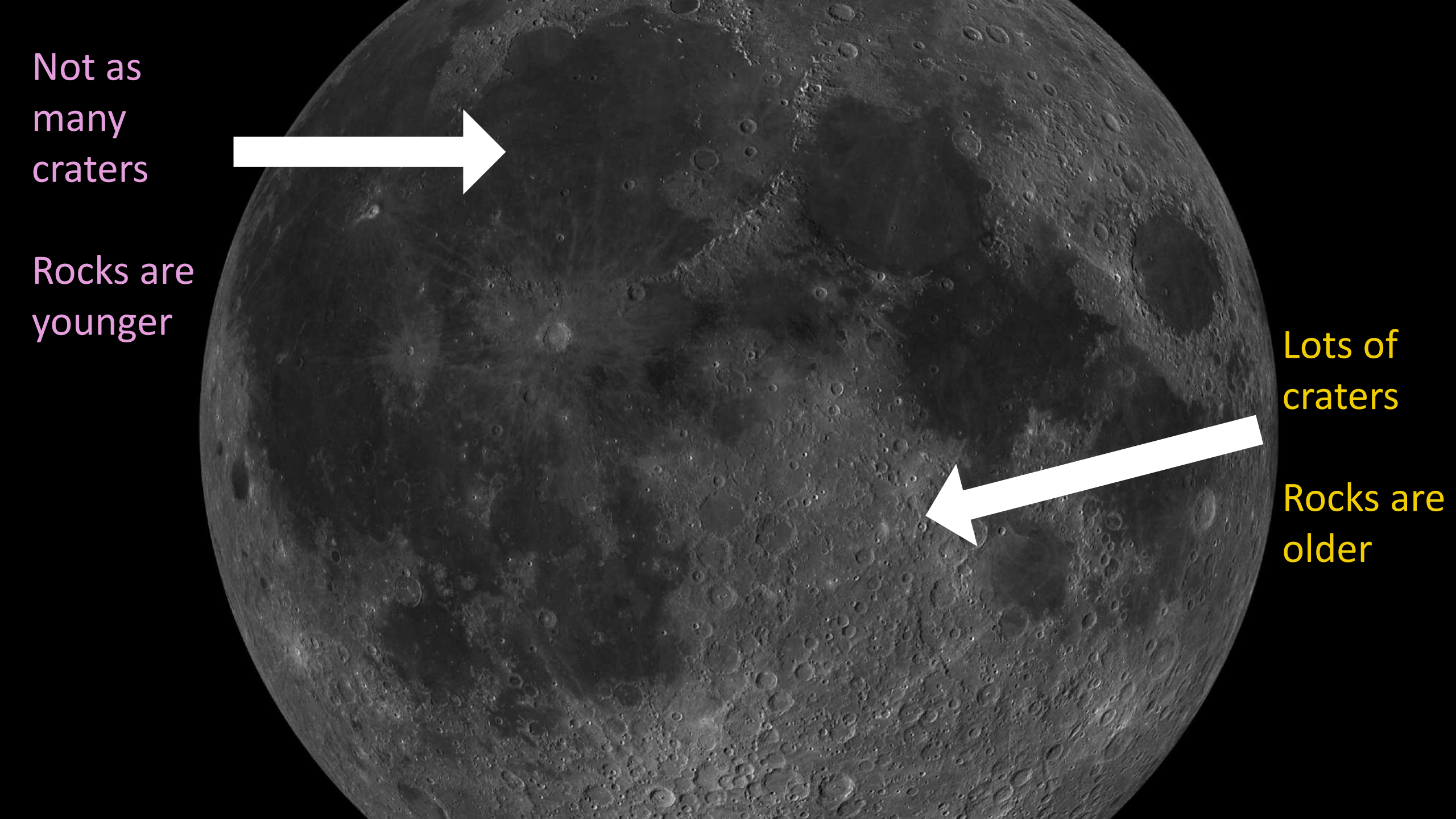
We Learned: Impact Craters are Real and Happen Regularly

Impact cratering is when something in space collides with a planetary body, usually at many miles per second

Impacts modify the surfaces of planetary bodies

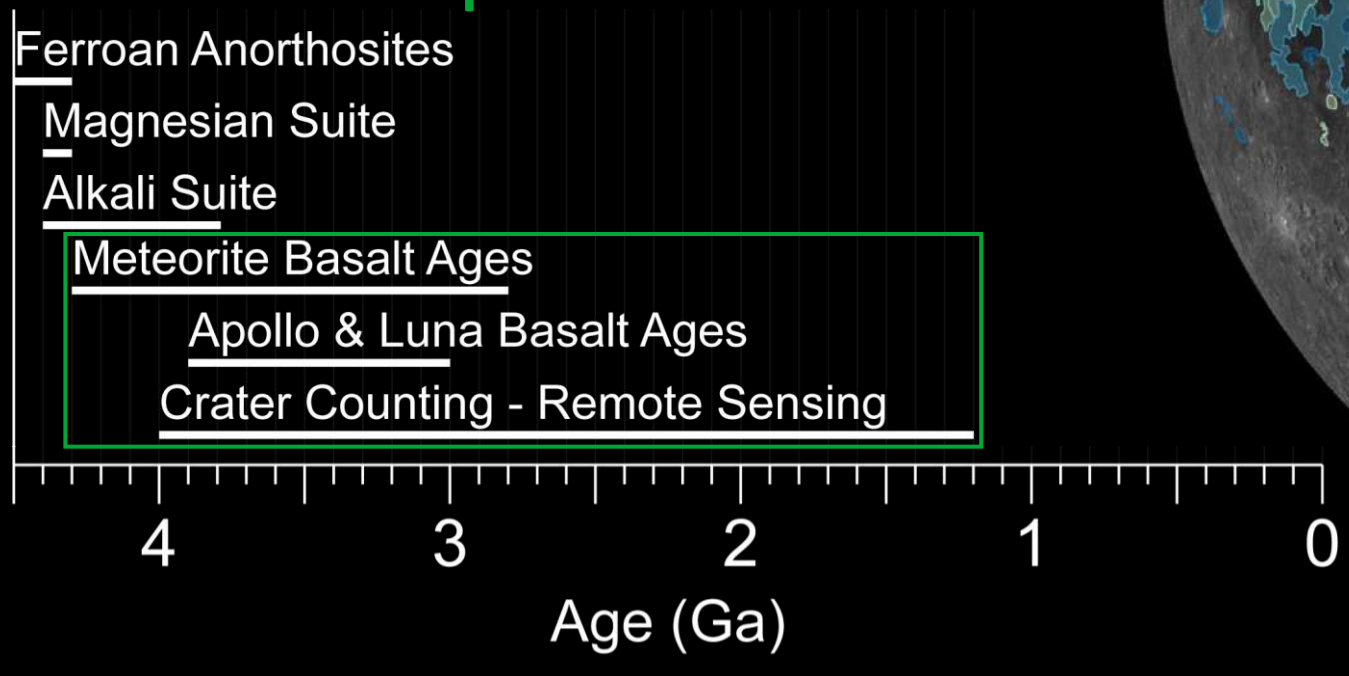
Impacts change the rocks they are striking

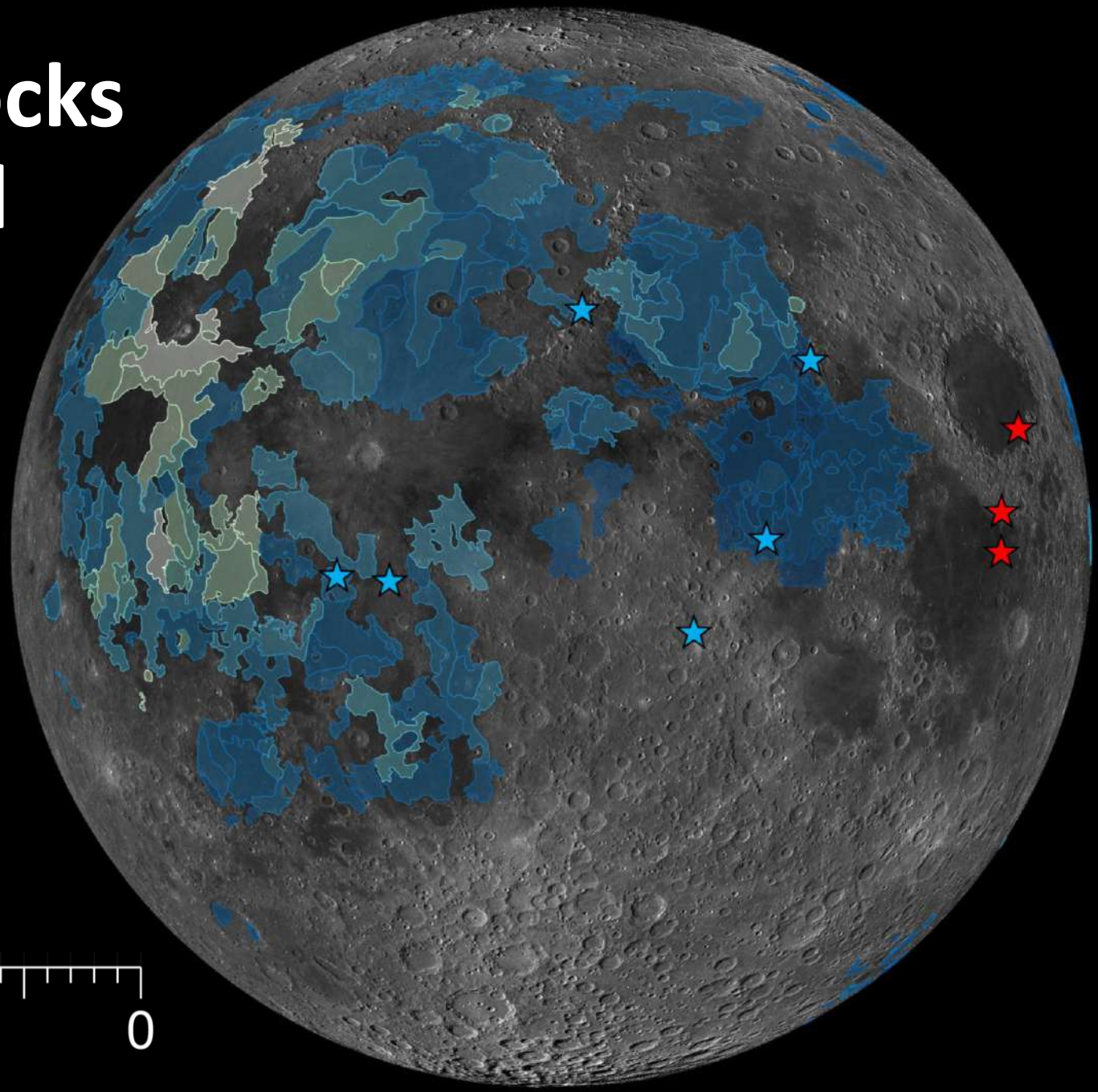
Apollo 16 astronaut Charles M. Duke Jr. near Plum crater


Not as many craters
Rocks are younger
Lots of craters
Rocks are older

We Learned: the Rocks We Have are Biased

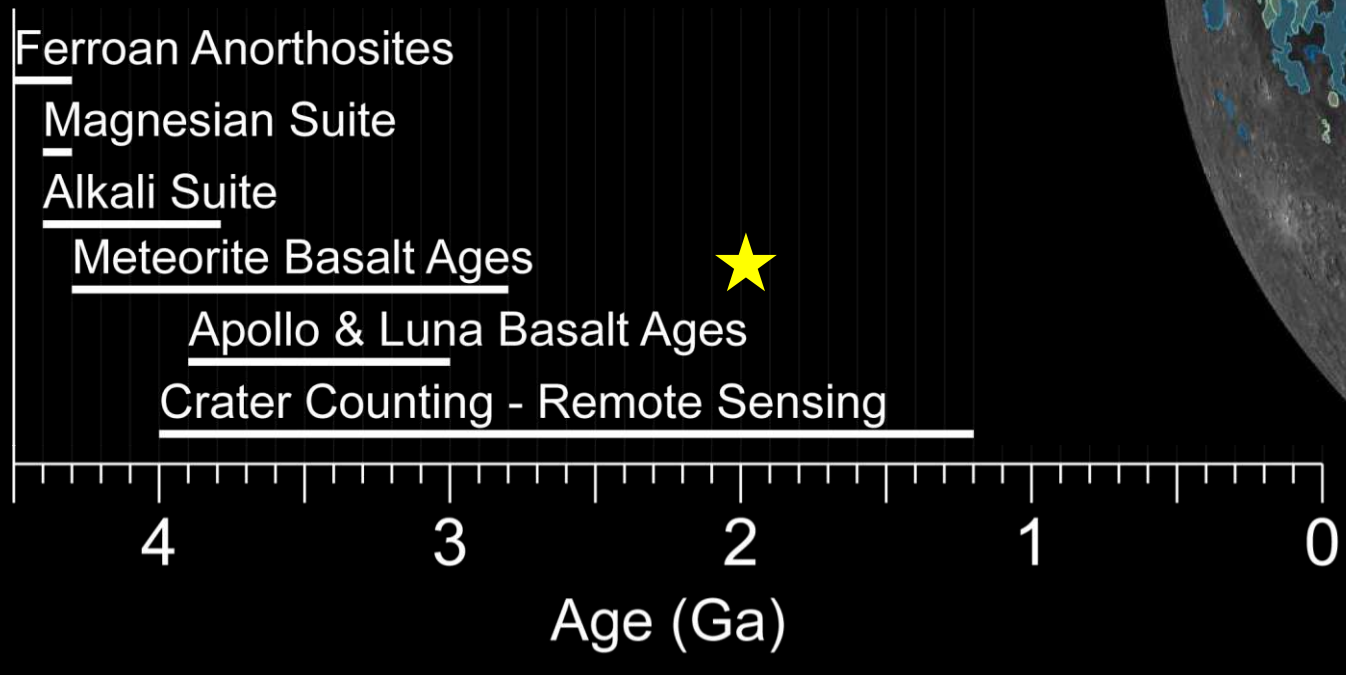
- All the Moon rocks we had on Earth didn't match up with the range of Moon rocks we see on the Moon
- **Next time we go to the Moon, can we pick better locations?**

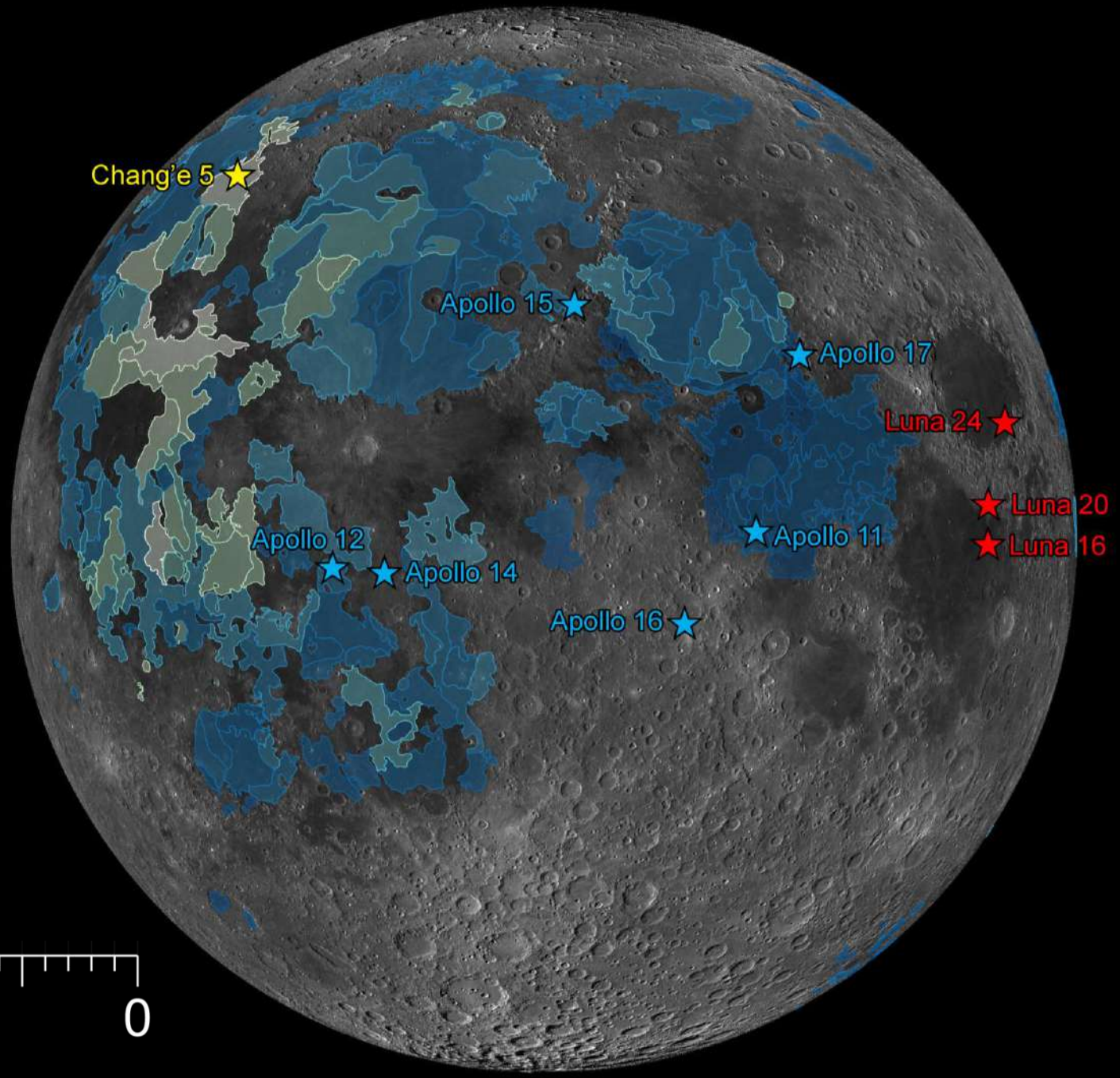




Chang’e 5 mission

- Returned first lunar samples since USSR’s Luna 24 mission (1976)
  - 3.8 lbs returned

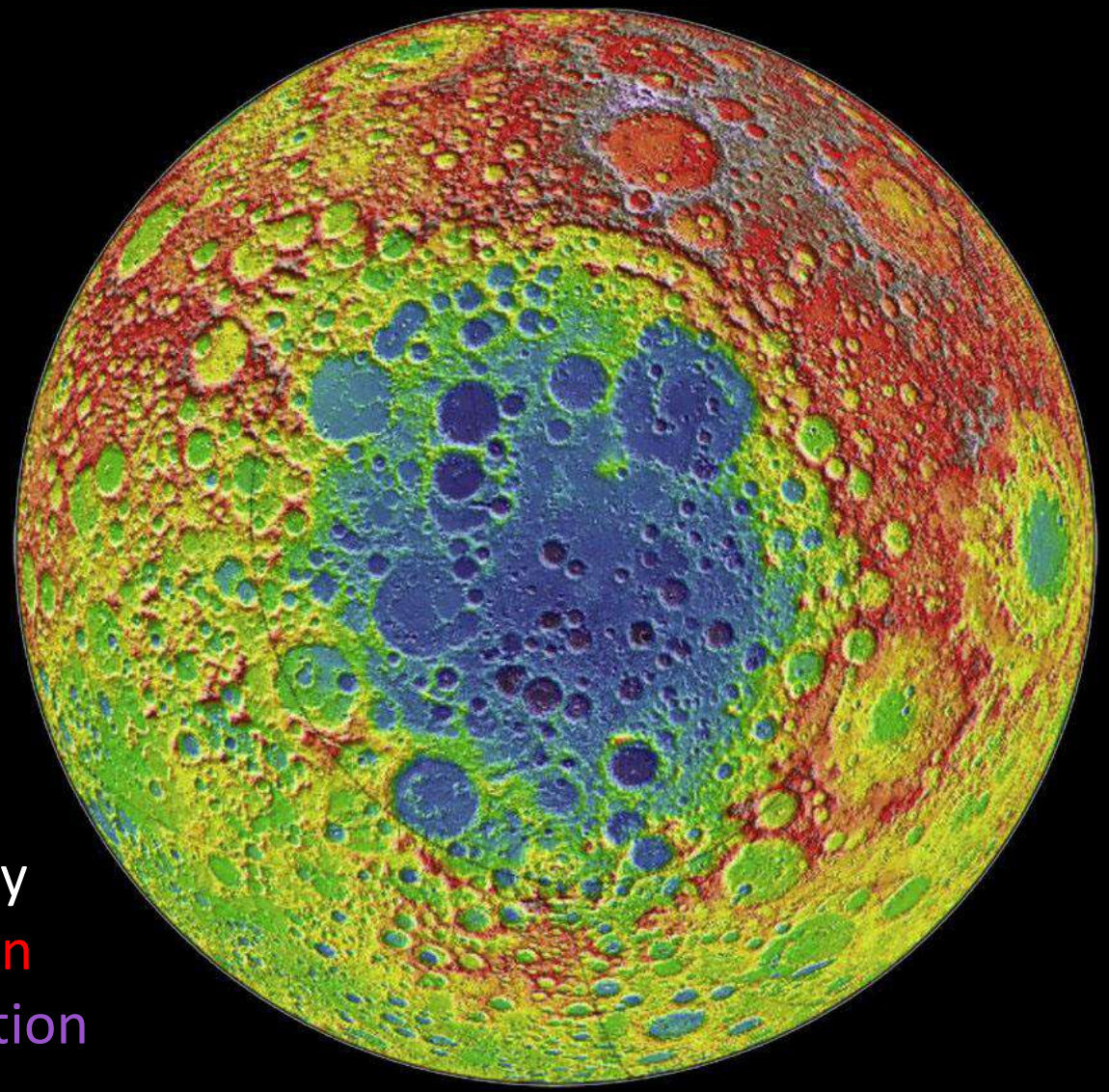




We Discovered: the Moon's biggest crater

South Pole-Aitken Basin (SPA)

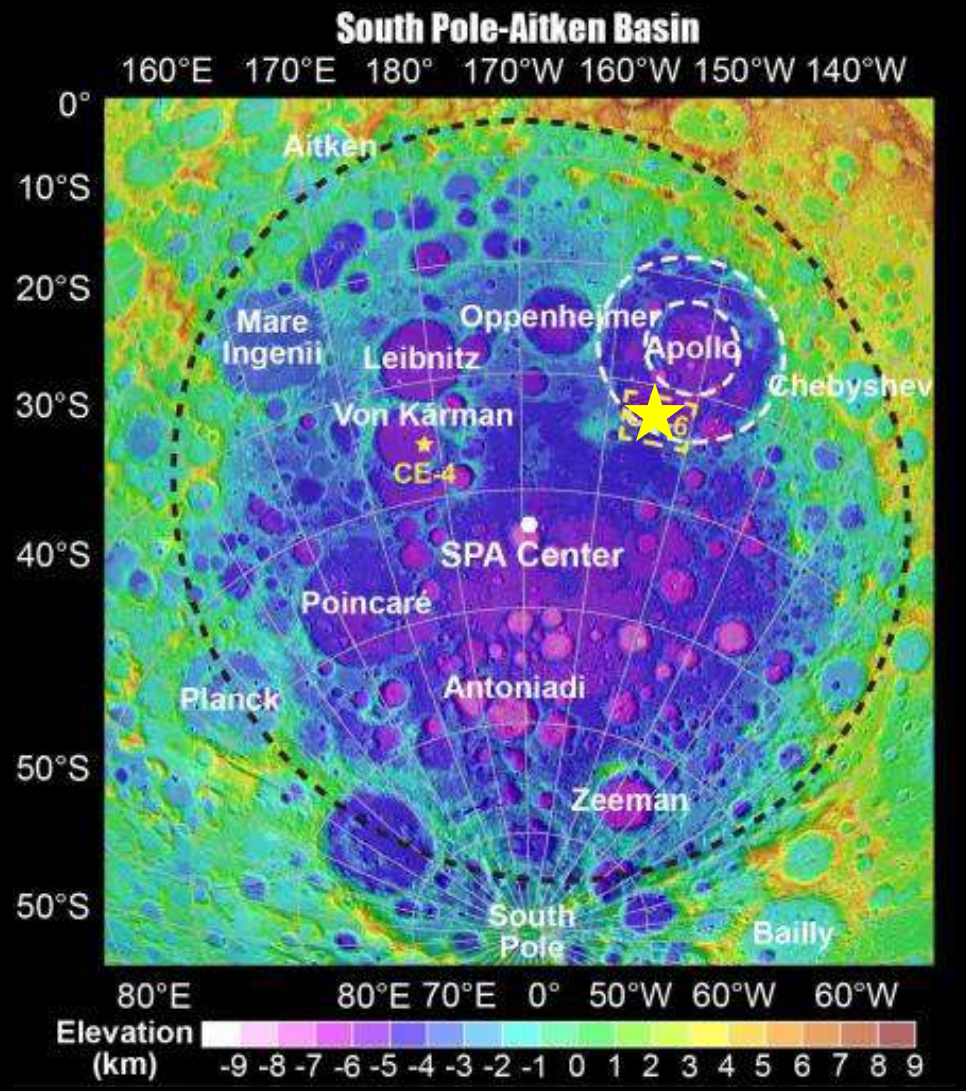
- Largest impact basin on the Moon; more than 1200 miles long
- Oldest preserved impact basin
- Complex geology
- On Moon's farside – hard to send astronauts to



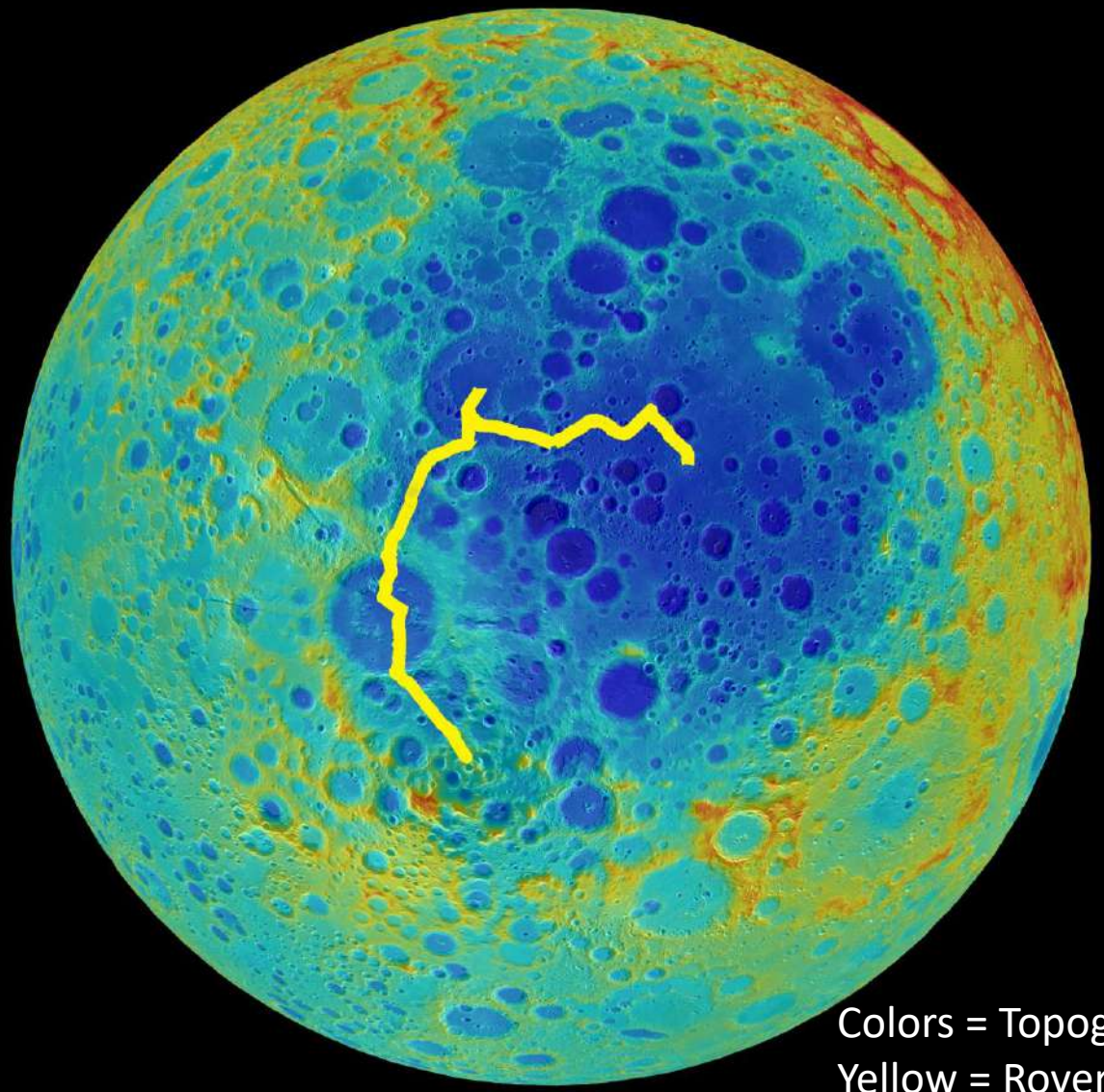
Colors = Topography
Red = High Elevation
Purple = Low Elevation

Chang’e 6: sample return from SPA

- Landed on farside of Moon June 2024
- Returned 4.3 lbs of samples – first from farside!
- **Result: biggest crater on the Moon formed 4.25 billion years ago**



NASA Rover to Traverse across the Crater

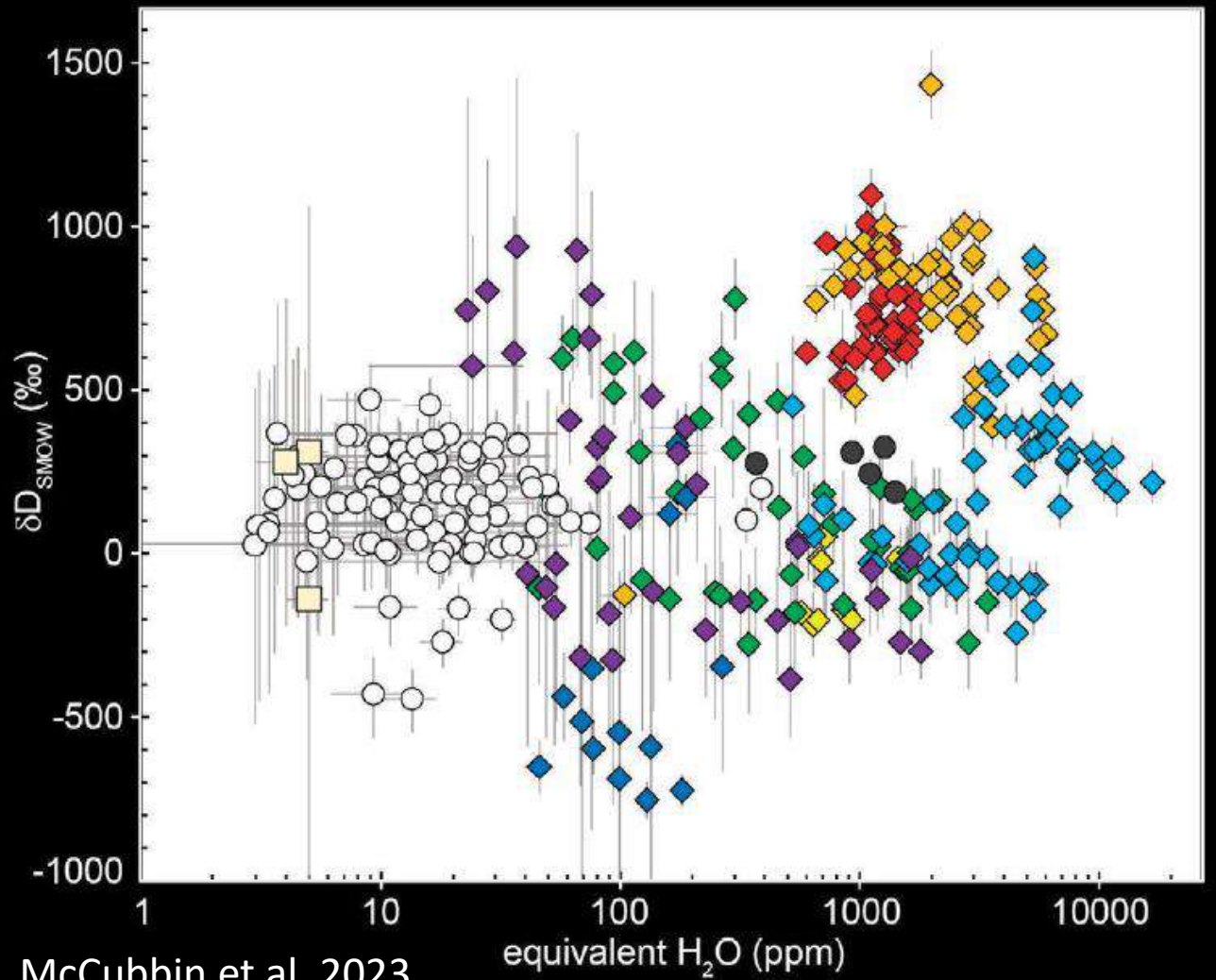


Colors = Topography
Yellow = Rover Path

- Rover will travel 1250 miles across the Moon
  - Clarksville to Denver
- Collect samples and data along the way
- Rendezvous with Artemis astronauts who will bring samples back to Earth

We Learned: the Moon isn't Completely Dry

- 2006: Moon is "bone dry"
  - < 1 ppb water in interior
- 2008: Volcanic glass beads have water
  - ≥260 ppm water
- 2010: Mineral apatite has water in its structure
  - 64 ppb to 5 ppm water
- 2011: Trapped glass in minerals have some water
  - 615 to 1410 ppm water

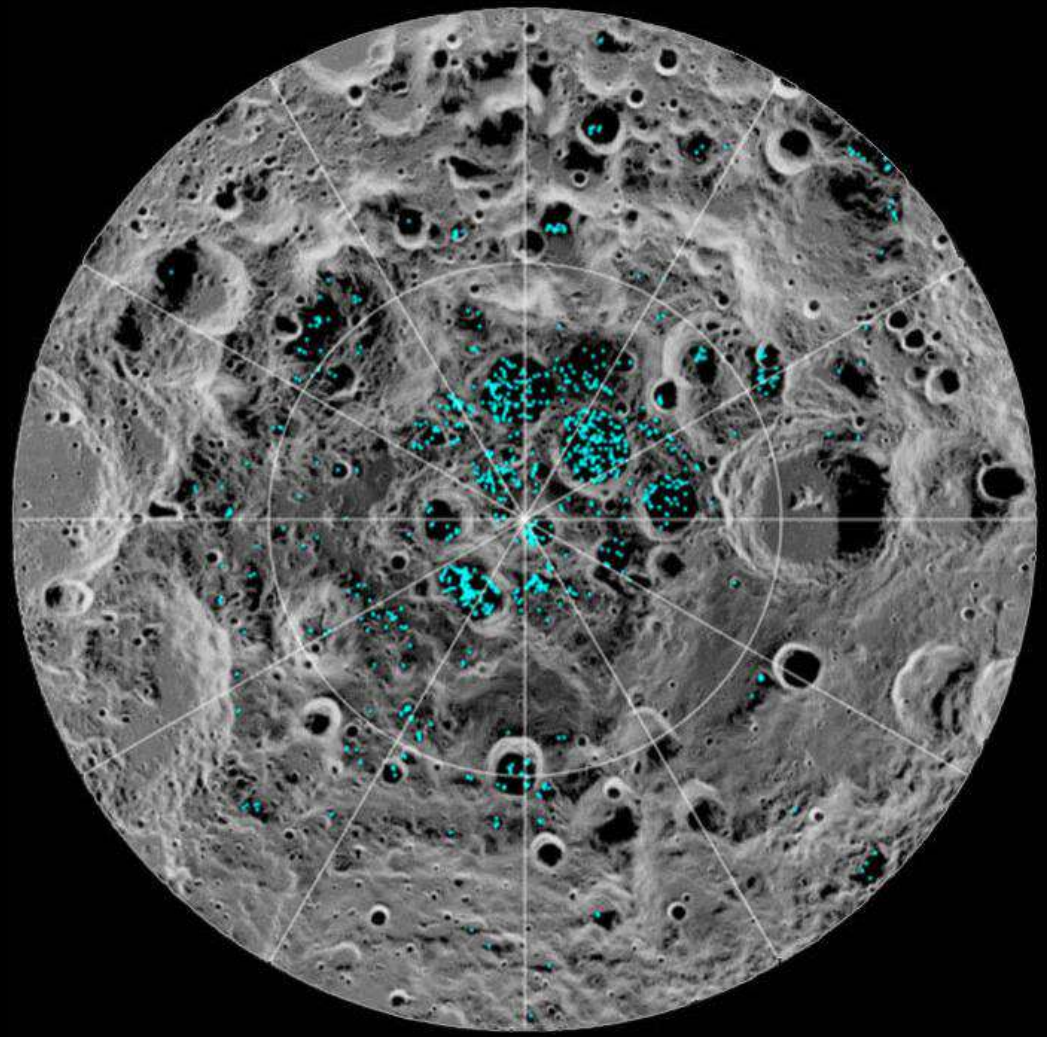


McCubbin et al. 2023

South Pole of the Moon

- Permanently shadowed areas in poles never receive sunlight
  - At equator: -280 to 250 °F
  - At poles: less than -370 °F (50 K)
- Ices trapped in permanently shadowed craters
- Where do these ice come from?
  - Comets?
  - Volcanic eruptions?

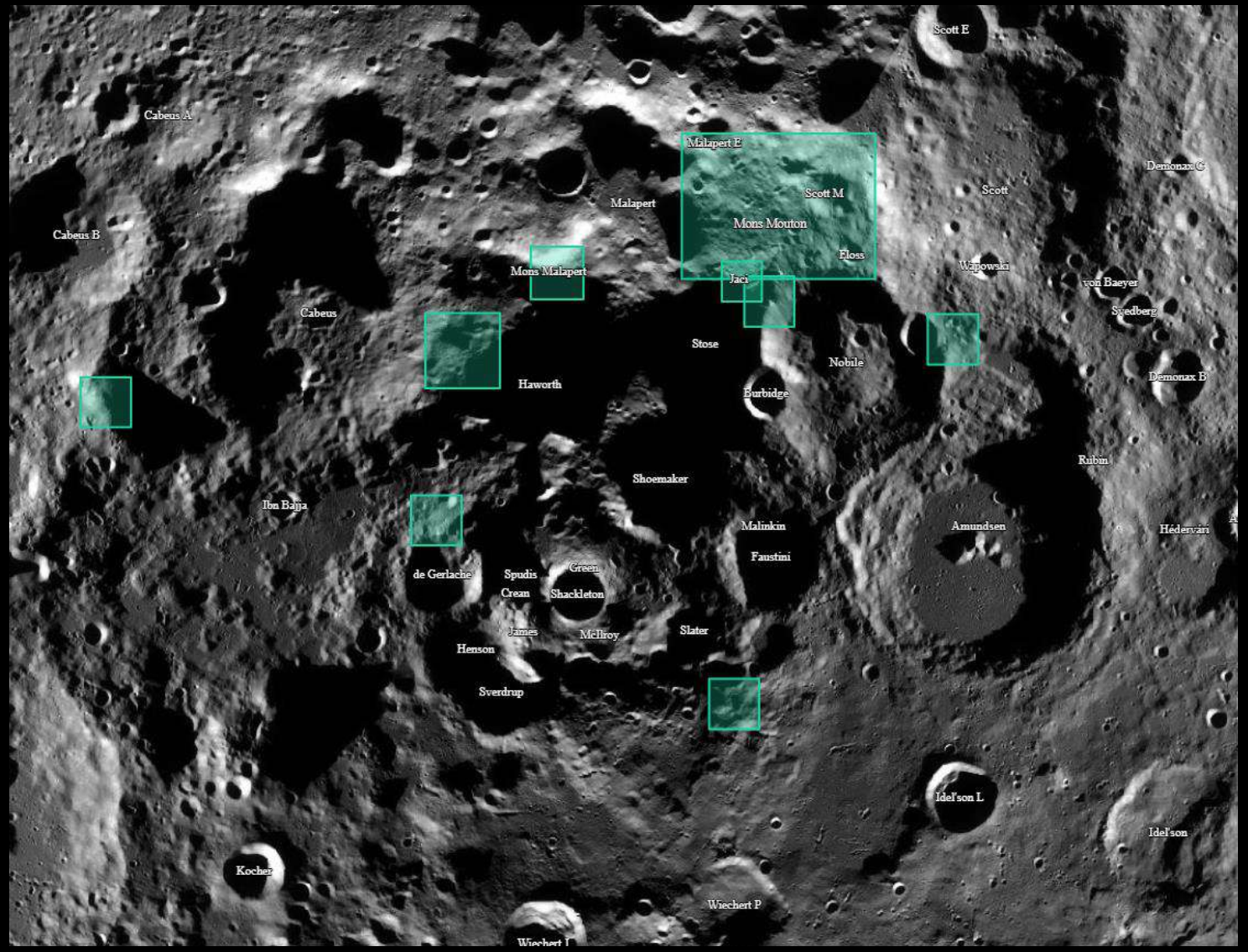
Water at south pole; Li et al. 2018



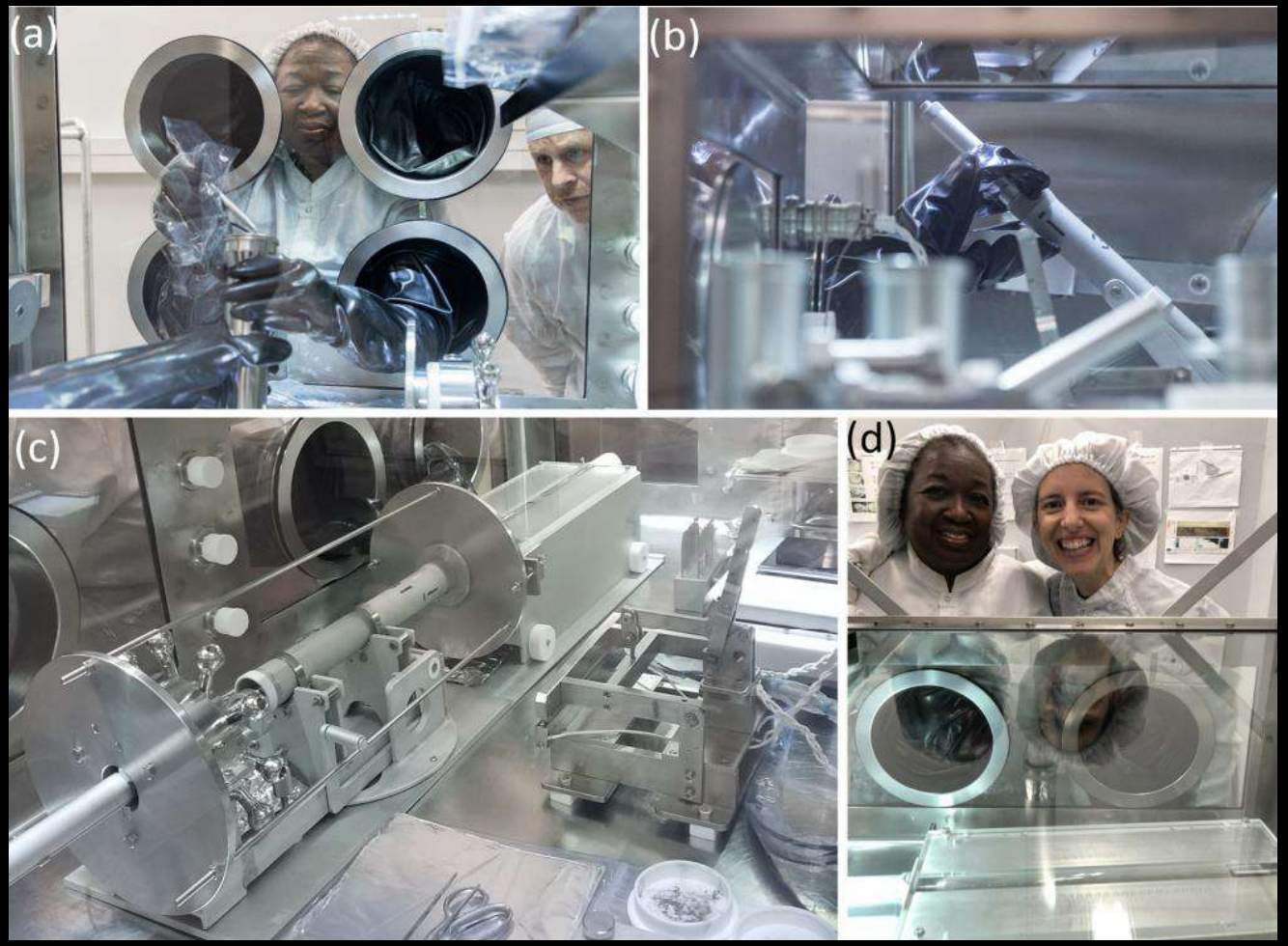
Artemis missions

- Artemis 1: uncrewed flyby, Nov-Dec 2022
- Artemis 2: crewed flyby, April 2026
  - Moon Joy!
- Artemis 3: crewed Earth orbit, *2027*
- Artemis 4: crewed landing on Moon, *early 2028*
- Artemis 5+: crewed landings, *late 2028+*

Artemis 4 candidate landing sites, 2024



Getting Ready for Artemis Samples



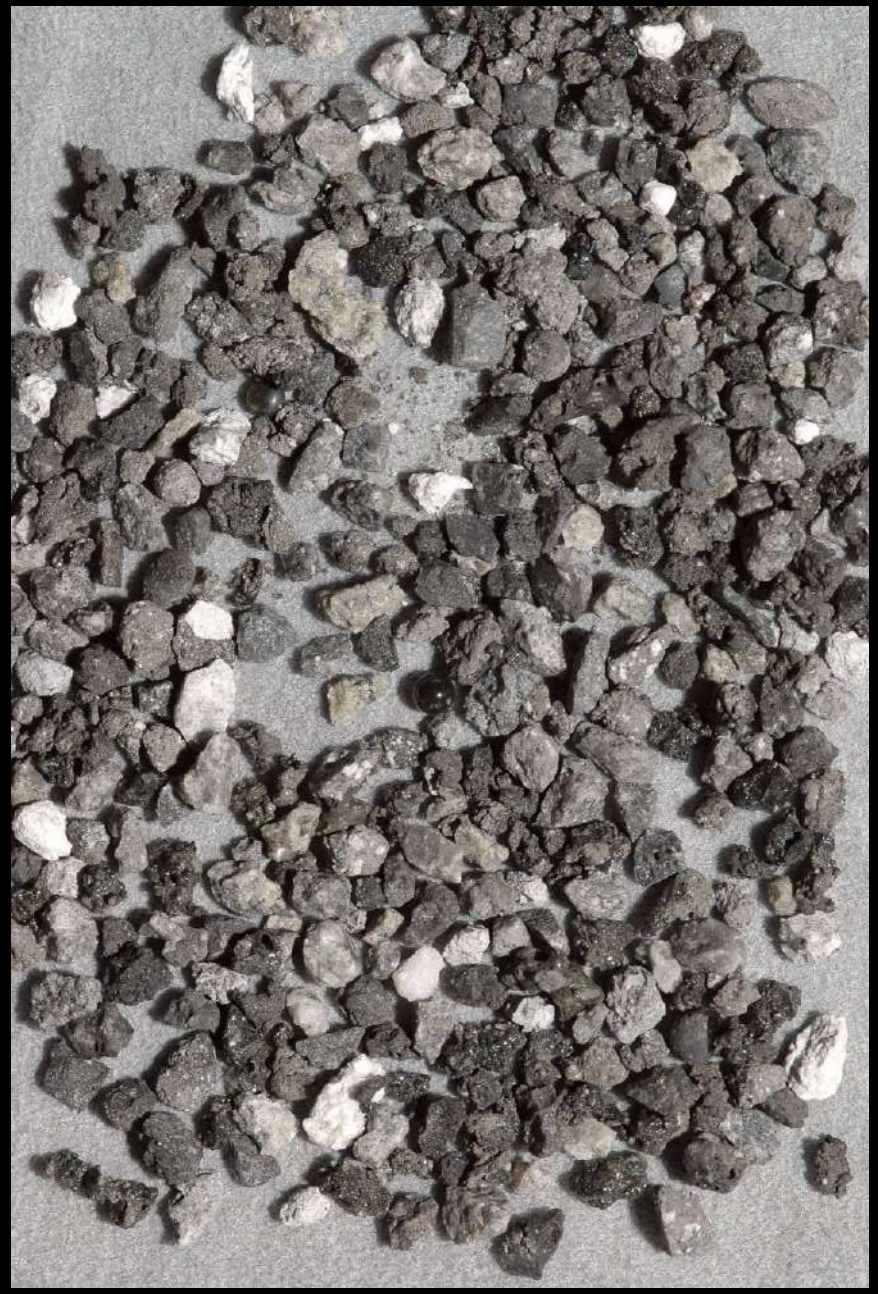
- **NASA's returned samples must be preserved for future generations**
- Some Apollo samples left completely unopened and unstudied
- Process lunar samples for the first time in decades
  - ANGSA program

South Pole Moon Rocks

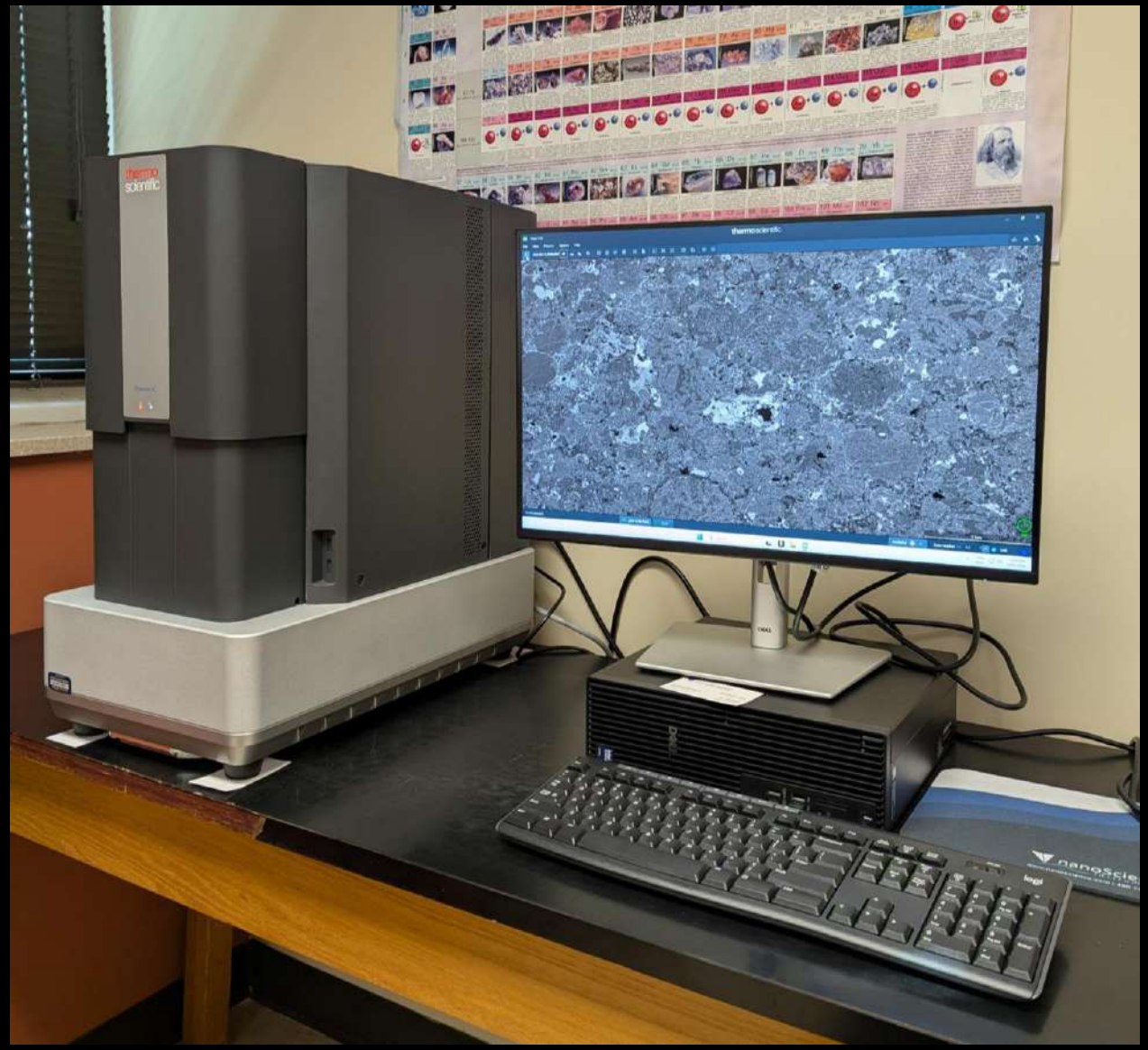
We will get:

- Ancient Moon rocks that record a large part of the Moon's history
- Rocks from the Moon's farside (from the rover)
- Moon ice?

- Something we didn't expect or anticipate
- Something we would not have gotten with only robots
- **Rocks for the next generations of scientists to analyze**



65902, Randy Korotev



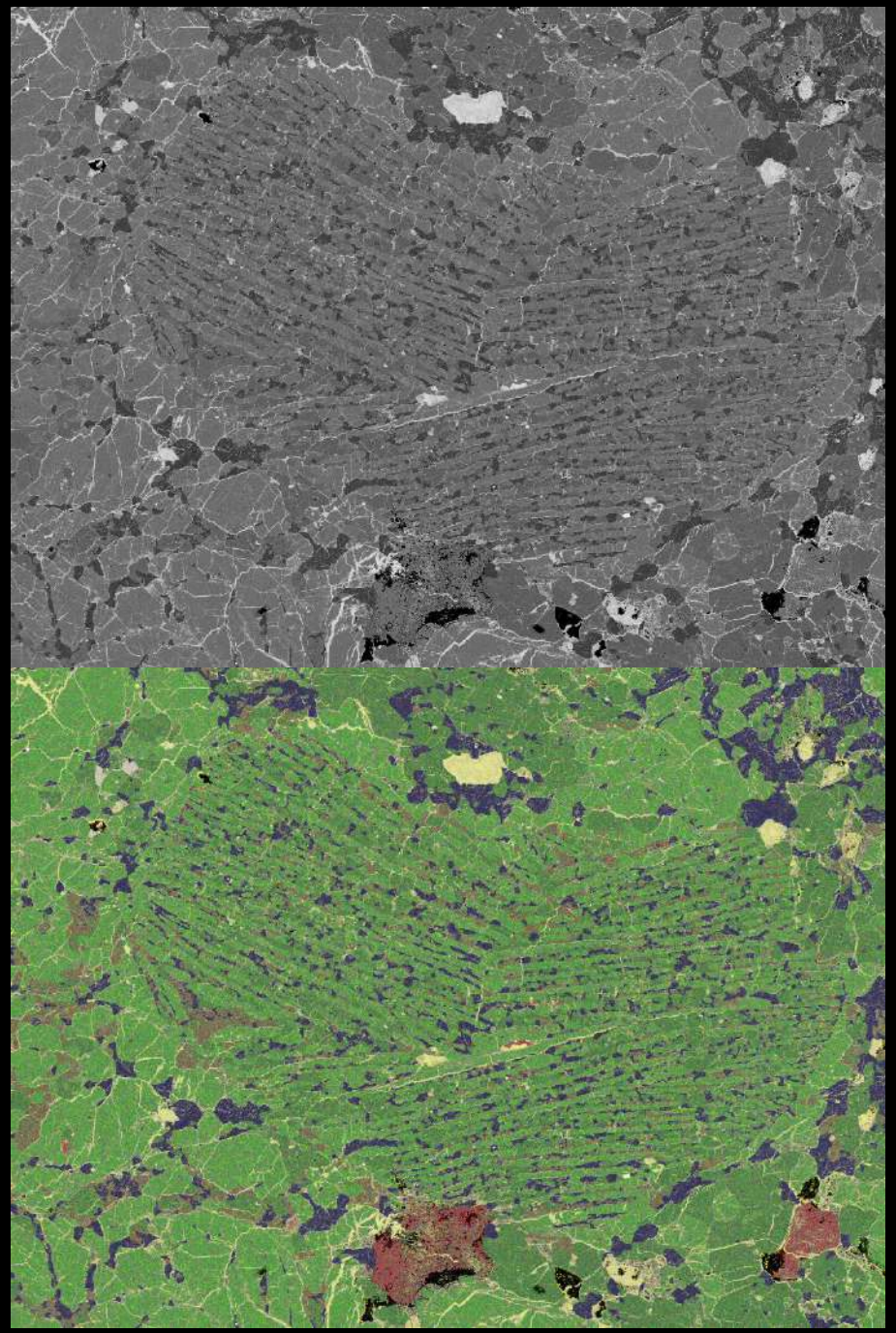
Meteorites at APSU

- Meteorites fall to Earth all the time
- From random places in our Solar System
- We can analyze them and learn about where they came from
- **New electron microscope is key to analyzing them!**

Why the SEM is key for analyzing meteorites?

- SEM reveals the minerals the rocks are made of
- Determine the chemistry of the minerals
- Understand how those minerals are related to each other (*texture*)

- Identify where in our solar system the meteorite came from
- What happened to the meteorite on its way to Earth



One thing in this picture is a meteorite

Which one?

Credit: Randy Korotev

Two things in this picture are meteorites

Which two?

Credit: Randy Korotev

Thank you!

Earthset, Artemis II astronaut Christina Koch