

Bell Ringer

1. Which two outer planets have the most moons in the Solar System?
2. Why are Saturn's rings so bright to us?
3. How many of the outer planets have rings?

OUR MOON

Goals for today:

1. Understand the origin of our Moon
2. What is the Moon made of
3. Understand what causes the phases of the Moon

Nearest Neighbor

- Earth-Moon distance 385,000 km
- 30 Earth diameters



Exploration of the Moon

- 1959
 - |-- Luna 1 - Jan 2, 1959 - Flyby
 - |-- Pioneer 4 - Mar 3, 1959 - Flyby
 - |-- Luna 2 - Sep 12, 1959 - Impact
 - |-- Luna 3 - Oct 4, 1959 - Probe
- 1962
 - |-- Ranger 4 - Apr 23, 1962 - Impact
- 1963
 - |-- Luna 4 - Apr 2, 1963 - Flyby
- 1964
 - |-- Ranger 6 - Jan 30, 1964 - Impact
 - |-- Ranger 7 - Jul 28, 1964 - Impact
- 1965
 - |-- Ranger 8 - Feb 17, 1965 - Impact
 - |-- Ranger 9 - Mar 21, 1965 - Impact
 - |-- Luna 5 - May 9, 1965 - Impact
 - |-- Zond 3 - Jul 18, 1965 - Flyby
 - |-- Luna 7 - Oct 4, 1965 - Impact
 - |-- Luna 8 - Dec 3, 1965 - Impact
- 1966
 - |-- Luna 9 - Jan 31, 1966 - Lander
 - |-- Luna 10 - Mar 31, 1966 - Orbiter
 - |-- Surveyor 1 - May 30, 1966 - Lander
 - |-- Lunar Orbiter 1 - Aug 10, 1966 - Orbiter
 - |-- Luna 11 - Aug 24, 1966 - Orbiter
 - |-- Luna 12 - Oct 22, 1966 - Orbiter
 - |-- Lunar Orbiter 2 - Nov 6, 1966 - Orbiter
 - |-- Luna 13 - Dec 21, 1966 - Lander
- 1967
 - |-- Lunar Orbiter 3 - Feb 4, 1967 - Orbiter
 - |-- Surveyor 3 - Apr 17, 1967 - Lander
 - |-- Lunar Orbiter 4 - May 8, 1967 - Orbiter
 - |-- Lunar Orbiter 5 - Aug 1, 1967 - Orbiter
 - |-- Surveyor 5 - Sep 8, 1967 - Lander
 - |-- Surveyor 6 - Nov 7, 1967 - Lander
- 1968
 - |-- Surveyor 7 - Jan 7, 1968 - Lander
 - |-- Luna 14 - Apr 7, 1968 - Orbiter
 - |-- Zond 5 - Sep 15, 1968 - Return Probe
 - |-- Zond 6 - Nov 10, 1968 - Return Probe
- 1969
 - |-- Apollo 8 - Dec 21, 1968 - Crewed Orbiter
 - 1969
 - |-- Apollo 10 - May 18, 1969 - Orbiter
 - |-- Luna 15 - Jul 13, 1969 - Orbiter
 - |-- Apollo 11 - Jul 16, 1969 - Crewed Landing
 - |-- Zond 7 - Aug 7, 1969 - Return Probe
 - |-- Apollo 12 - Nov 14, 1969 - Crewed Landing
- 1970
 - |-- Apollo 13 - Apr 11, 1970 - Crewed Landing (aborted)
 - |-- Luna 16 - Sep 12, 1970 - Sample Return
 - |-- Zond 8 - Oct 20, 1970 - Return Probe
 - |-- Luna 17 - Nov 10, 1970 - Rover
- 1971
 - |-- Apollo 14 - Jan 31, 1971 - Crewed Landing
 - |-- Apollo 15 - Jul 26, 1971 - Crewed Landing
 - |-- Luna 18 - Sep 2, 1971 - Impact
 - |-- Luna 19 - Sep 28, 1971 - Orbiter
- 1972
 - |-- Luna 20 - Feb 14, 1972 - Sample Return
 - |-- Apollo 16 - Apr 16, 1972 - Crewed Landing
 - |-- Apollo 17 - Dec 7, 1972 - Crewed Landing
- 1973
 - |-- Luna 21 - Jan 8, 1973 - Rover
- 1974
 - |-- Luna 22 - Jun 2, 1974 - Orbiter
 - |-- Luna 23 - Oct 28, 1974 - Lander
 - |-- Luna 24 - Aug 14, 1976 - Sample Return
 - |-- Hiten - Jan 24, 1990 - Flyby and Orbiter
 - |-- Clementine - Jan 25, 1994 - Orber
 - |-- AsiaSat 3/HGS-1 - Dec 24, 1997 - Lunar Flyby
 - |-- Lunar Prospector - Jan 7, 1998 - Orbiter
- 2003
 - |-- SMART 1 - Sep, 2003 - Lunar Orbiter
- 2007
 - |-- Chandrayaan-1 - Sep, 2007 - Lunar Orbiter
 - |-- Chang'e 1 - Sep, 2007 - Lunar Orbiter
 - |-- Kaguya (Selene -)2007 - Lunar Orbiter
- 2008
 - |-- Lunar Reconnaissance Orbiter - Oct, 2008 - Lunar Orbiter
- 2011
 - |--GRAIL - Gravity Recovery and Interior Laboratory - Dec 2011 - Lunar Orbiter

[Luna Program](#) (space is hard)



By the numbers

3500 km diameter

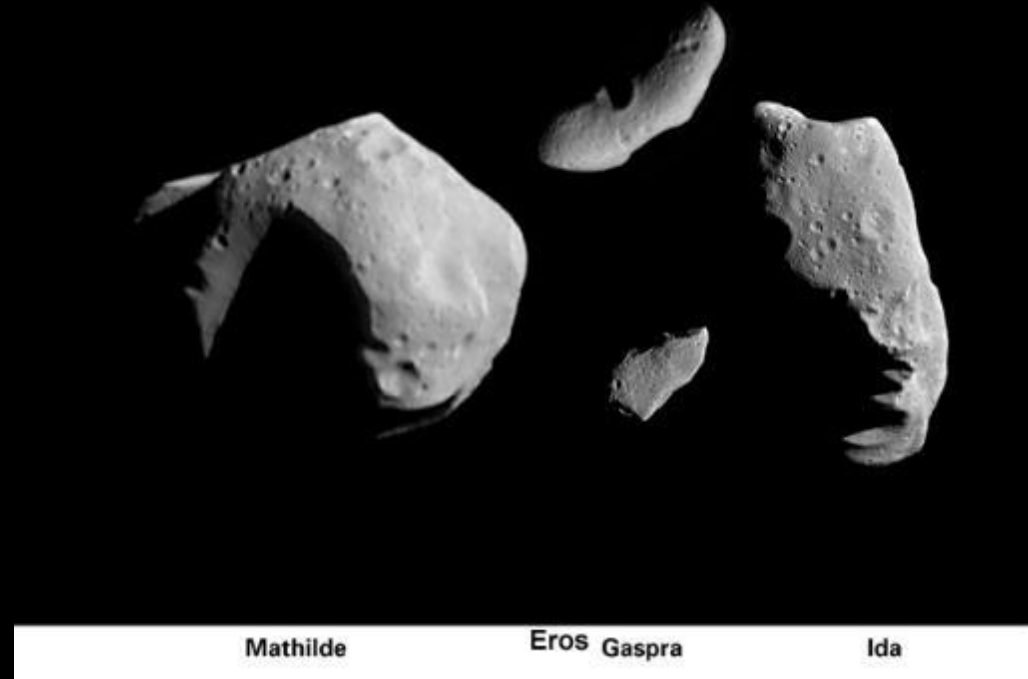
0.01 Mass of Earth

1/6 Gravity

3.3 g/cm³

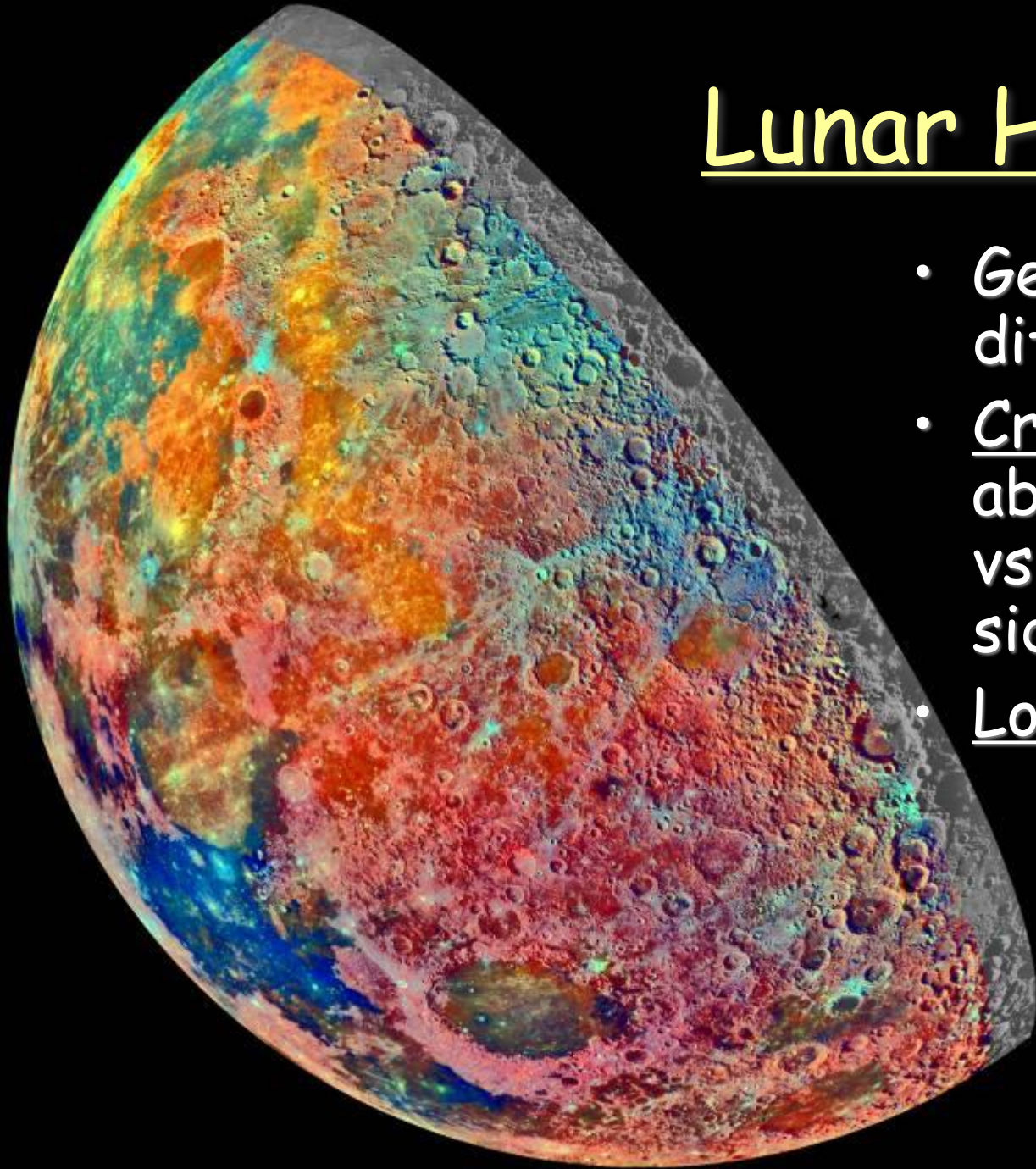
Moon versus Asteroids

- In what way is the Moon like a planet?
- In what ways is it more like an asteroid?





- Two terrain types
- Highlands
- Lowlands-Maria



Lunar Highlands

- Geochemically different
- Crust is thicker about 100 km thick vs 40 km below near side.
- Lots of craters

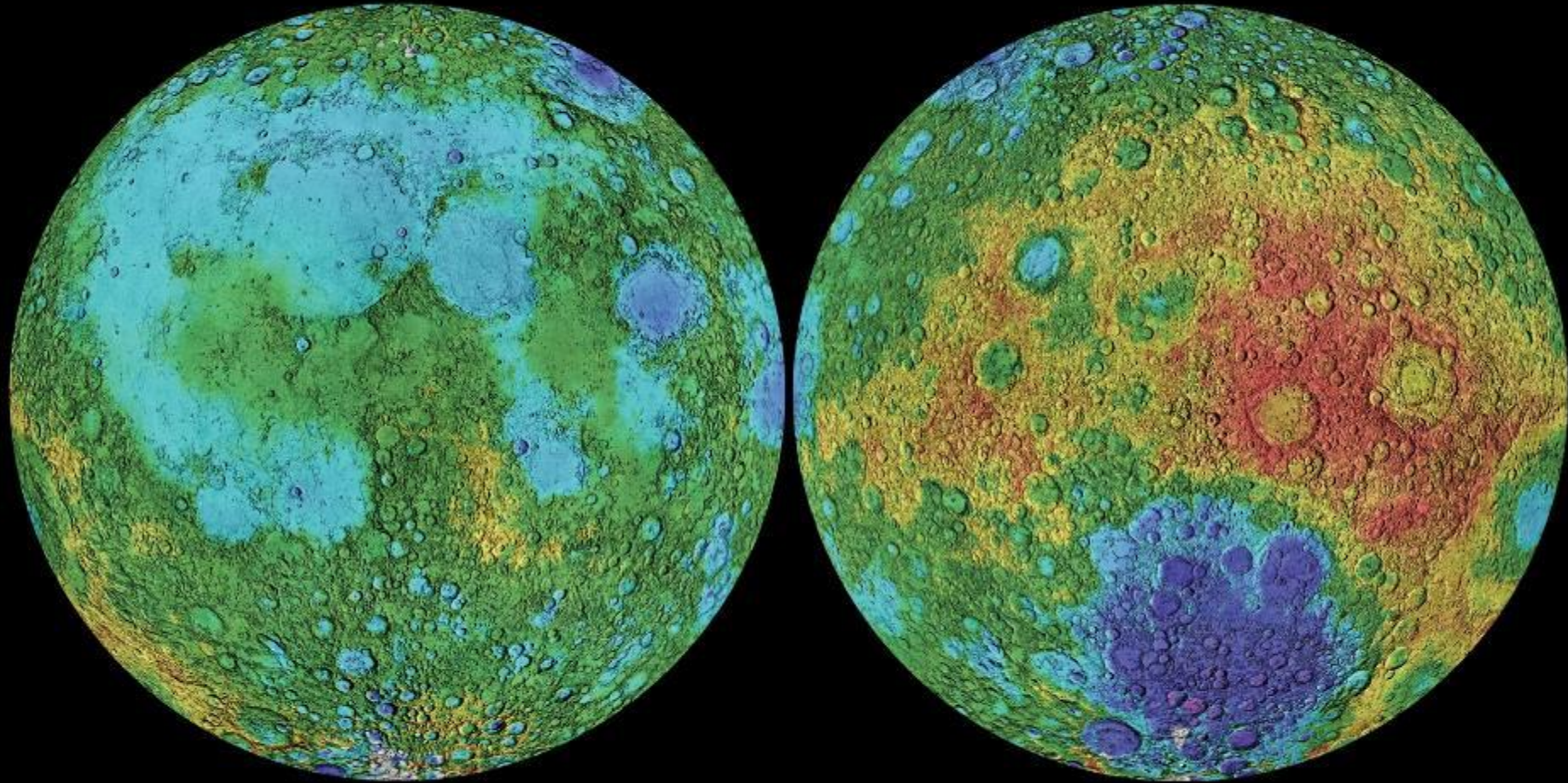




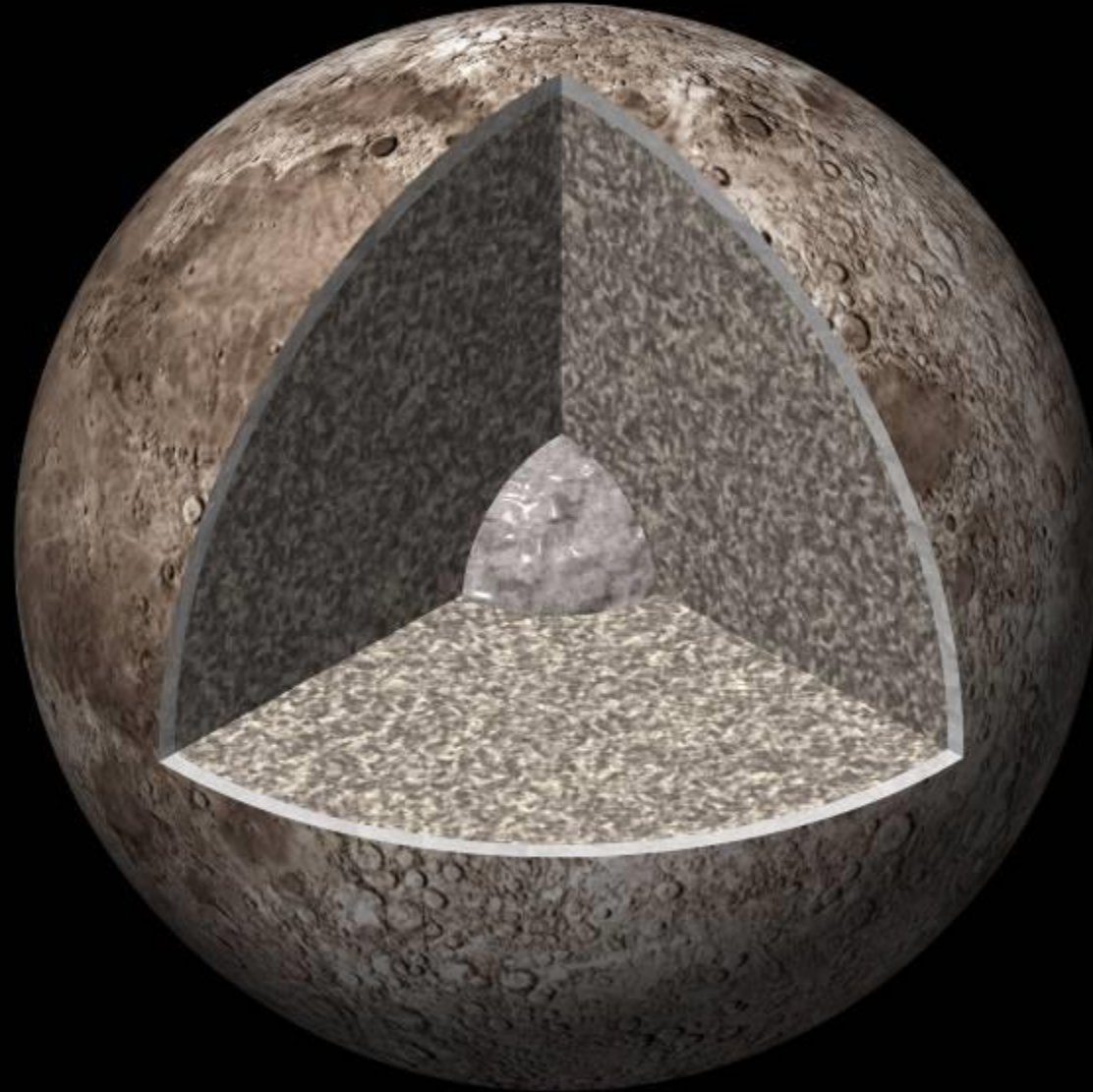
Maria

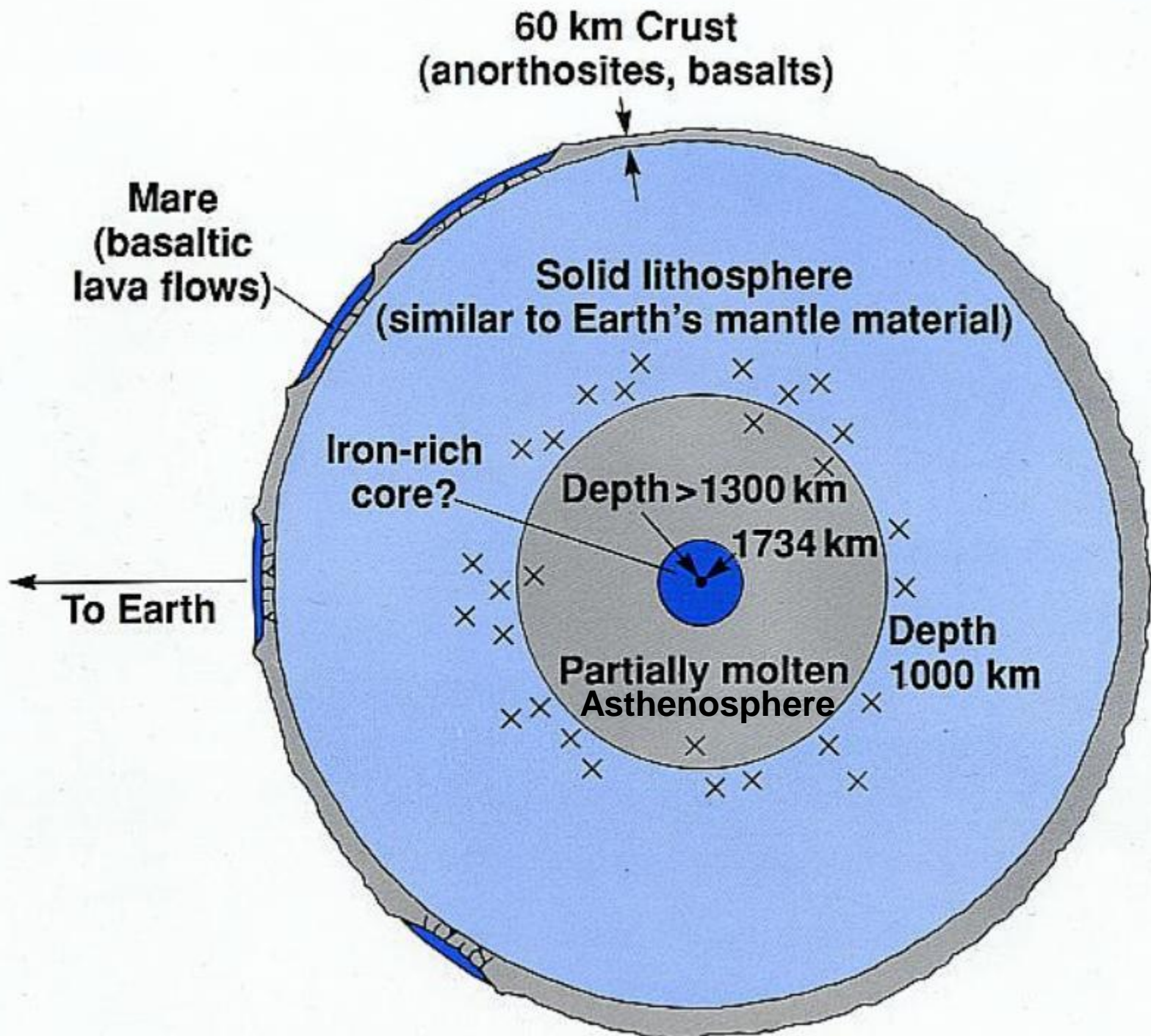
- Dark
- Lowlands
- Nearside
- Thin crust
- Lava plains

Moon's Topography



Moon's Internal Structure







Moon's Origin

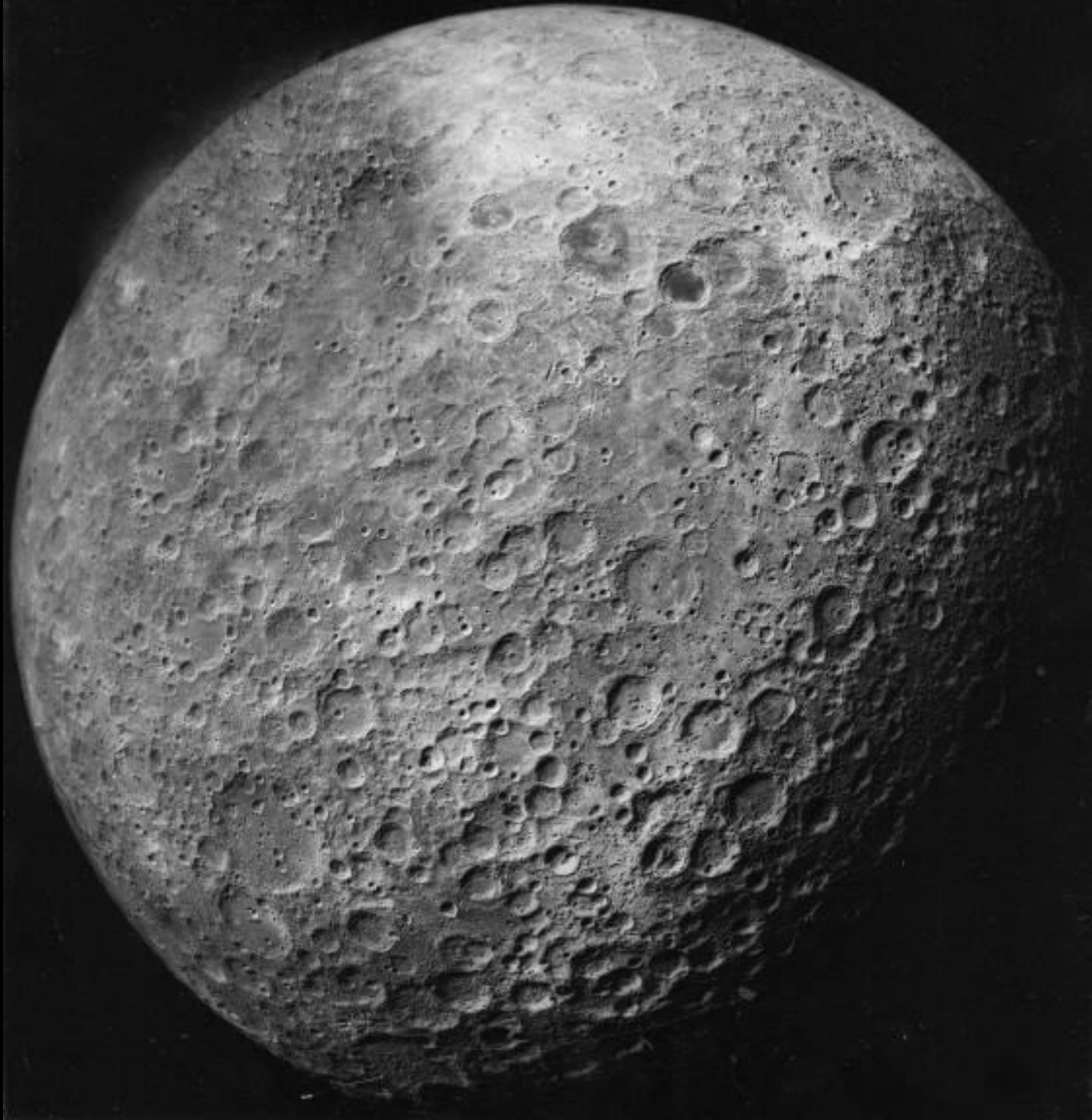


Moon's Origin

Hypothetical Models

- Fission (Just decided to break off one day)
- Co-Accretion (Both formed in same area)
- Capture (A captured asteroid)
- Giant Impact (Blasted off of Earth)

Observations (Not inferences)



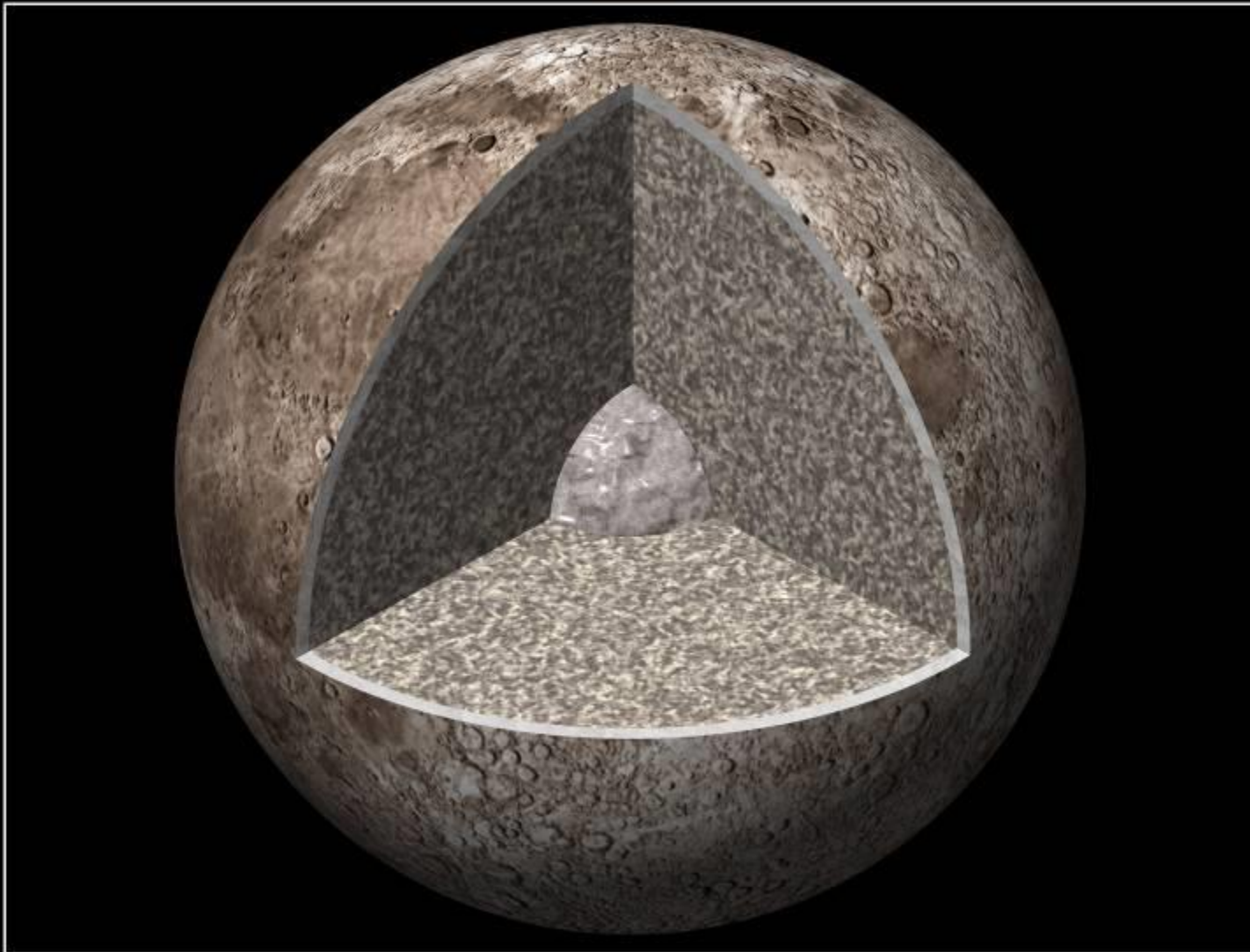
- Moon is Earth's companion
- Moon's composition is similar to Earth's

No water. No atmosphere. Why?

Moon's bulk
chemical
composition is not
exactly like Earth:
Moon poor in
volatiles (water,
gasses, etc).



Small Lunar Core: Why?



Moon rich in rocky material but iron poor.

Origin of the Moon

Hypothetical Models

- Fission
- Co-Accretion
- Capture
- Giant Impact

Observations

- Moon's average composition is like Earth's and unlike meteorites
- It is water and **volatile** poor
- Moon is rich in most rocky elements
- But Moon is iron poor



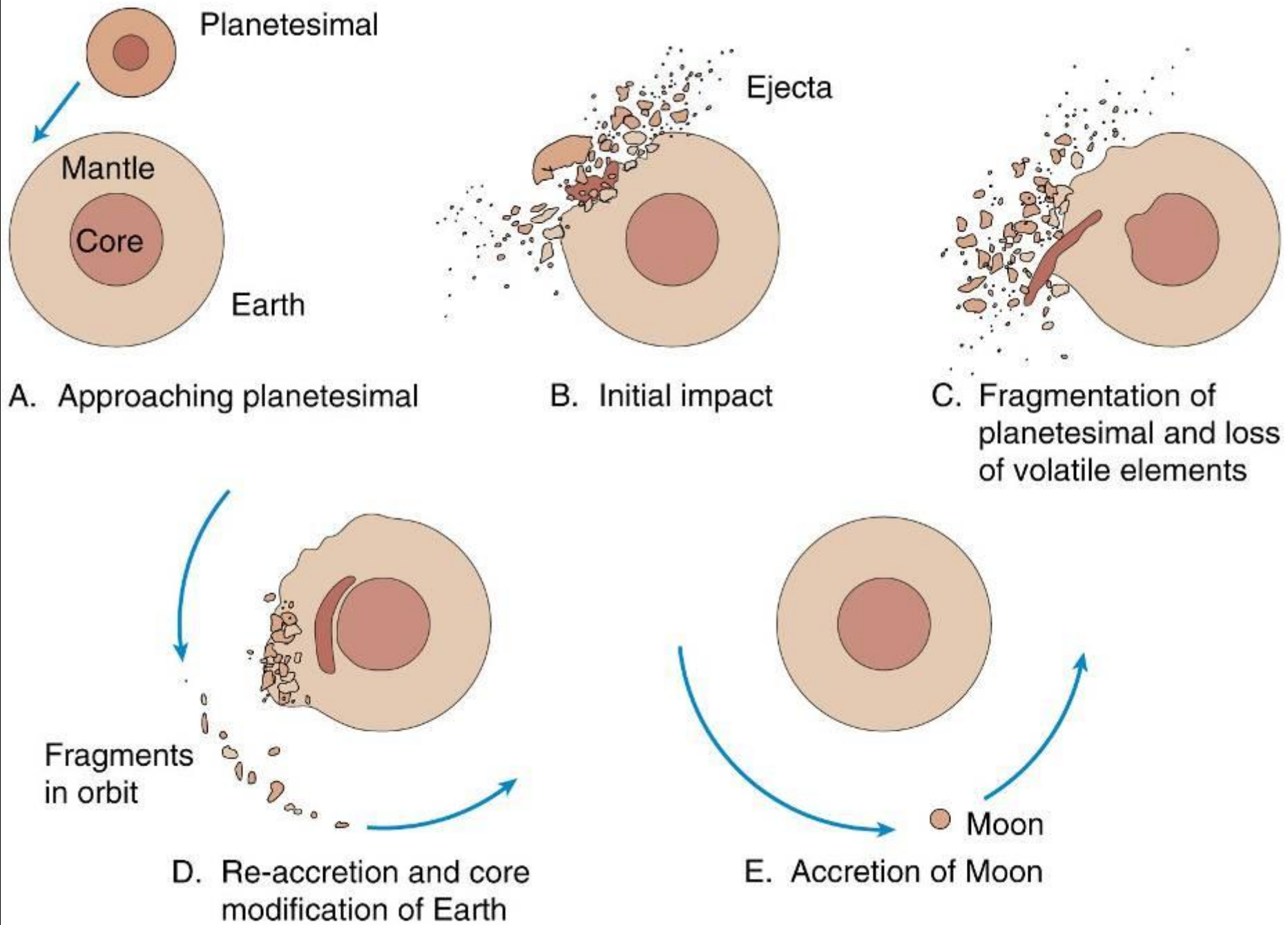
Giant Impact

Proposed by
Hartmann and
Davis, 1975

Cameron and
Ward, Thompson
and Stevenson

Debated in Kona,
1984 - "most
successful meeting
in planetary
science" - Drake

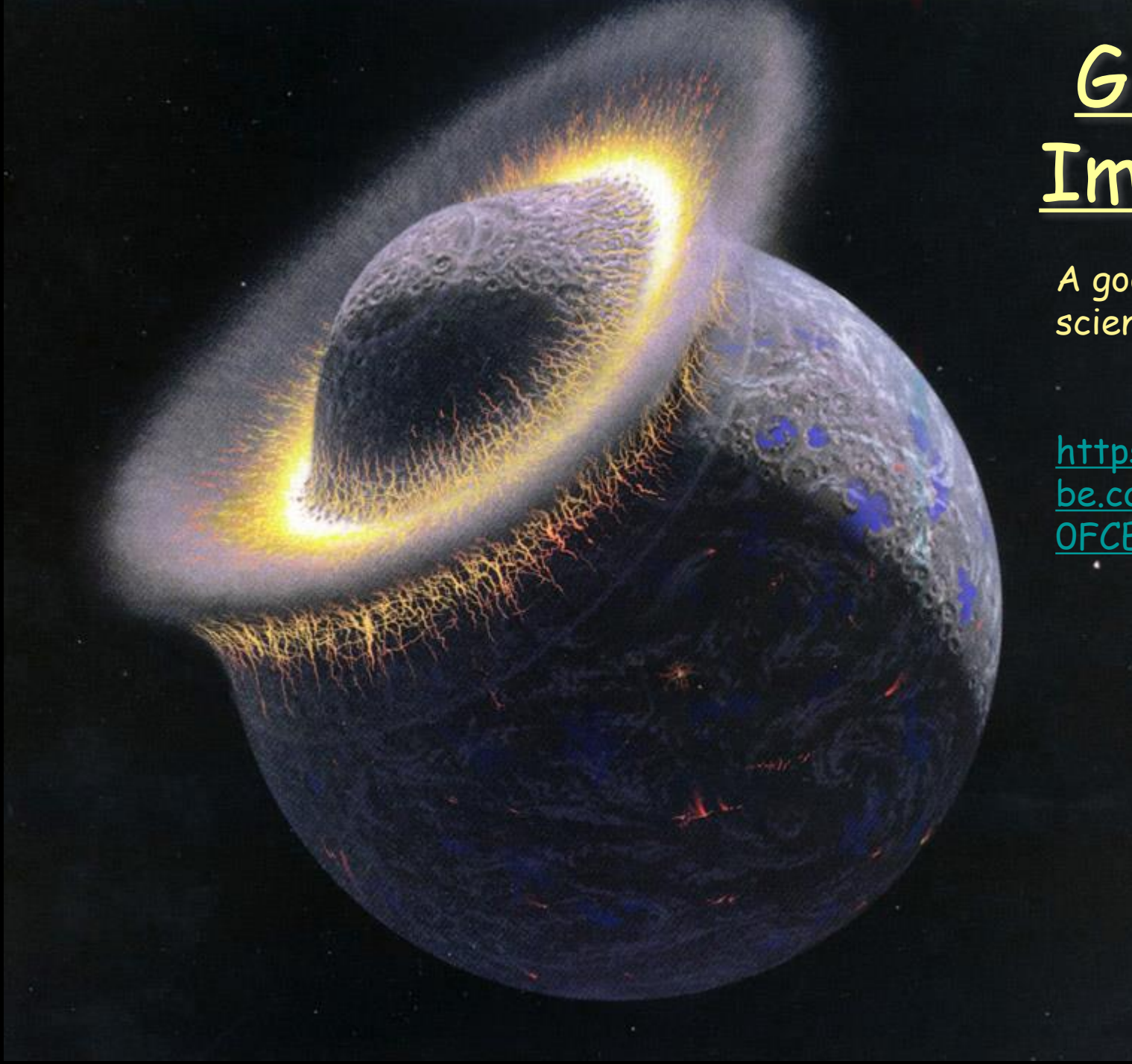
Modeled (Melosh,
etc.) and published
1986



Giant Impact

A good example of
science in action

<https://www.youtube.com/watch?v=c0FCE4H0Dro>



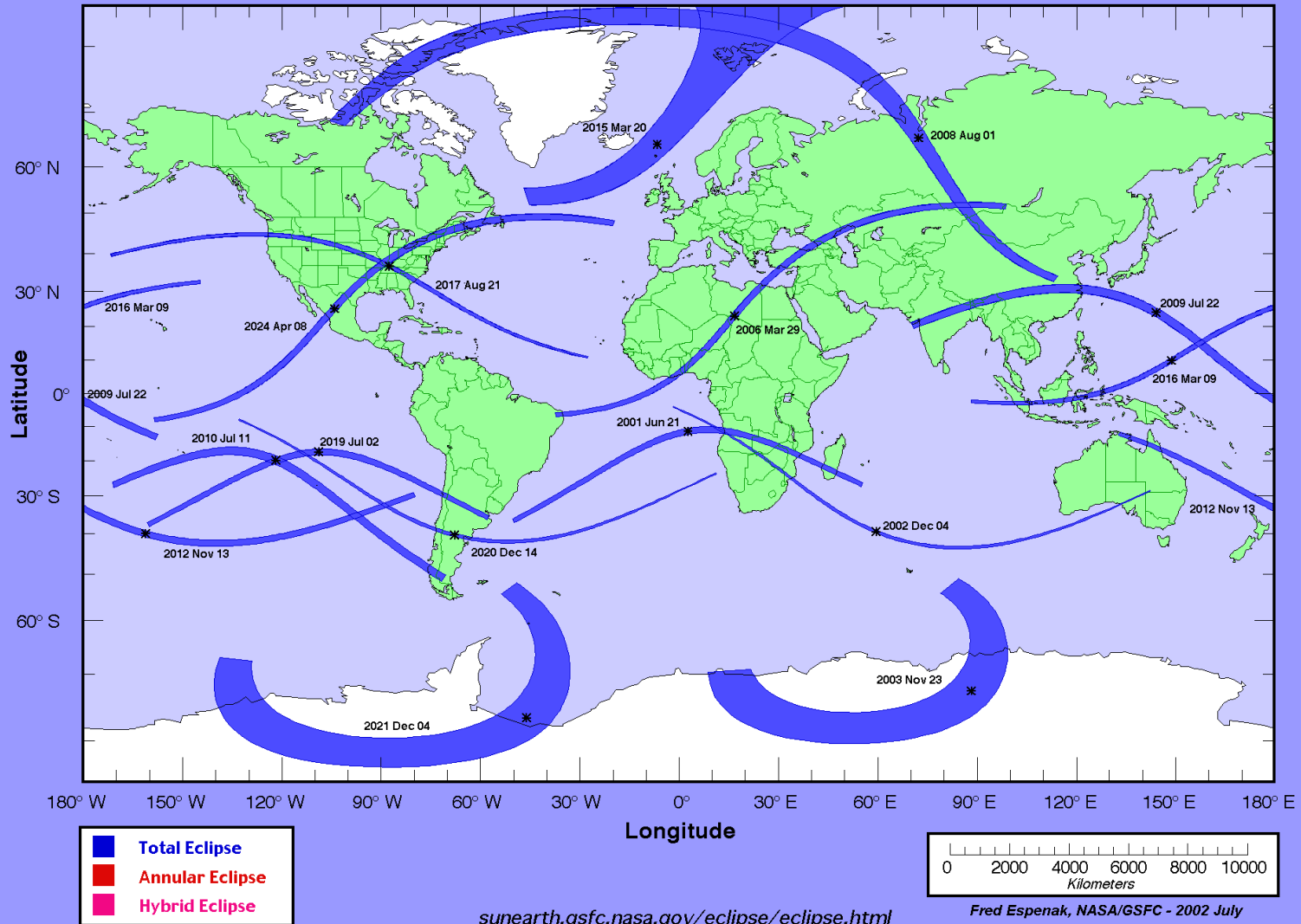
Earth, Sun, and Moon model

Lunar Eclipses



Solar Eclipses

Total Solar Eclipse Paths: 2001–2025



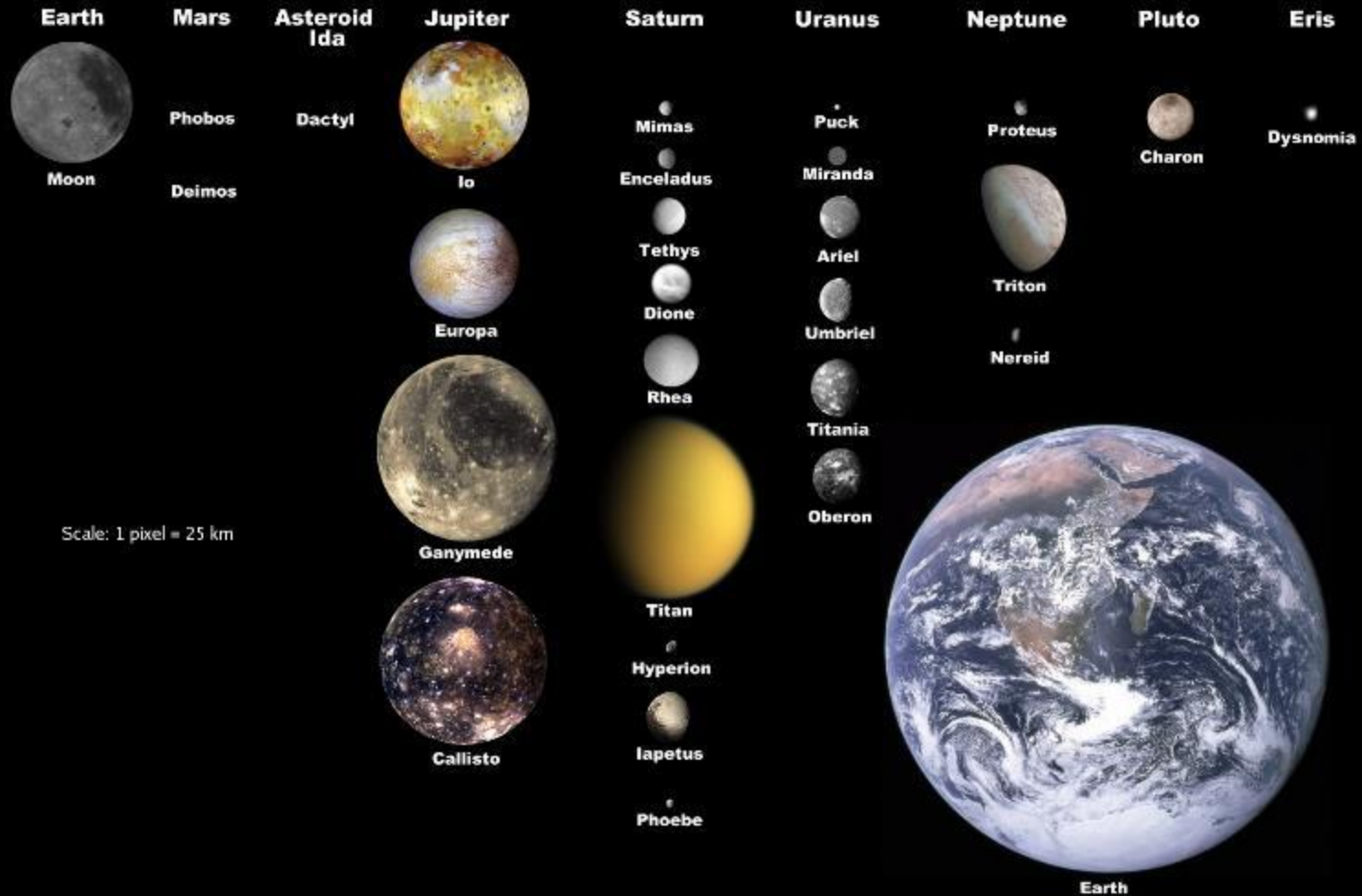
Annular Vs. Total



Moon = Only other body in Solar System besides Earth that Humans have been on.

OTHER MOONS IN THE SOLAR SYSTEM

Selected Moons of the Solar System, with Earth for Scale



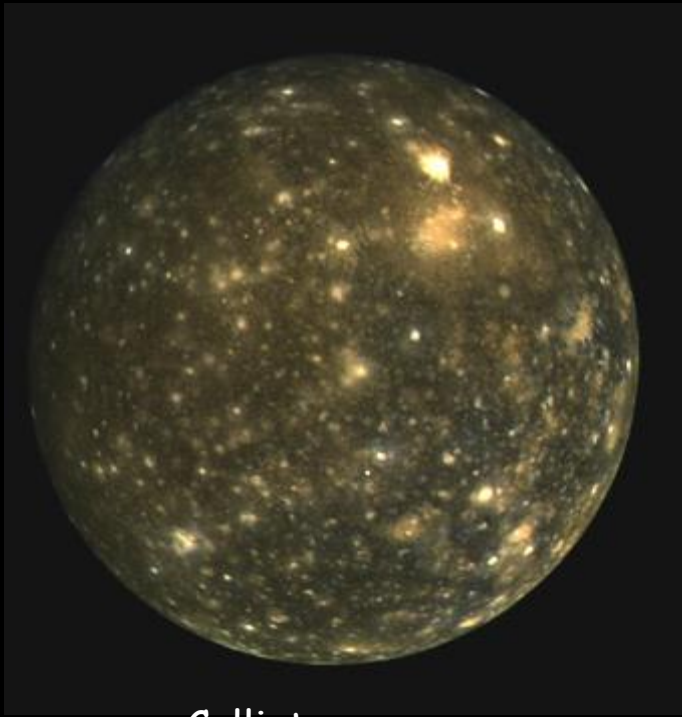


MARS' MOONS



1. Mars has two moons.
2. We think both were asteroids captured by Mars.
3. Very small, very insignificant.
4. Phobos will one day be ripped apart by Mars' gravity, giving Mars a small ring.
5. Deimos will eventually escape Mars' hold on it and fly away.

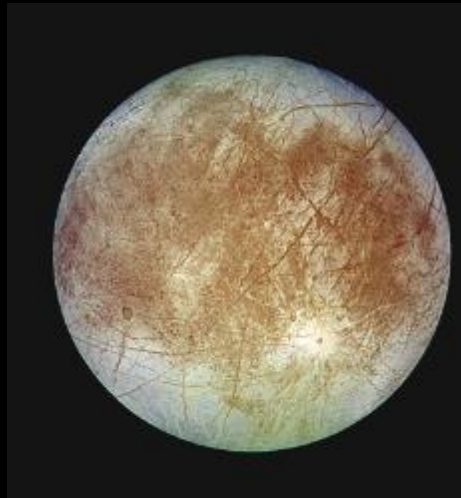
Jupiter's Moons



Callisto



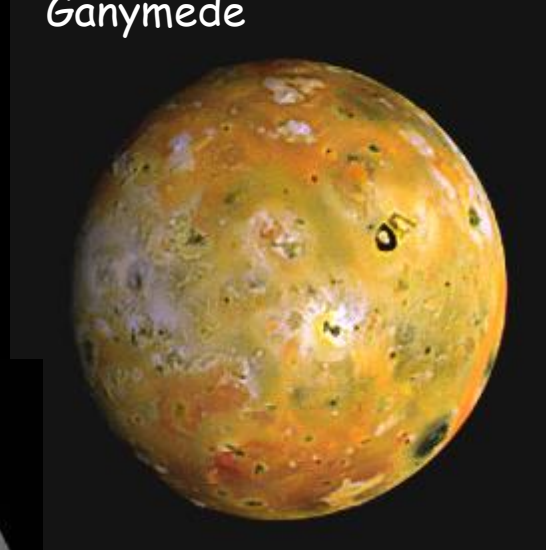
Ganymede



Europa



Mercury



Io

Ganymede



Ganymede

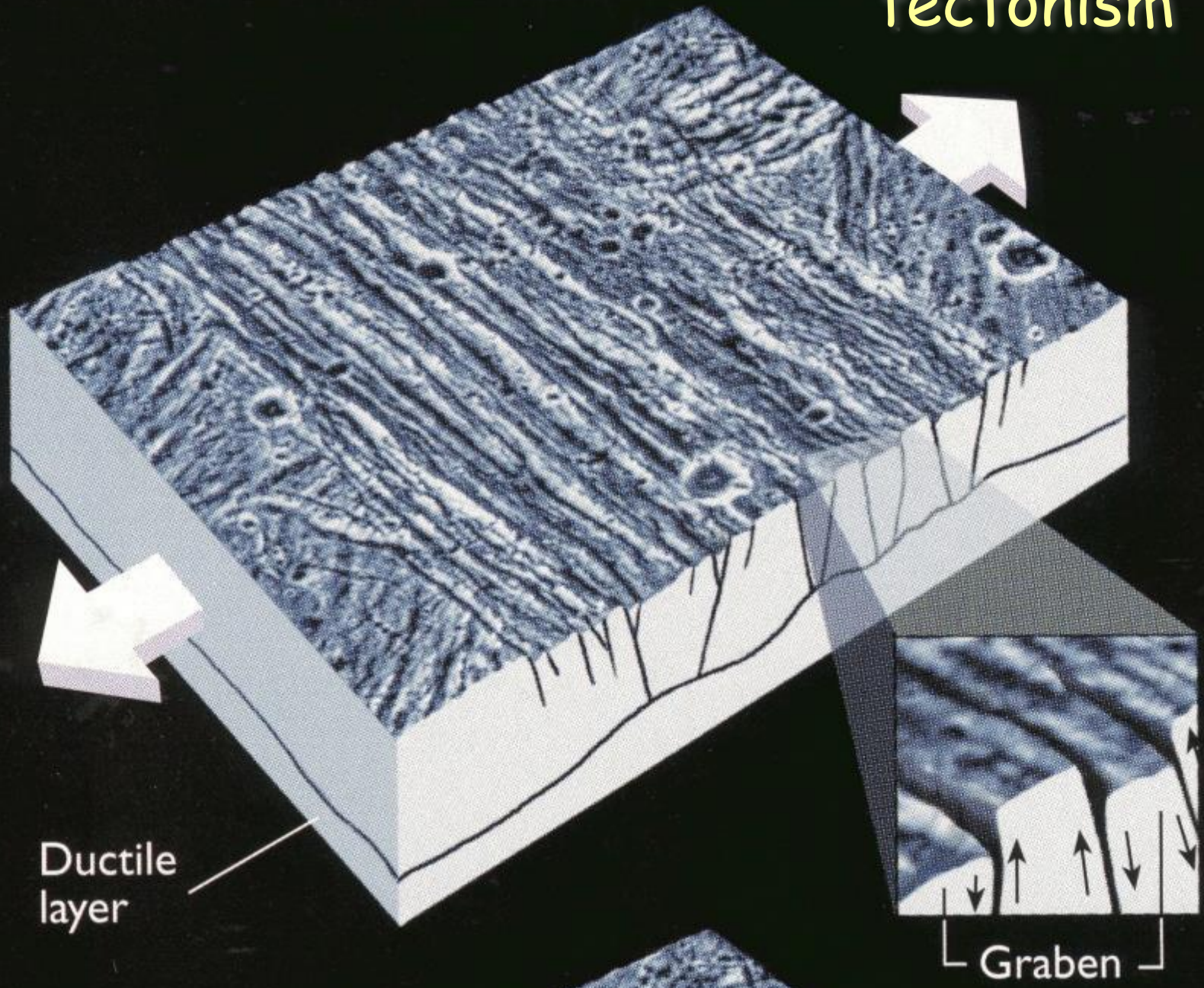


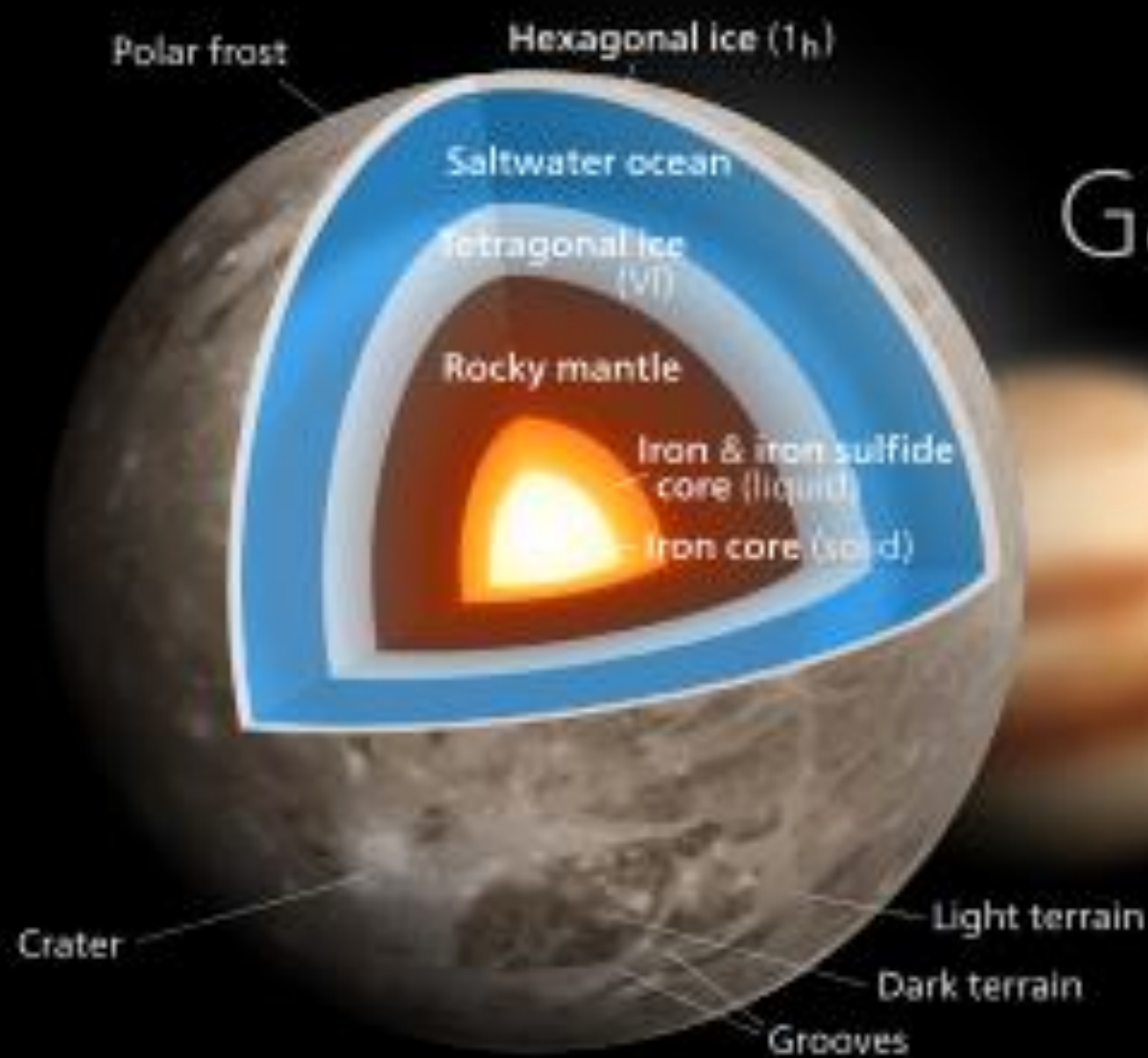
- . Biggest Natural Satellite in the Solar System
- . Cratered

Light and dark terrain



tectonism

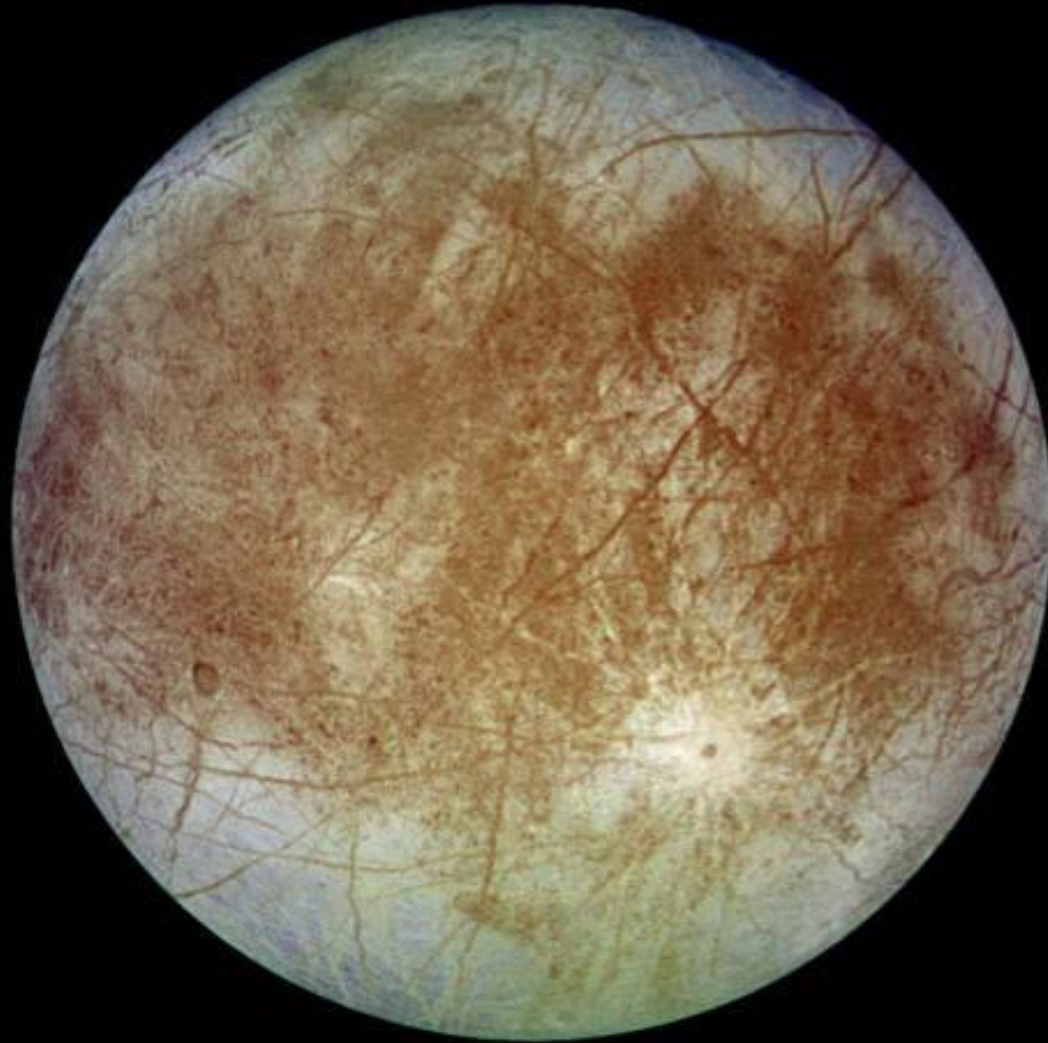


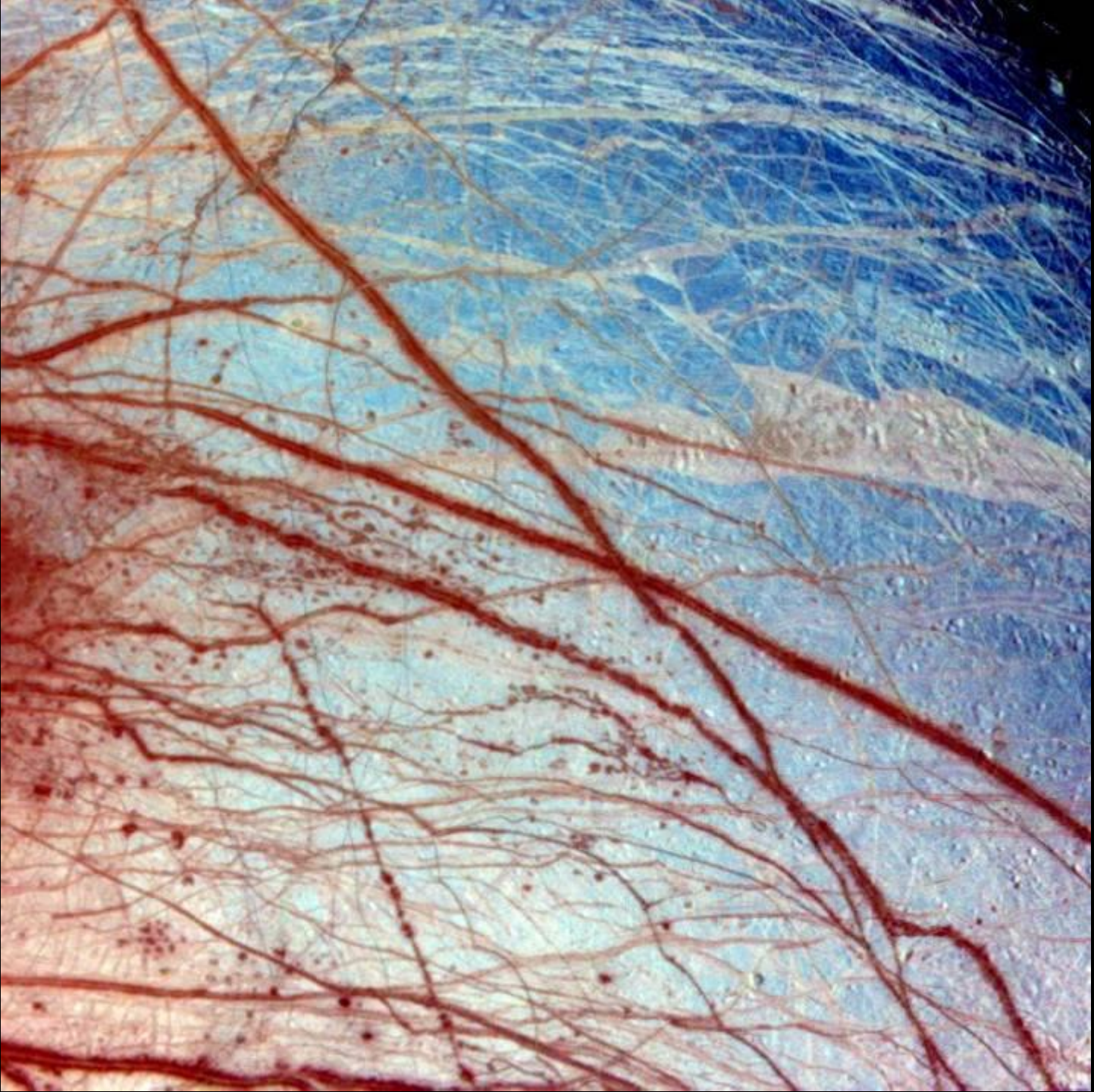


Ganymede

layers drawn to scale

Europa





False color

What do you notice?



Upwellings? -
Water seeping
up through
cracks.