

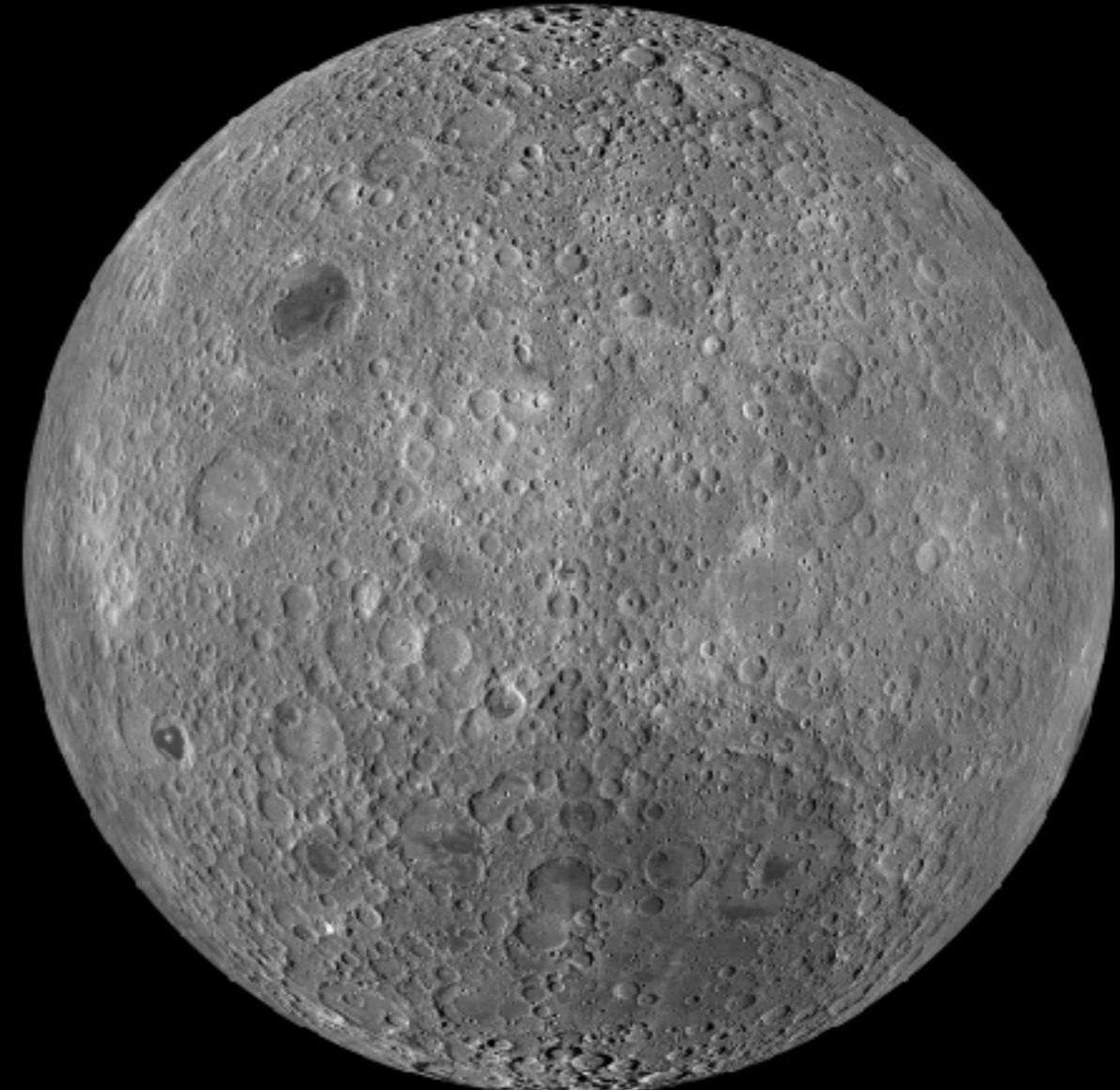


NO one ever
visITS me anymore

Our Moon

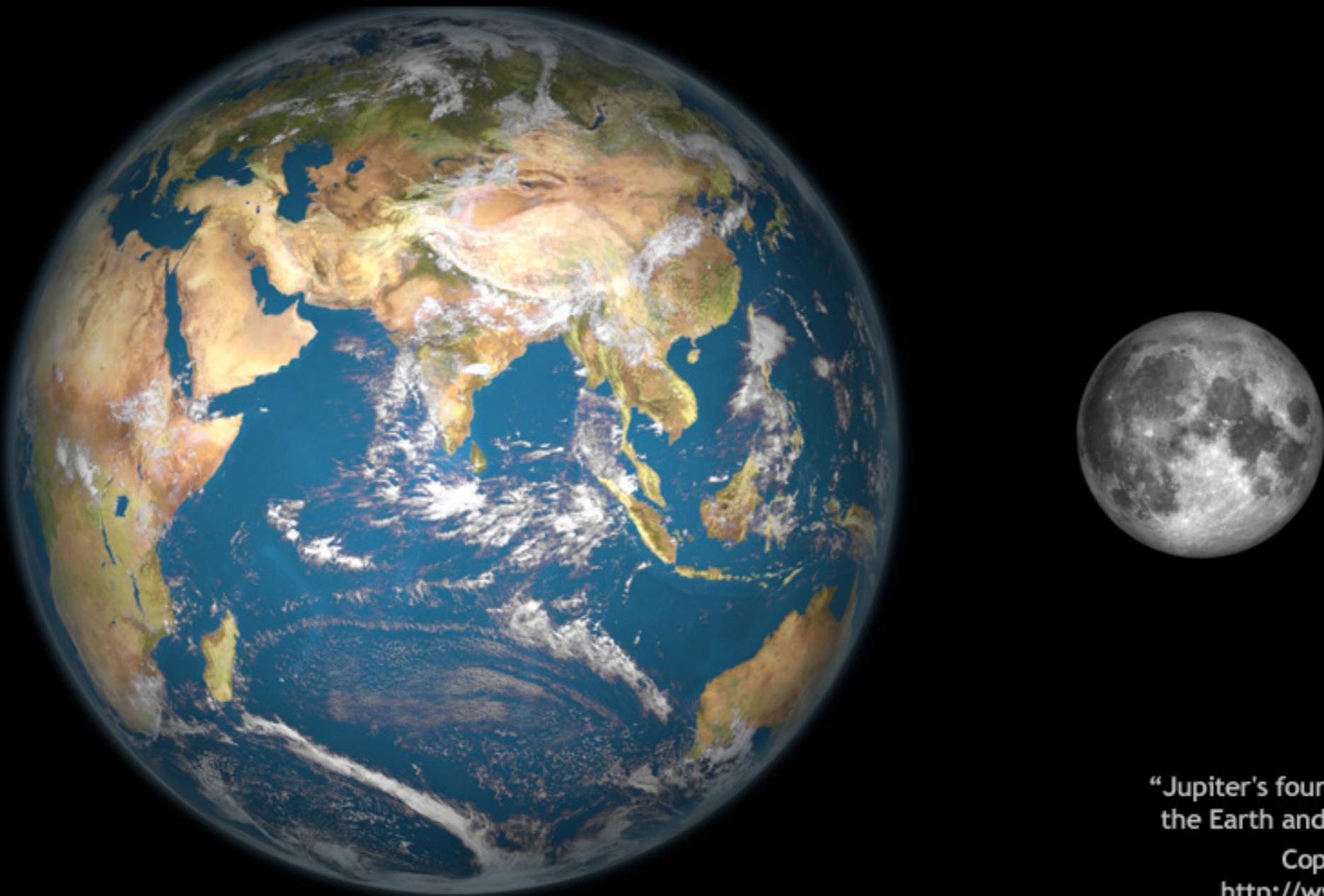


Side facing us



Side facing away

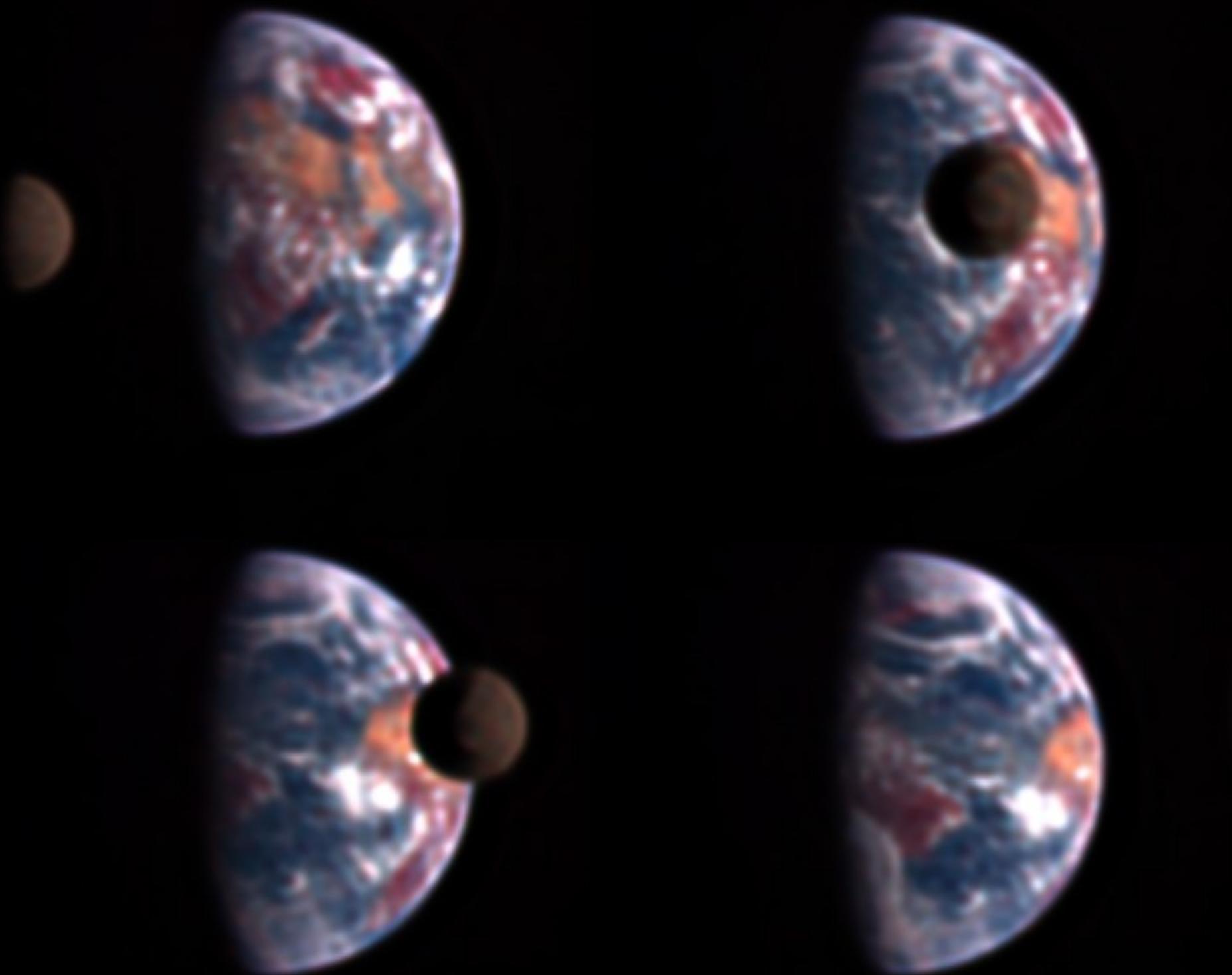
If the Earth and moon were side by side...



"Jupiter's four largest satellites and
the Earth and the Moon compared"

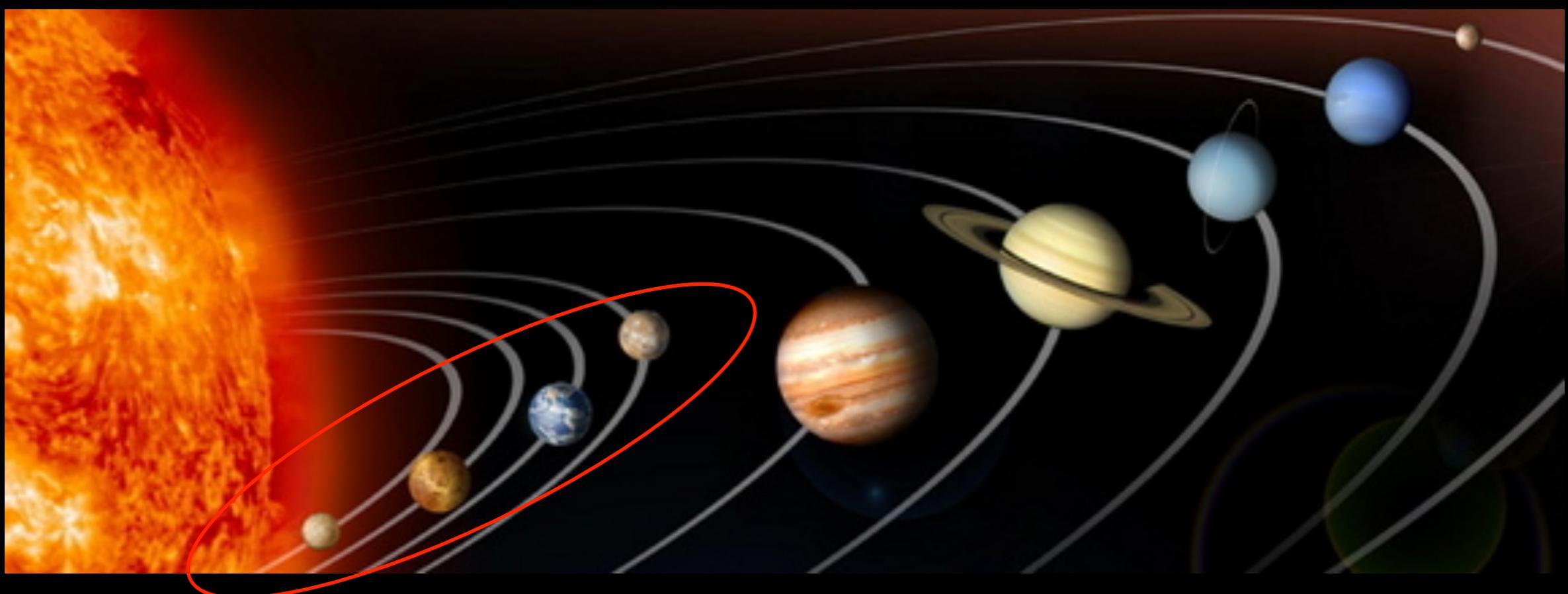
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Pictures of Earth/moon from the Deep Impact satellite



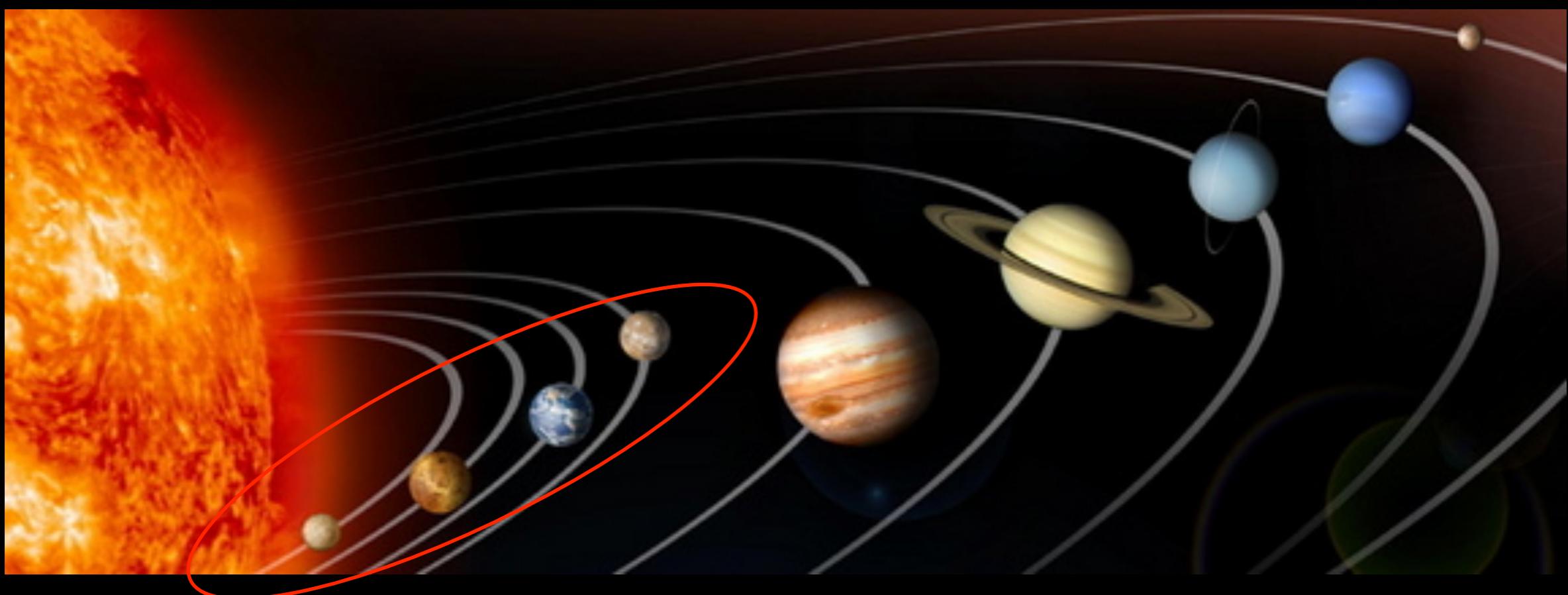
There are multiple aspects of **terrestrial** (or rocky) planets we will focus on

- 1) Interiors
- 2) Surfaces
- 2) Atmospheres
- 3) Magnetic fields

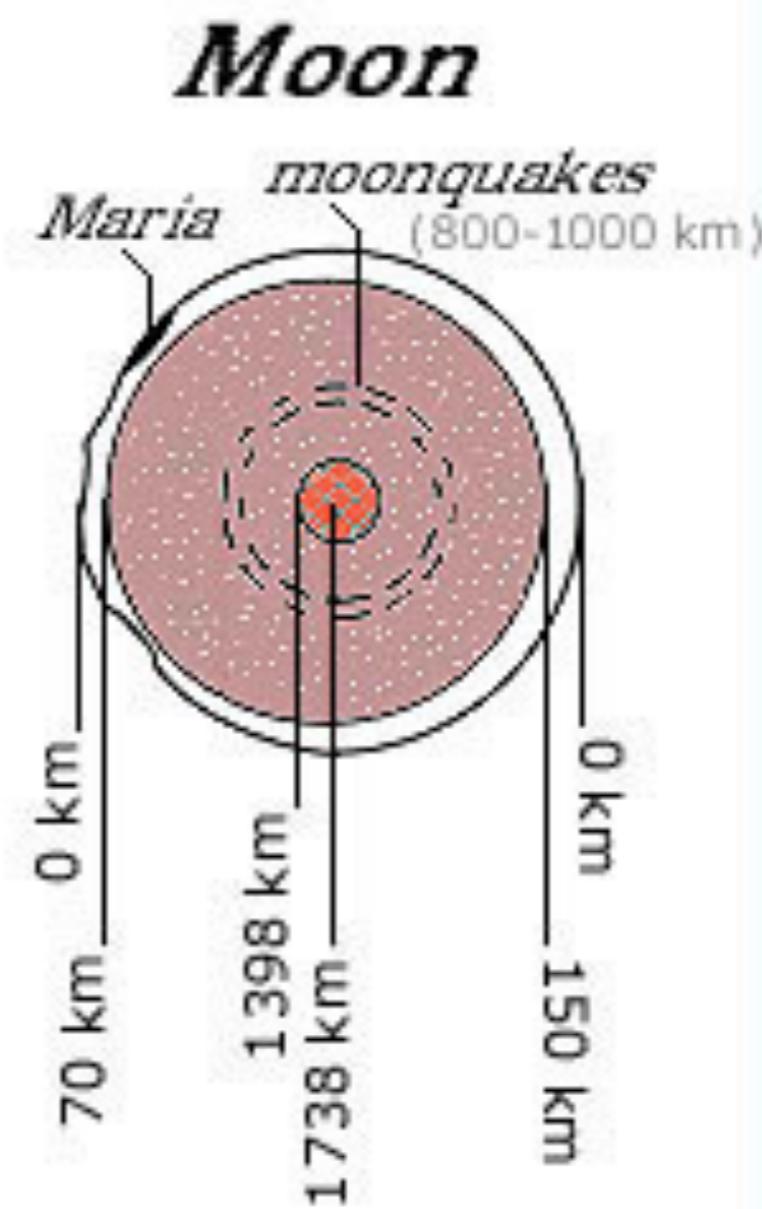
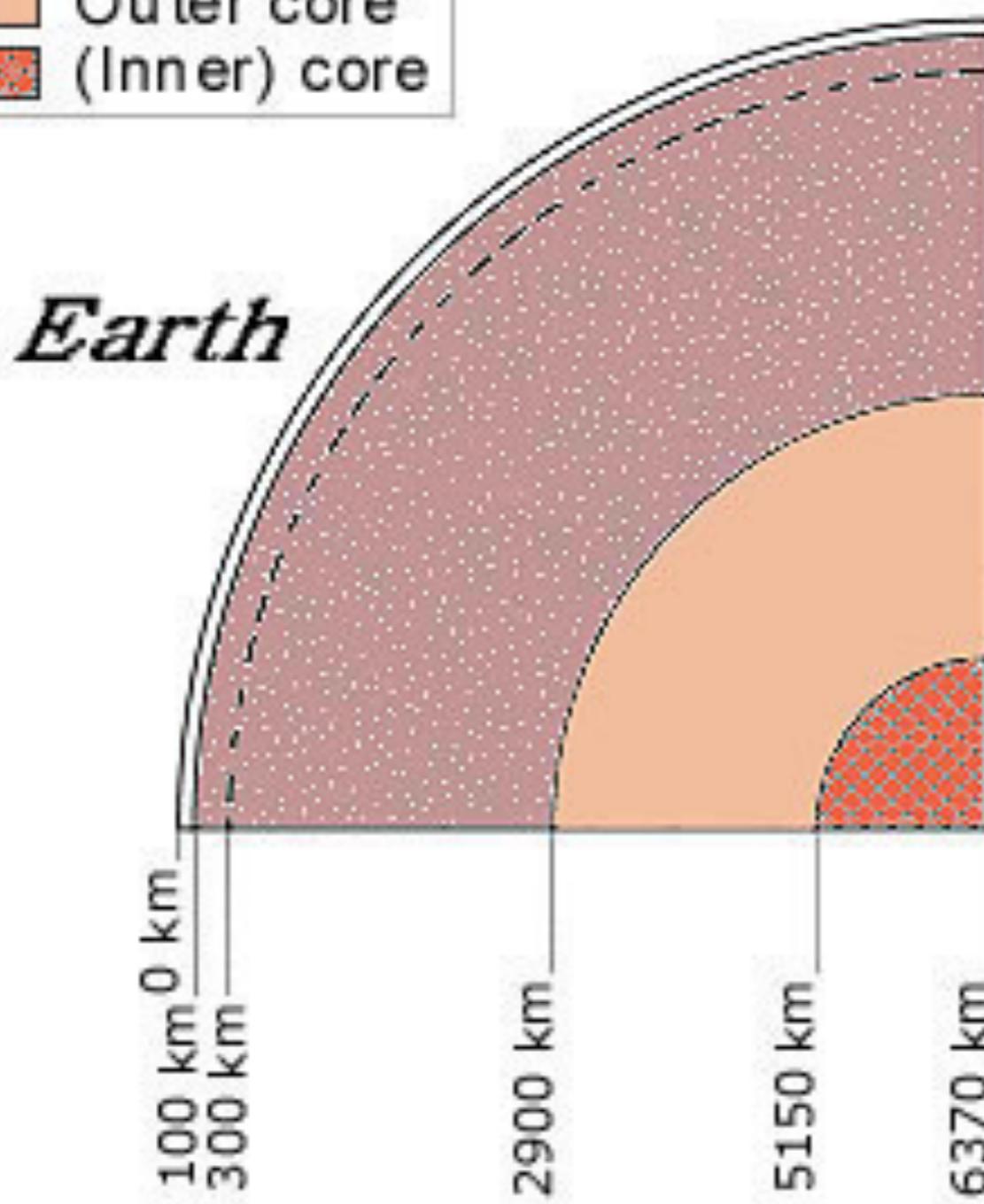
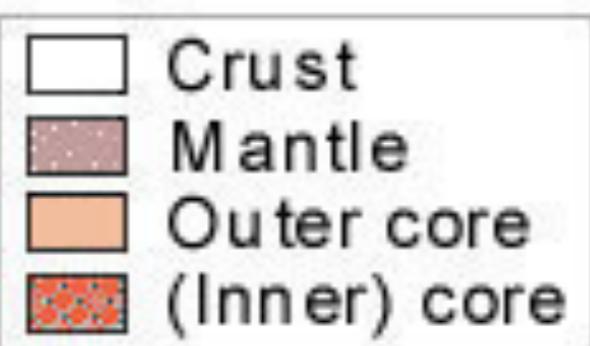


There are multiple aspects of **the moon** that we will focus on

- 1) Interior
- 2) Surface
- 2) ~~Atmosphere~~
- 3) ~~Magnetic field~~



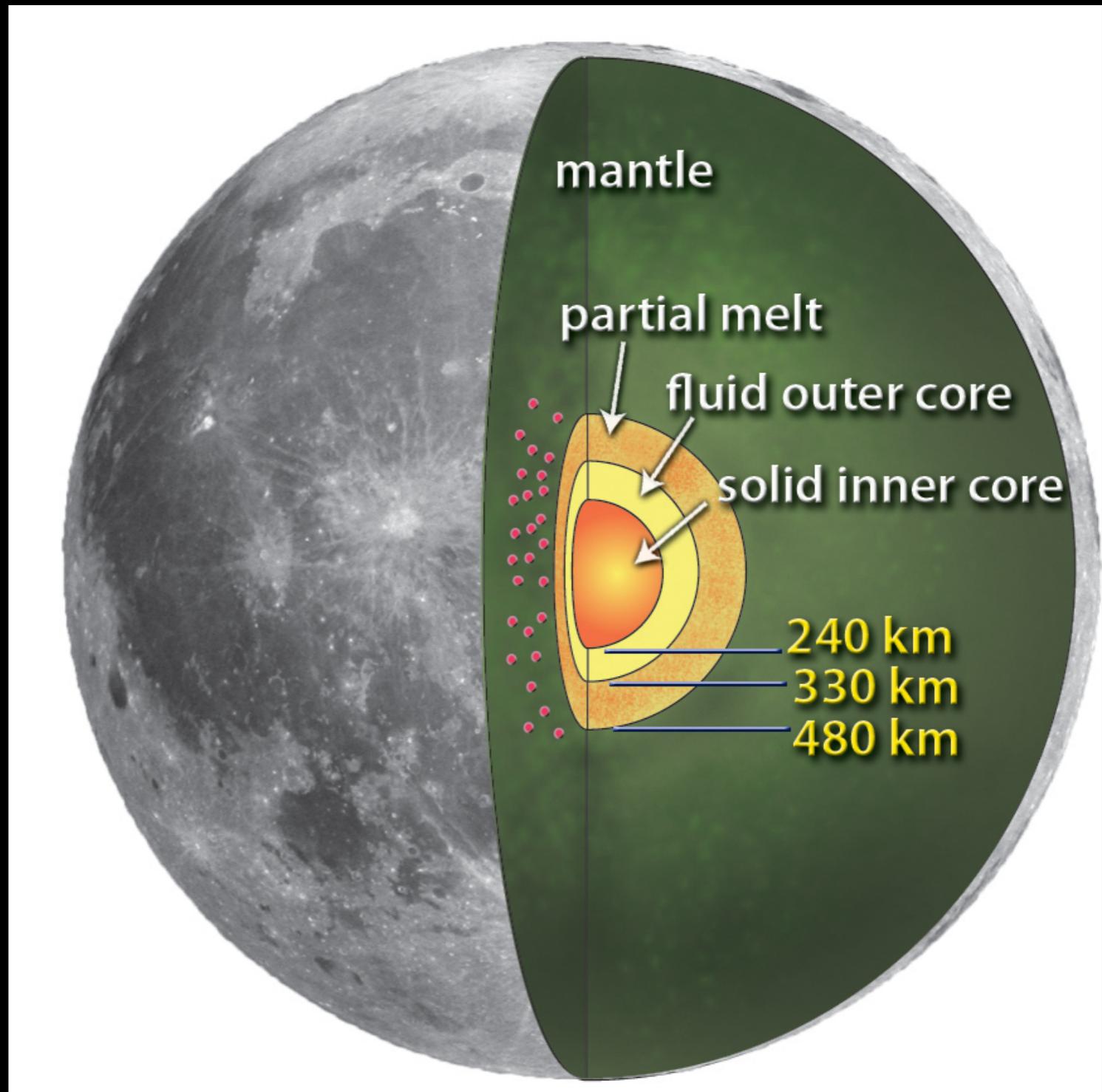
EARTH AND MOON COMPARED



(Adapted from *Exploring the Moon*, NASA pub. EG-1997-10-116-HQ.)

Moon's Interior

- Has a core like Earth's (though not a very large one).
- Moon is low density (3.3 g/cm^3 on avg) and primarily made of silicate rocks.
- Moonquakes may happen because the moon is shriveling as it shrinks!

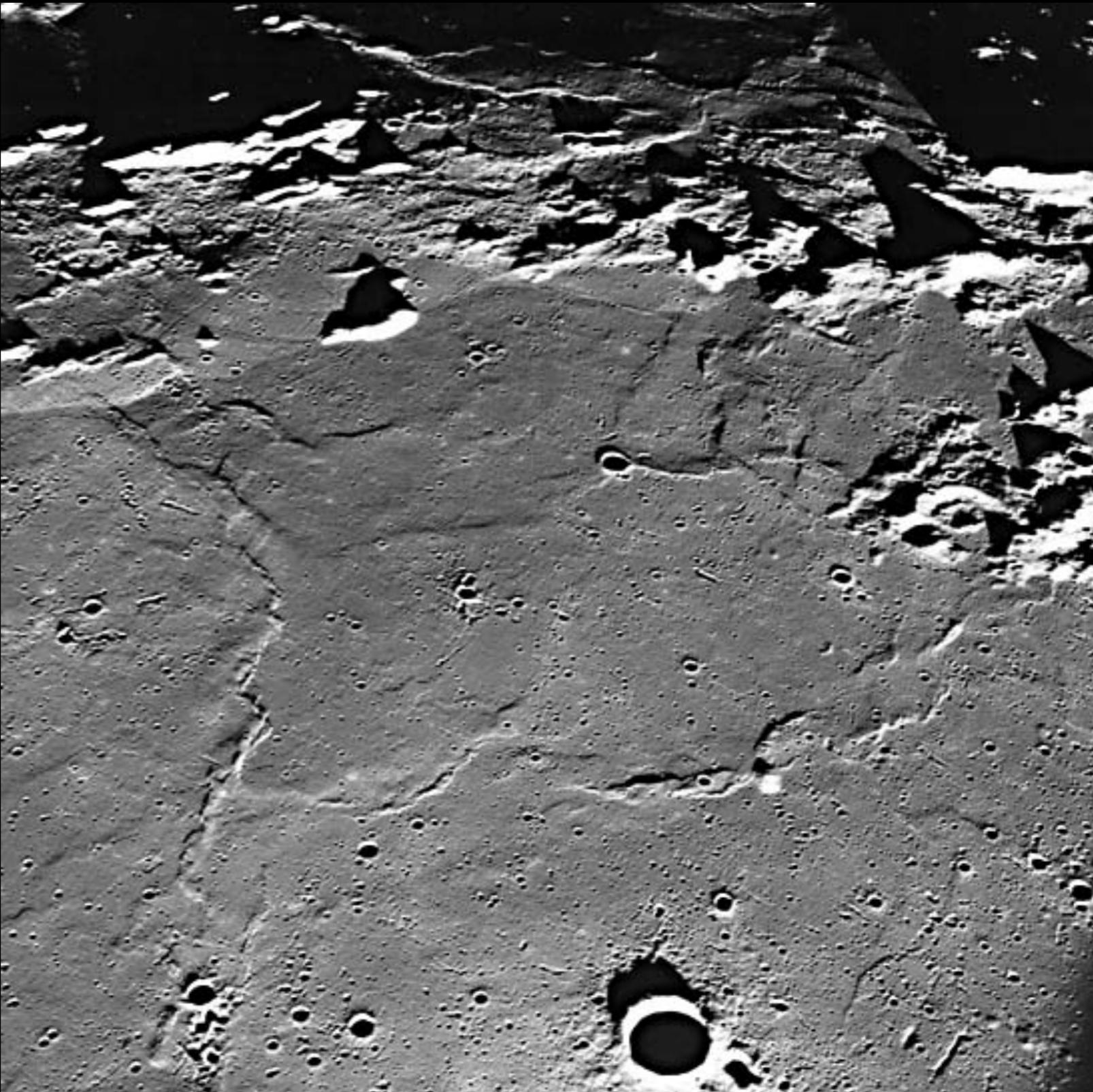


Basic Geology of the Moon



Which type of landscape is older??

Lunar Maria: Smoother, darker terrain caused by volcanic activity



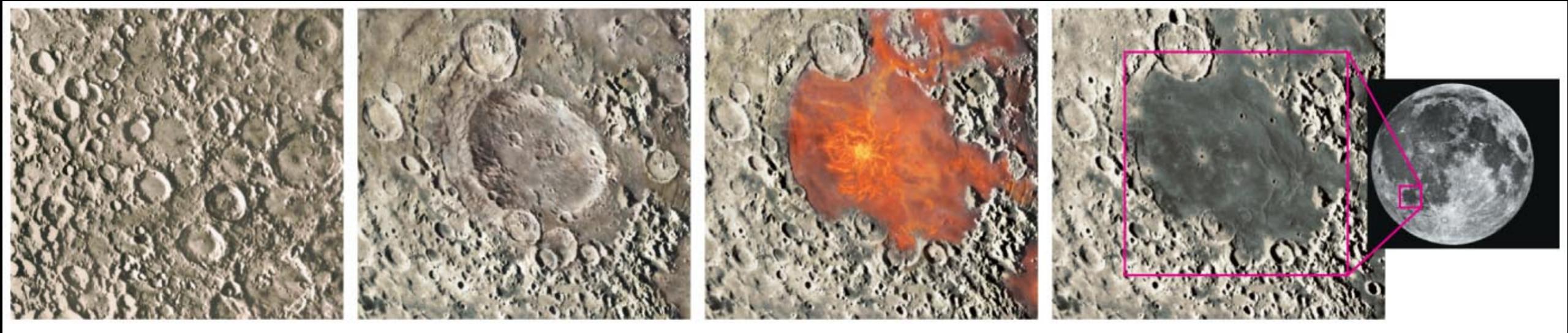
Does this look like volcanoes on Earth?

Lunar Maria: Smoother, darker terrain caused by volcanic activity



Does this look like volcanoes on Earth?

Formation of Lunar Maria



Early surface is covered with craters.

Large impact crater weakens crust.

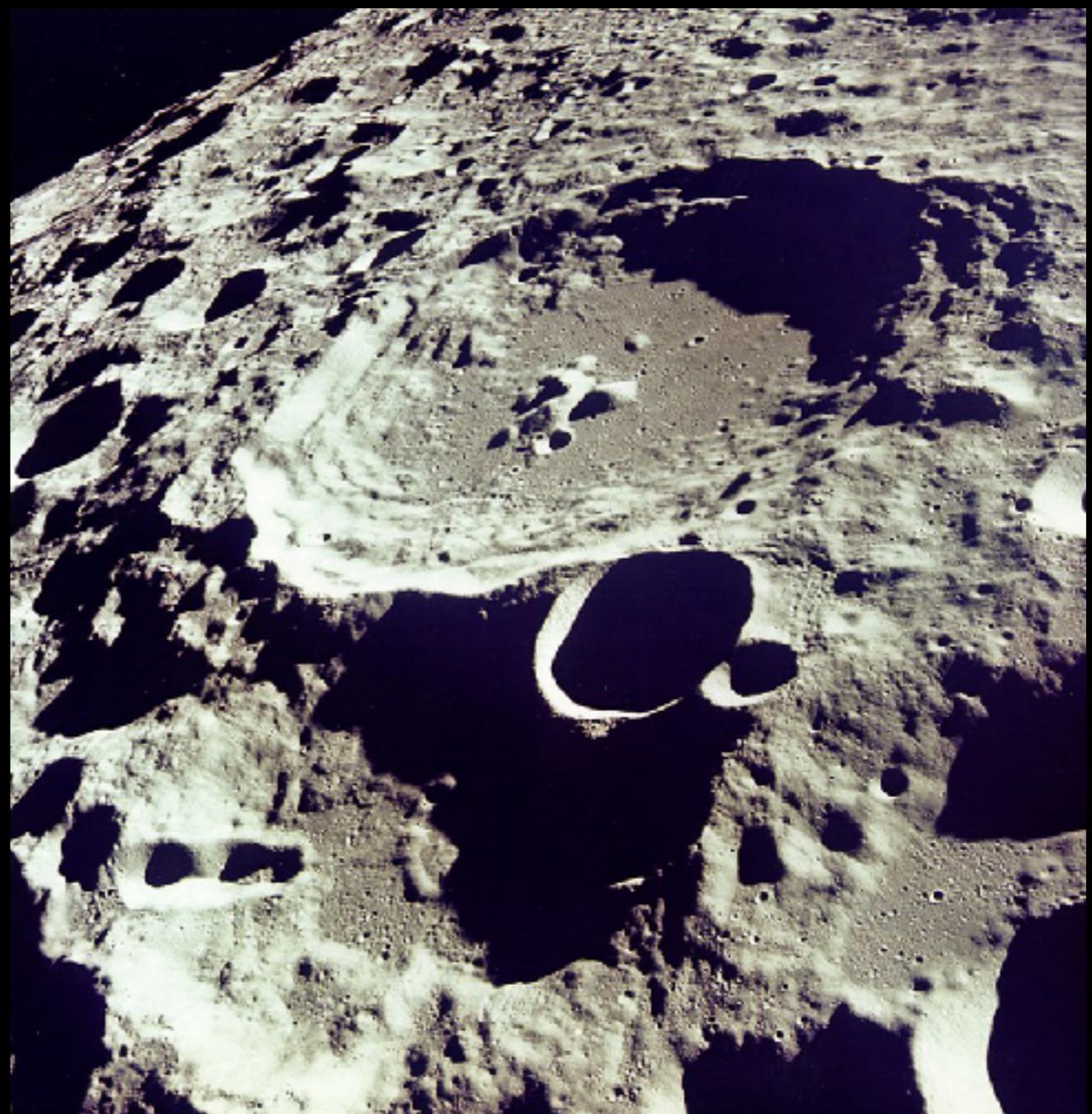
Heat build-up allows lava to well up to surface.

Cooled lava is smoother and darker than surroundings.

Moon rocks brought back by astronauts are 3.3-4.4 billion years old.

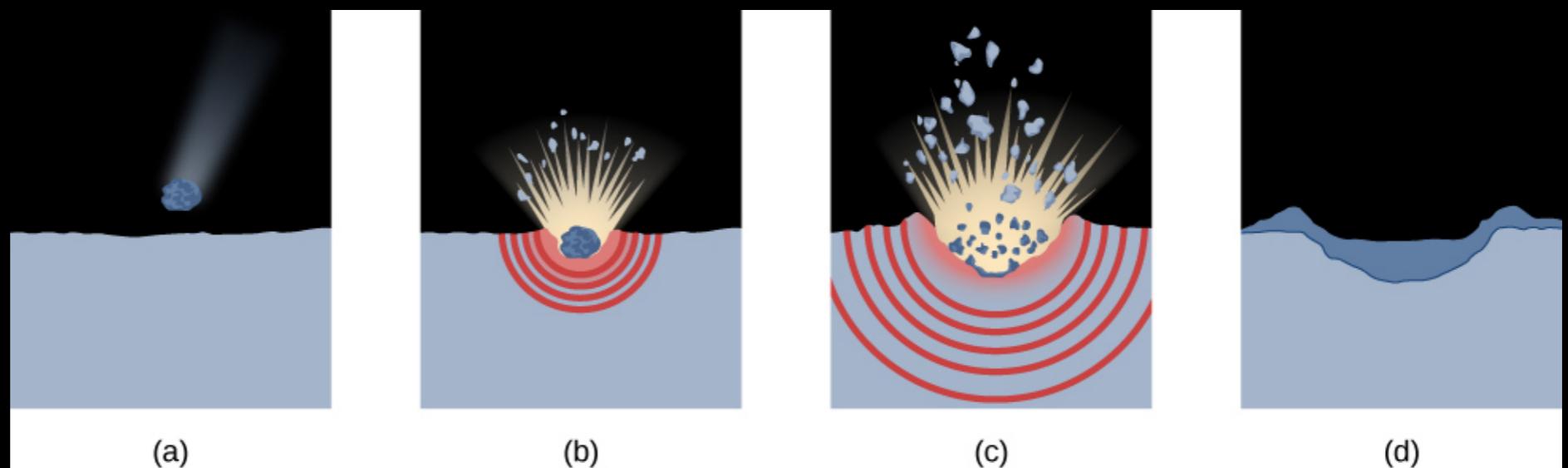
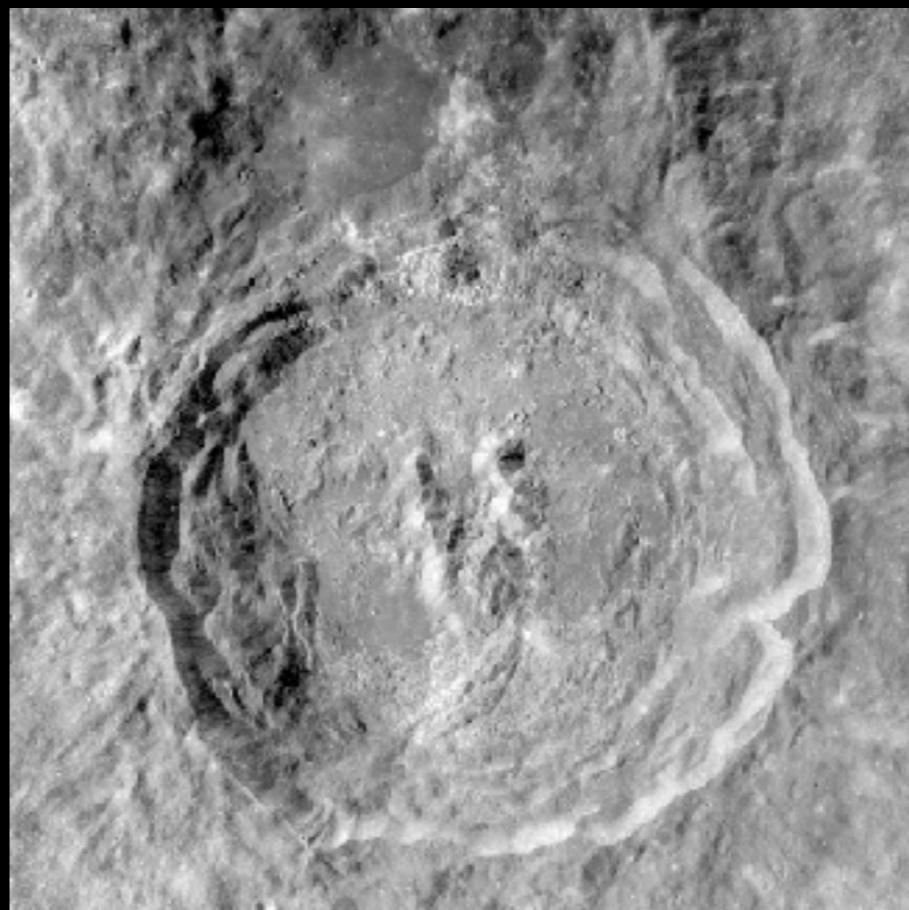
Lunar Highlands

- Make up 83% of the moon's surface
- Heavily cratered
- Older rocks (~4.4 billion years!)
- Mountains are rounded because there is no weather to carve them as on Earth.



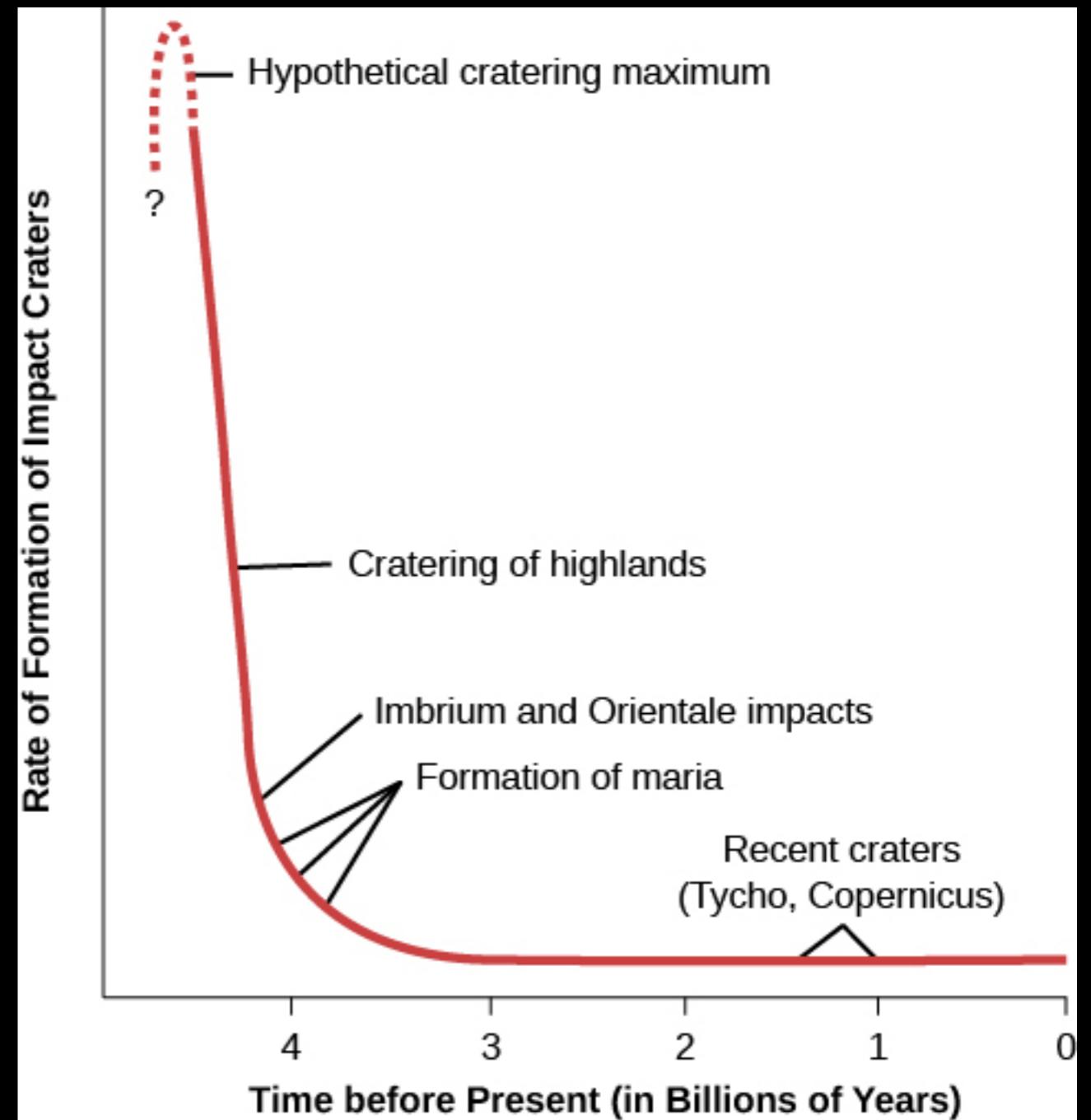
Craters

- Impact explosion makes circular bowl shape
- Bowl then fills in a bit
- Terraced rim



Crater Rates

- Many more craters in the lunar highlands than the maria
- Moon must have been bombarded heavily early on
- We can estimate the rate of impacts during this Heavy Bombardment period



Crater Rates

- Find the set of largest craters and estimate their size in km
- How many large craters do you see in this image?
- The moon's total area is 38 million km^2 . How many large impactors have hit the moon??



- If the Heavy Bombardment lasted 300 million years, how often were the large impacts?

Crater Rates

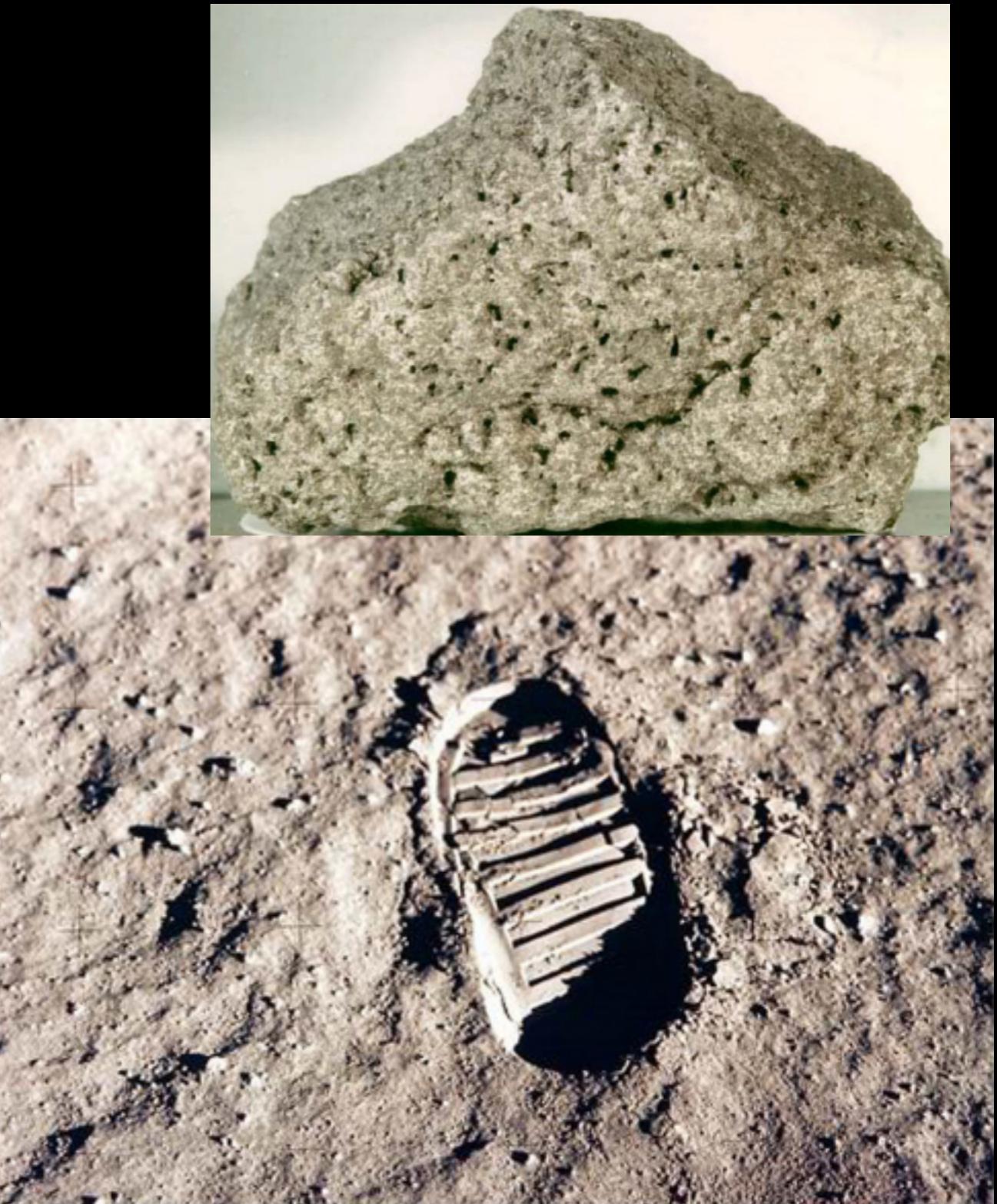
- ~6 craters of 10km size each
- Image area is about $70 \times 90 = 6300 \text{ km}^2$
- $38 \text{ million} / 6300 \text{ km}^2$
= ~36,000 large impactors hit the moon
- $300 \text{ million years} / 36,000 = 8,300$ years between impacts



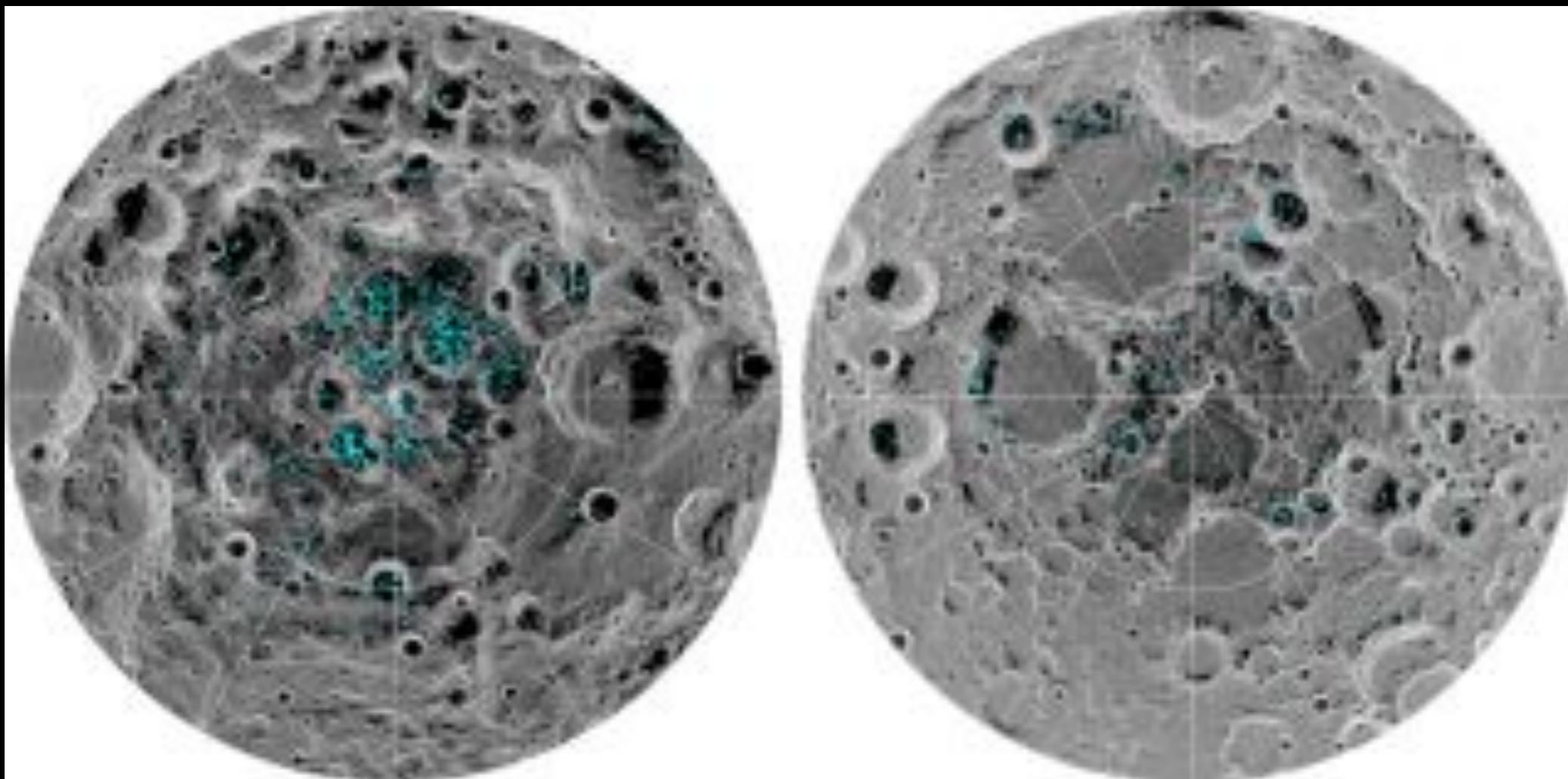
→ Compare with the current rate of a few million years per impact of a 10km asteroid

On the surface

- Rock: dark basalts in the mare regions
- Dirt: a fine-grained soil of shattered rock
- Lunar soil is the product of impacts



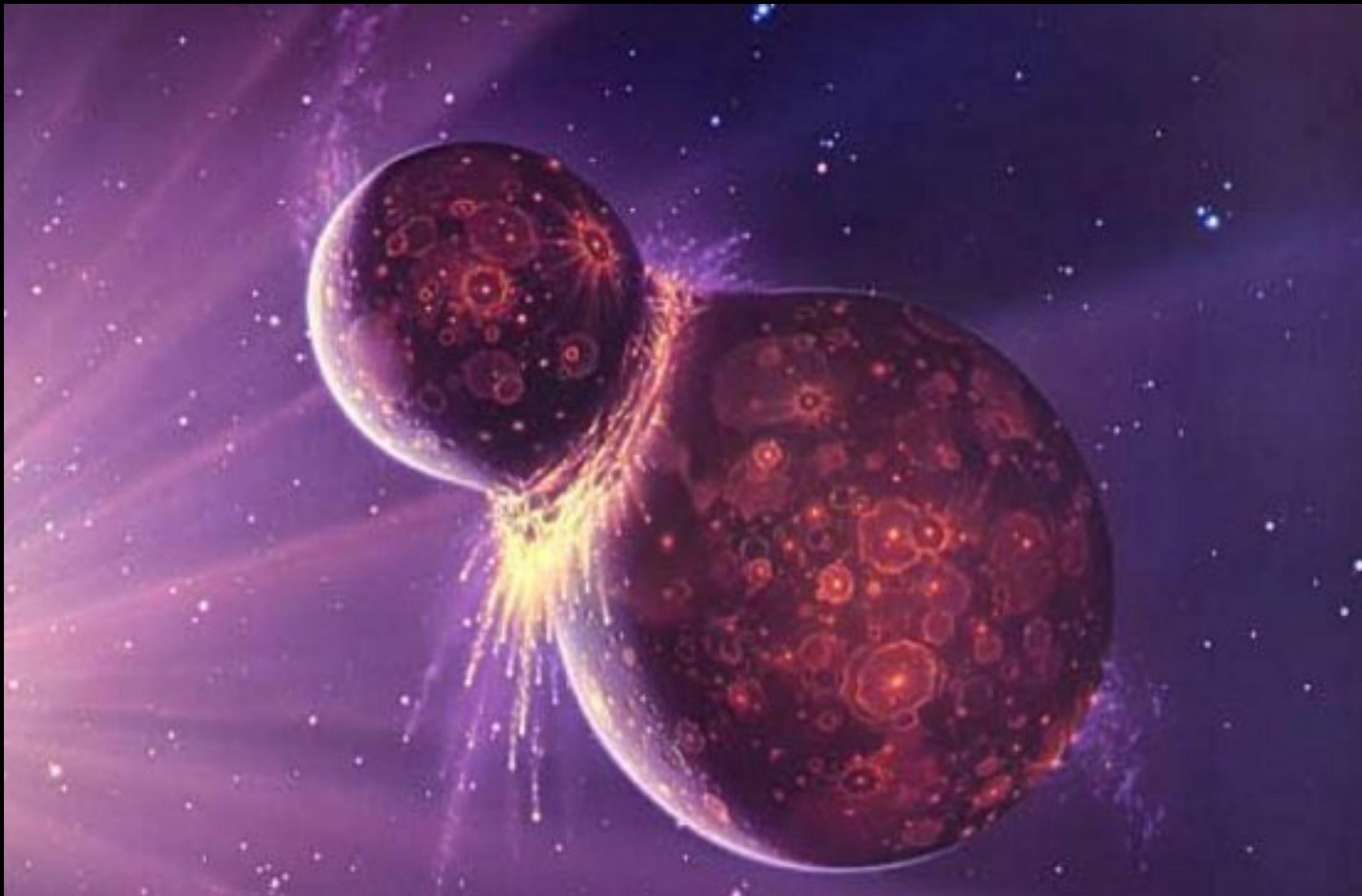
Water on the Moon?



YES.

- First discovered a bit under the surface when NASA mission LCROSS impacted the moon.
- More recently (2018), we have found ice at the S pole

How did the moon form?

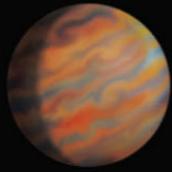


Moon and Earth have surprisingly similar compositions...

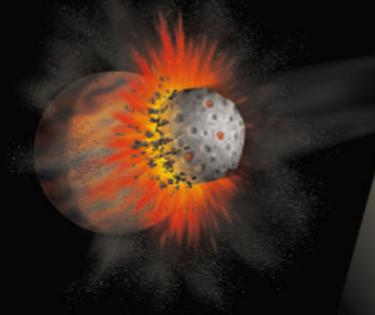
The Origin of Earth's Moon

- The large-impact hypothesis

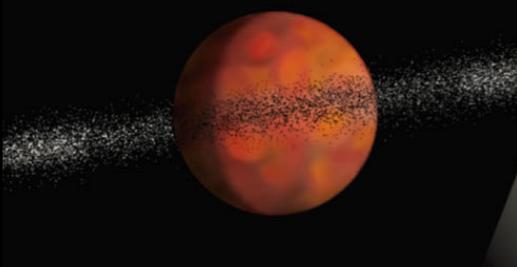
- The moon formed when a planetesimal estimated to have been at least as large as Mars smashed into the proto-Earth.
- This helps explain the orbital period as well



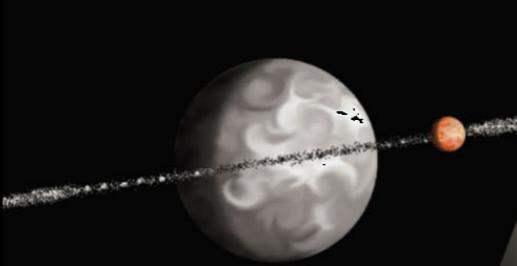
A protoplanet nearly the size of Earth differentiates to form an iron core.



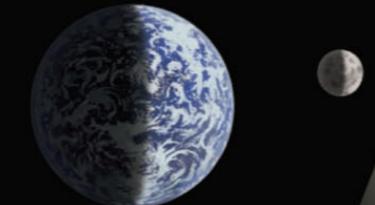
Another body that has also formed an iron core strikes the larger body and merges, trapping most of the iron inside.



Iron-poor rock from the mantles of the two bodies forms a ring of debris.



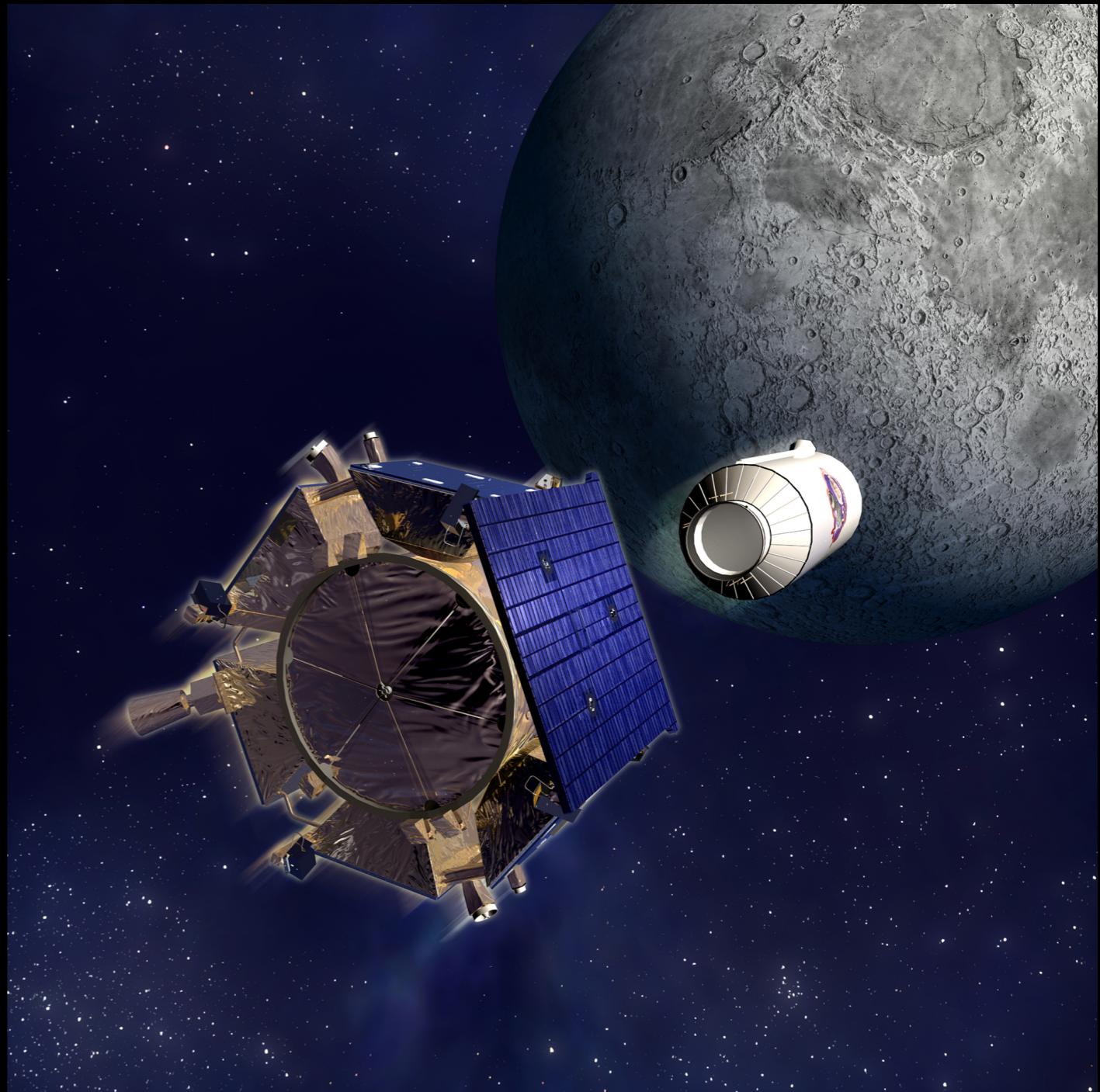
Volatiles are lost to space as the particles in the ring begin to accrete into larger bodies.



Eventually the moon forms from the iron-poor and volatile-poor matter in the disk.

Missions to the Moon: Unmanned

- NASA has launched 5+ orbiters to map features
- GRAIL orbiters mapped structures underneath the moon's surface
- LCROSS Impactor found water ice in a dark, cold crater

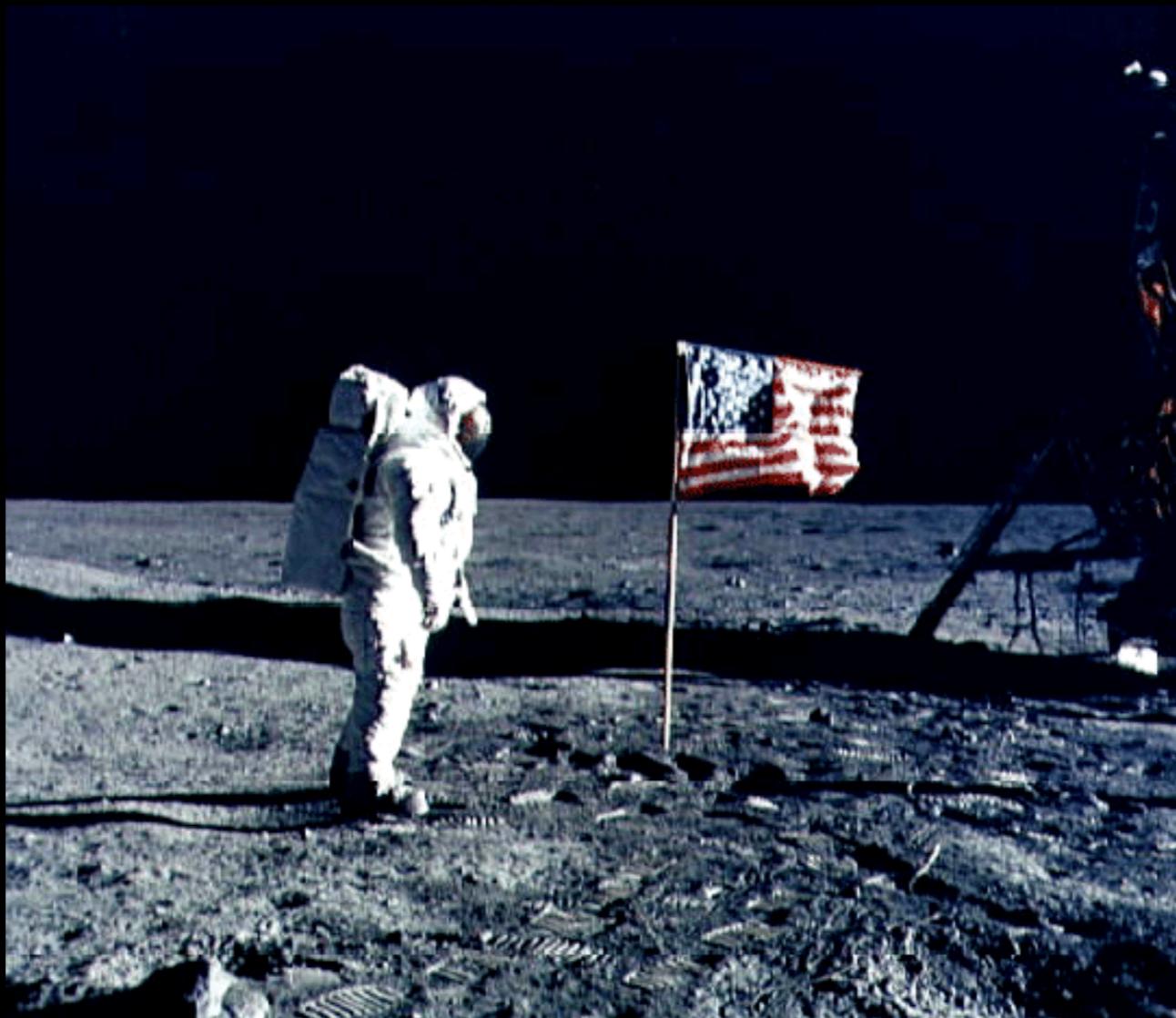


Missions to the Moon: Objectives

- Sample collection: many kilograms of rock have been returned to Earth.
- Deploy surface experiments
- Image the moon from orbit above it



The Apollo program sent people and spacecraft to the moon from 1968-1972. No spacecraft have landed on the moon since.



Should we go back? Are manned missions worthwhile?
NASA Artemis Mission by 2024.

Top 6 things to know about the Moon

- 1) The only other planetary object visited by people
- 2) Has $1/80^{\text{th}}$ of the MASS of the Earth and $1/6^{\text{th}}$ the gravity
- 3) It has TWO kinds of terrains - a) **maria** - dark gray, smooth areas a.k.a. lunar lowlands and b) **lunar highlands** - the lighter-colored mountainous areas
- 4) Maria has less cratering because they are YOUNGER
- 5) A year on the moon is the same as a day on the moon
- 6) Life on Earth might be quite different without it