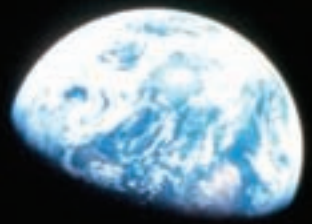
Lunar History



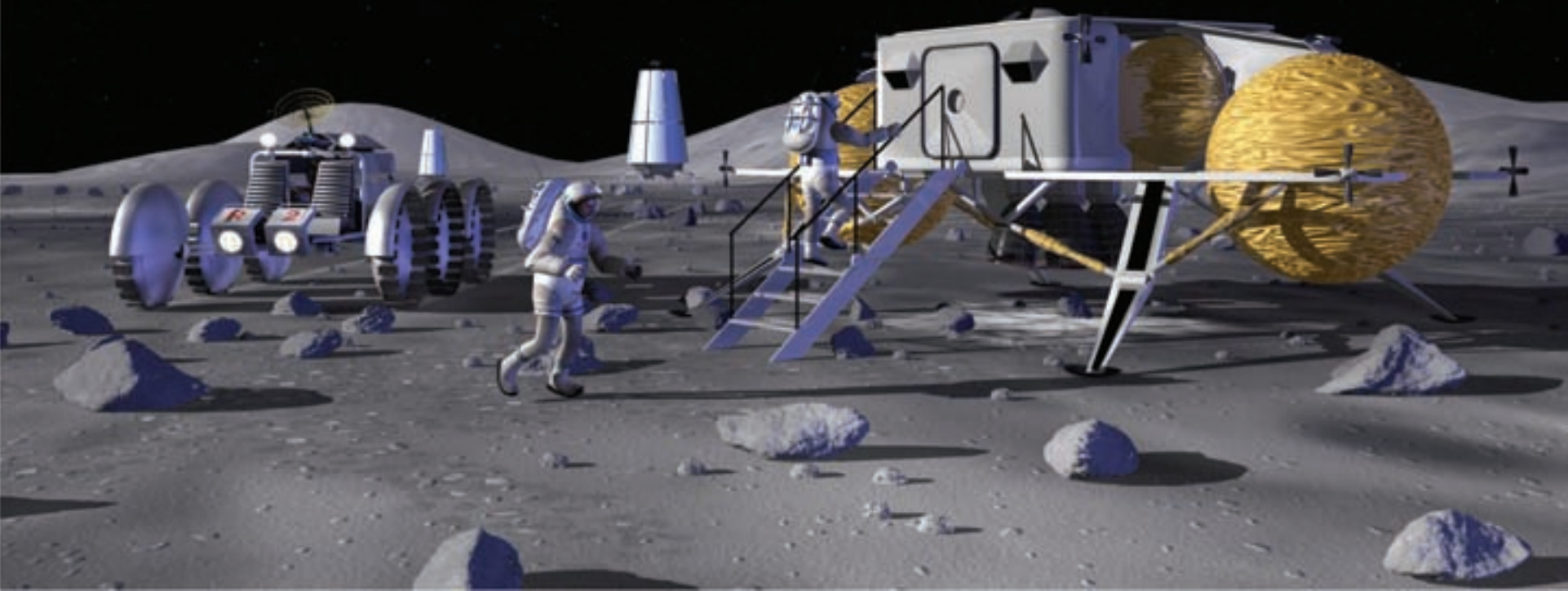
Dr. Jennifer Edmunson

March 17, 2009

Why is it important for engineers and simulant users to understand lunar history?

Because…

It explains the motivation for the exploration of the Moon



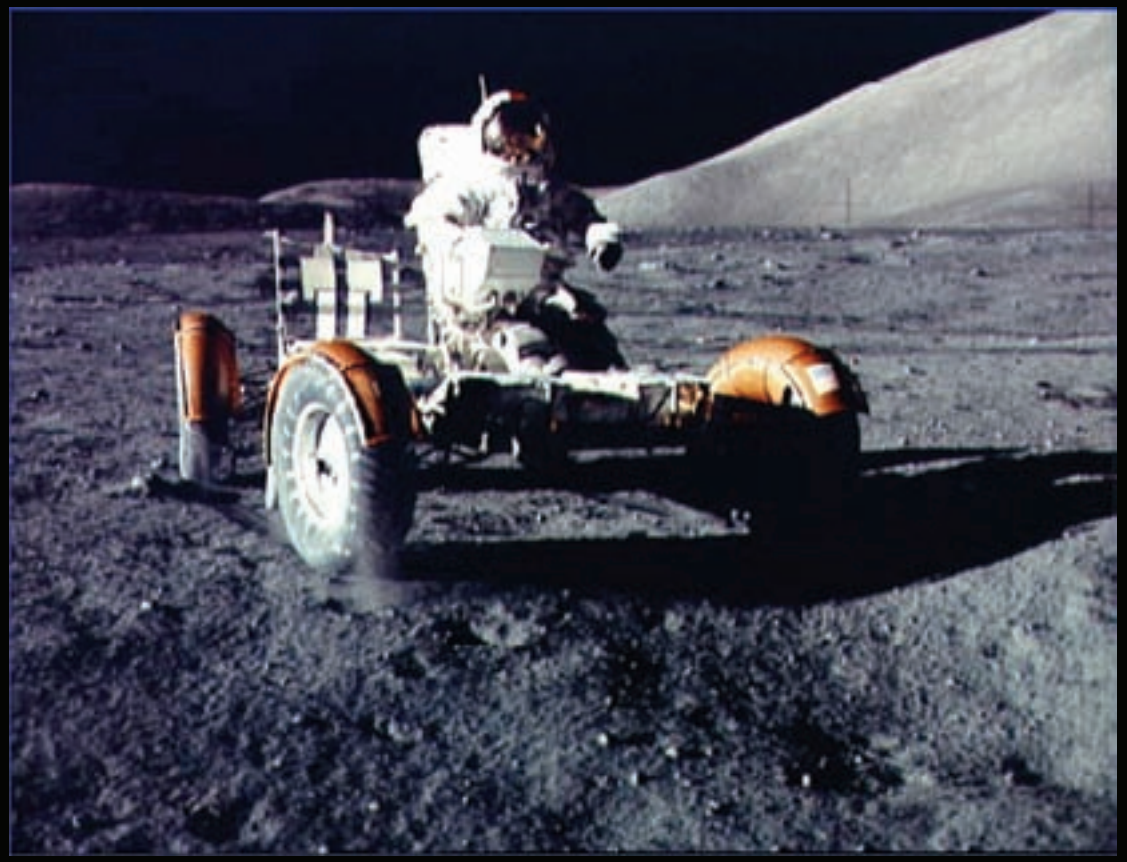
Earth is Dynamic

- Plate Tectonics
  - Surface is constantly recycled
- Water
  - Weathering of the surface
  - Breakdown of rocks and minerals
- Atmosphere
- Life!
  - Vegetation, animals

The Moon is Static

- Rock formation 4.5-2.8 billion years ago
- Major craters formed ≥ 3.9 billion years ago
- The Moon serves as a window into the early experiences of our own planet
- By understanding lunar history, we may better understand the history of Earth

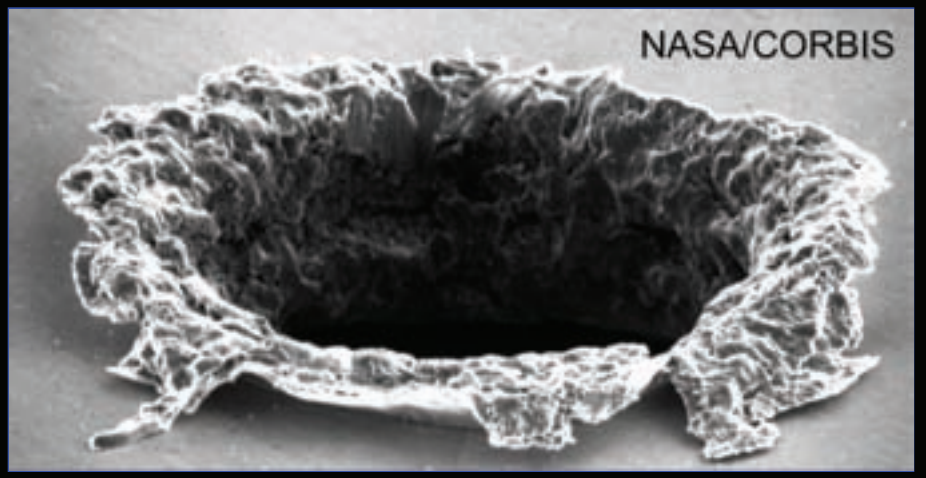
It explains the origin of the operating environment for spacecraft



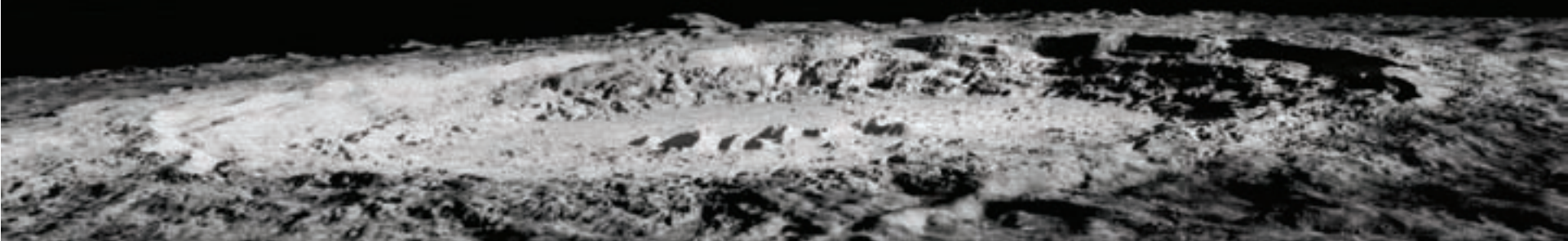
It describes hazards to humans and spacecraft

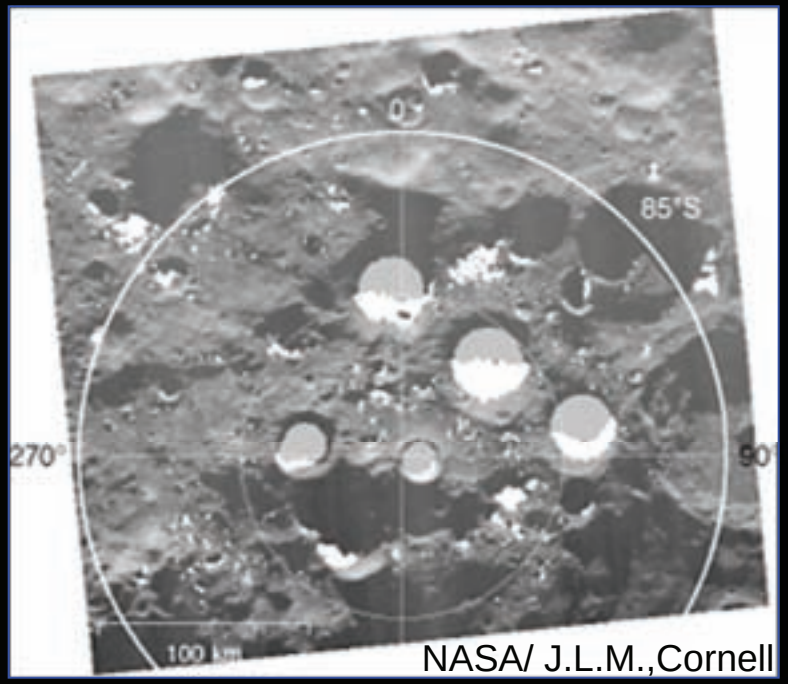
Regolith

Micrometeorites



Morphology

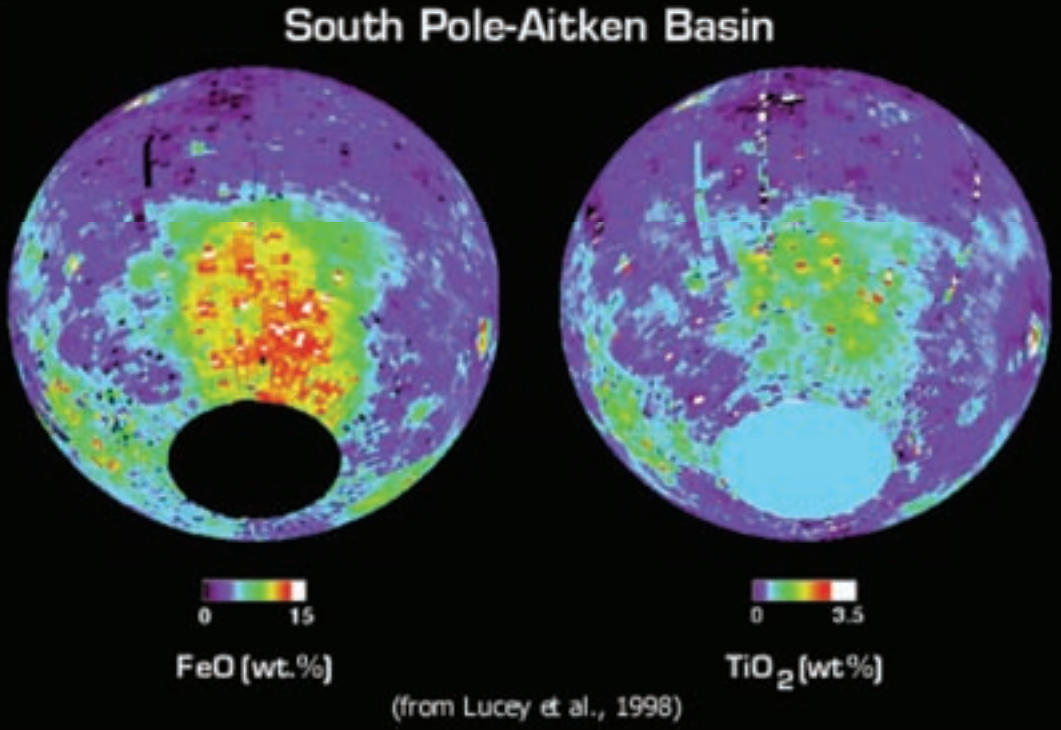




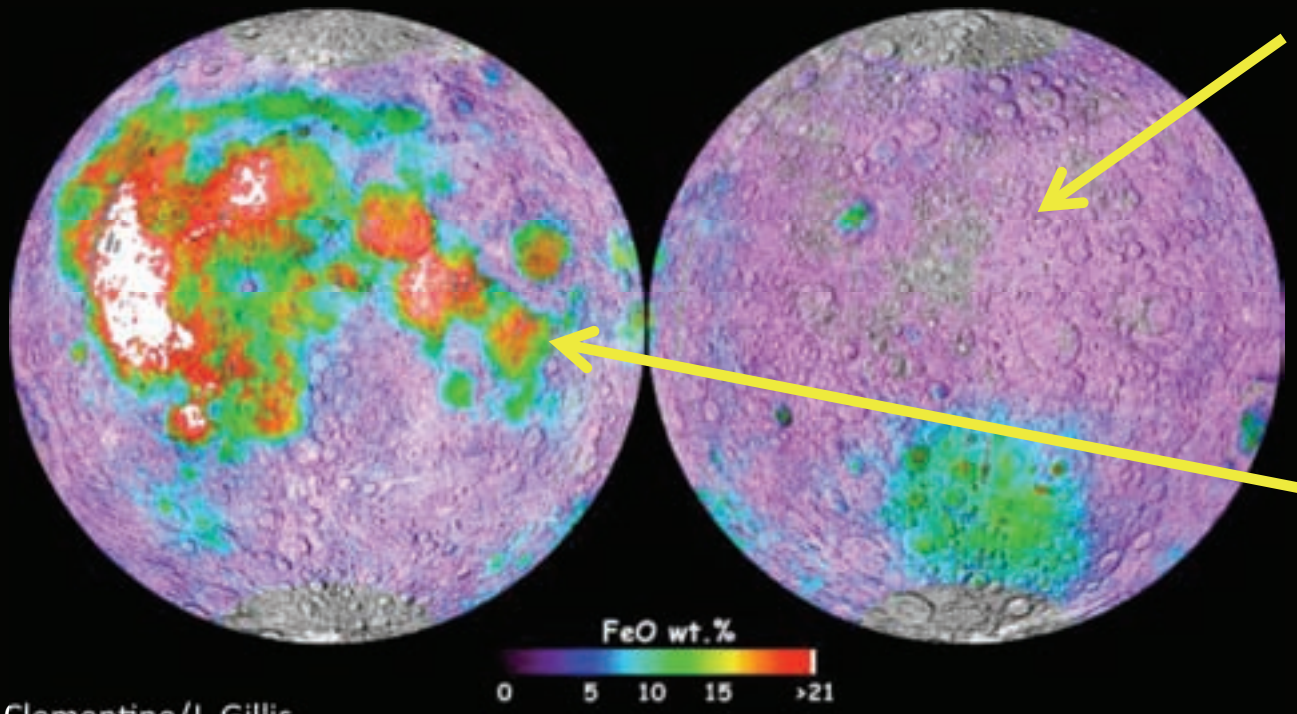
NASA/ J.L.M.,Cornell

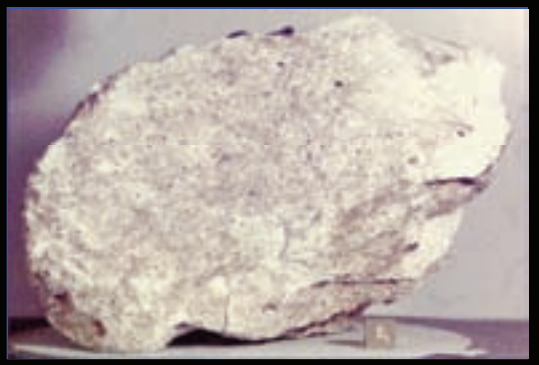
Permanent Shadow Volatiles

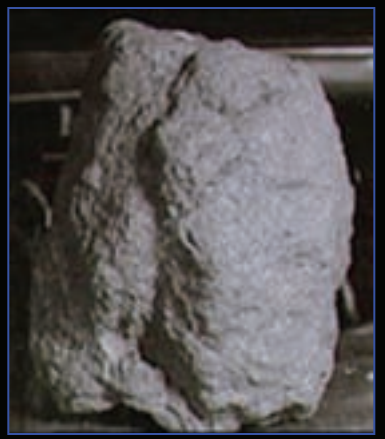
It influences landing site locations



It provides the basis for predicting the chemical composition of the lunar surface at specific sites



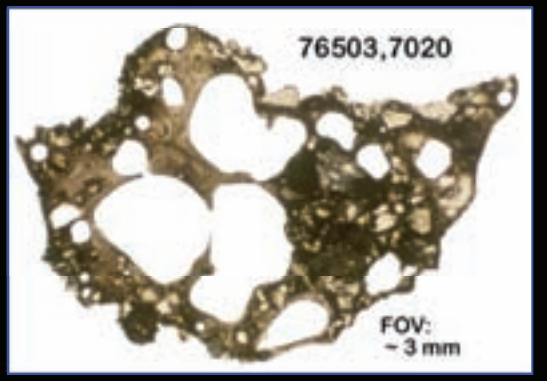




It explains the origin of the regolith

False color image of Meteor Crater, AZ (Infrared) J. Garvin

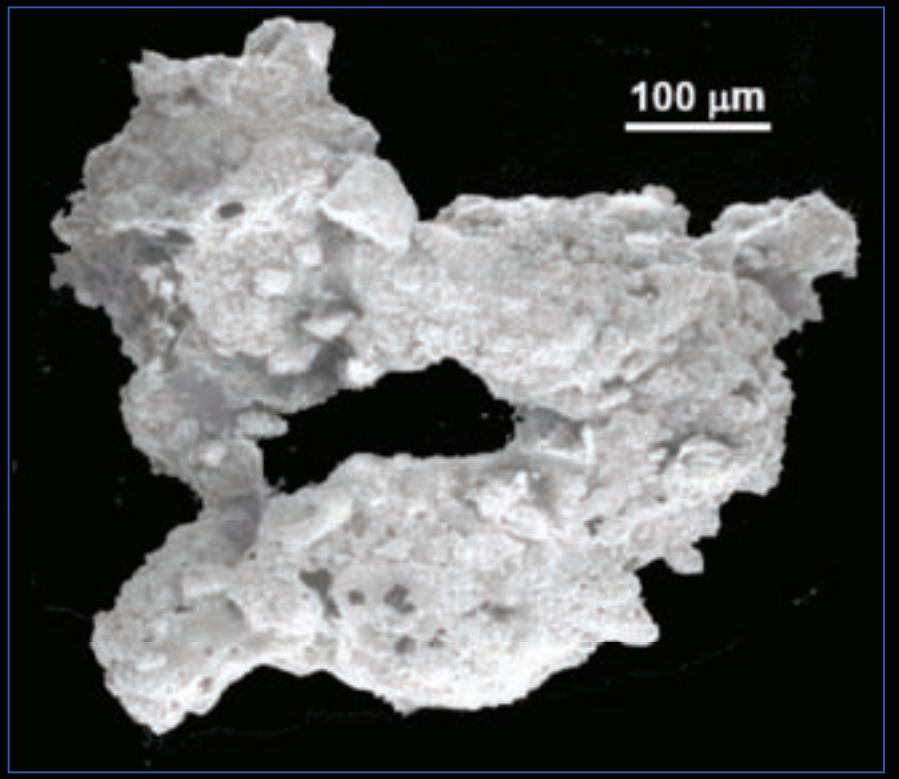
Albedo



Agglutinates

B. Jolliff

It explains the size distribution of regolith components



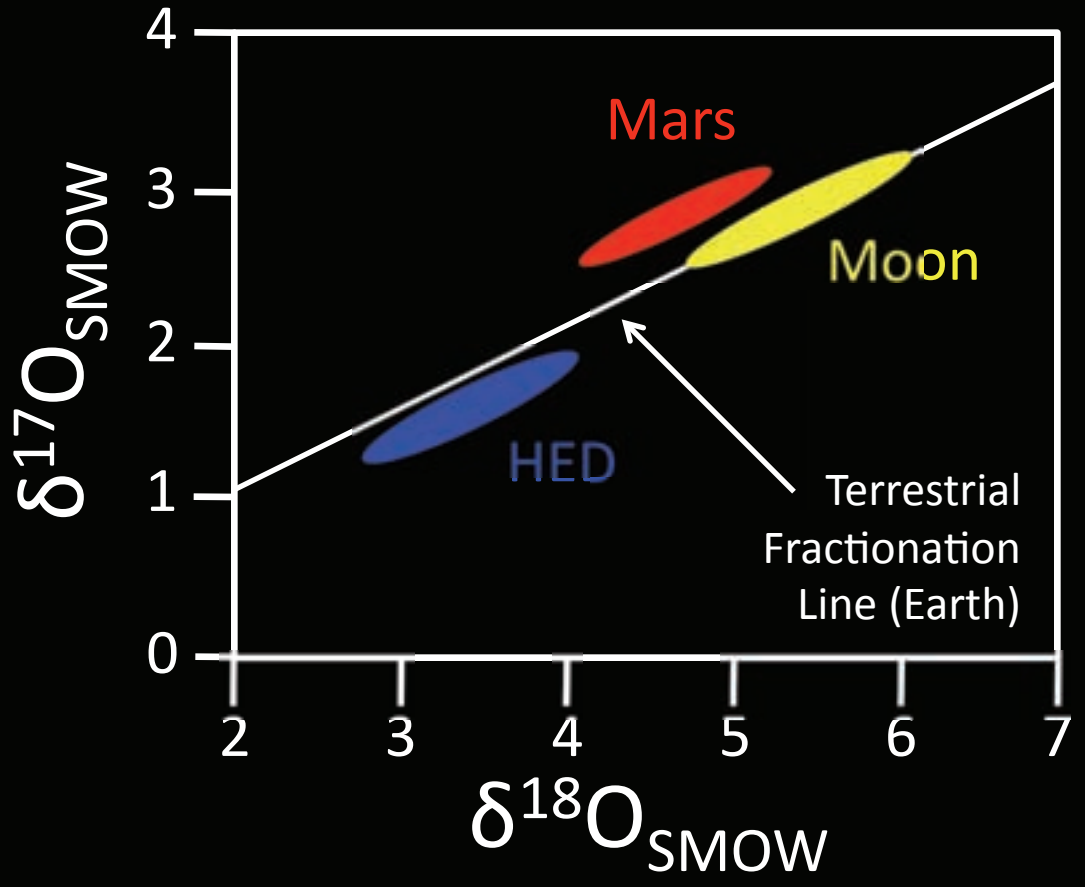
Boulders and agglutinates

D. S. McKay

Formation of the Moon

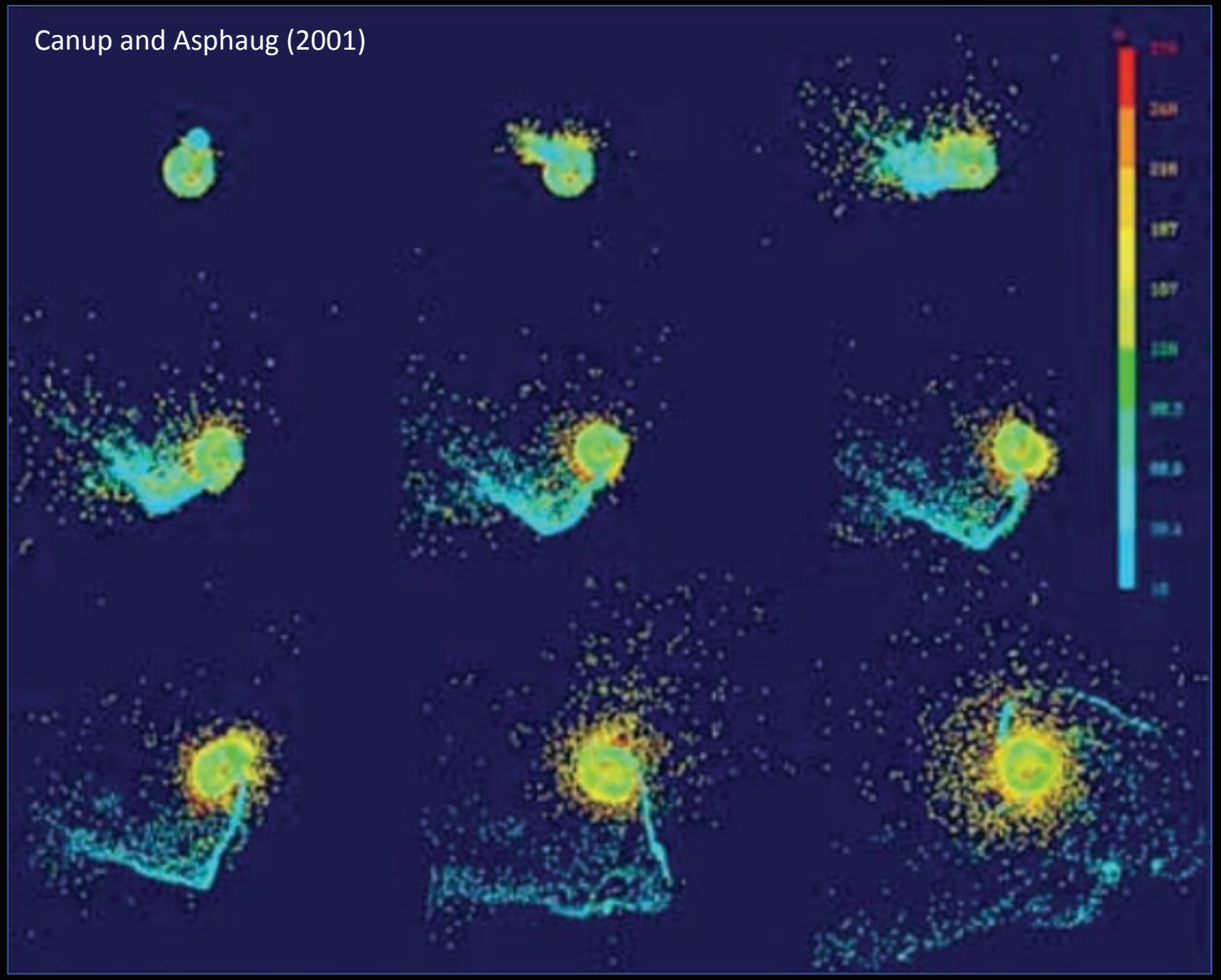
Earth and Moon:

- Similar chemistry
- Oxygen isotope signature
- Unique angular momentum

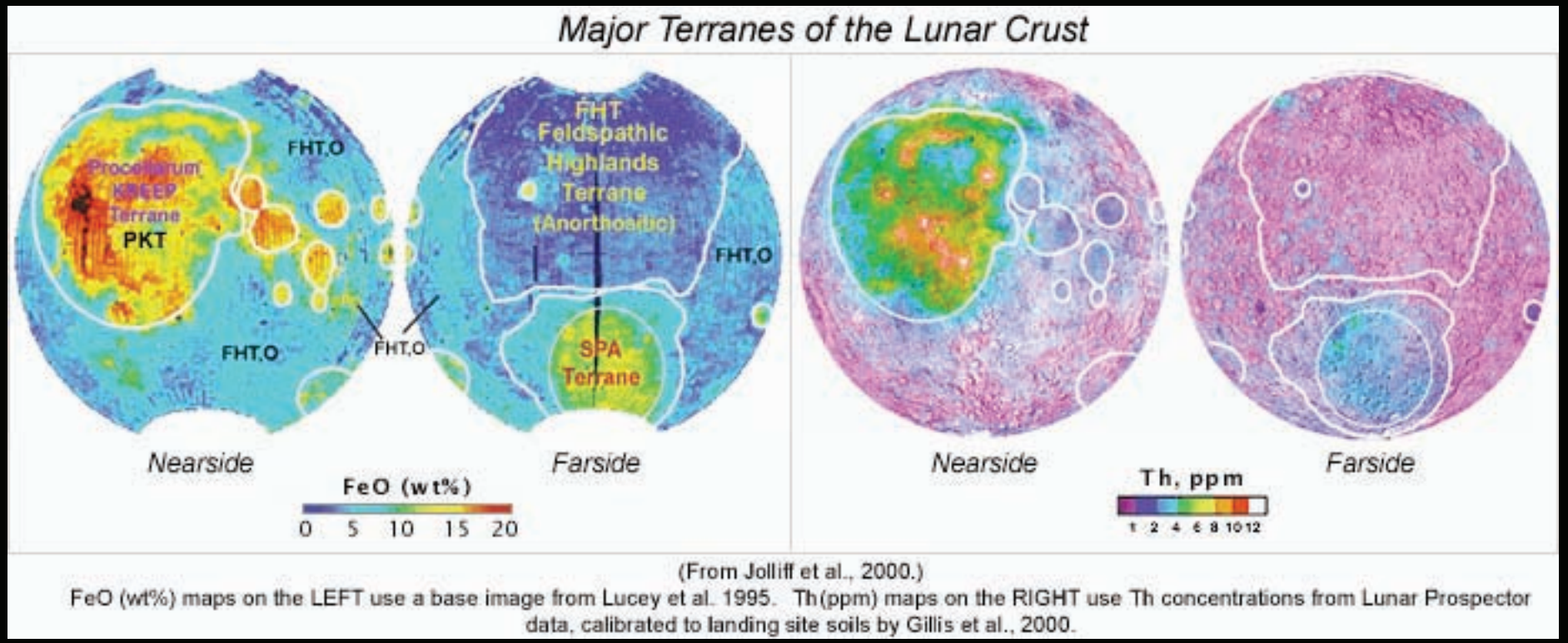


Modified from J. M. Saxon, U Manchester/R. N. Clayton, U Chicago. Values in per million.

Lunar History



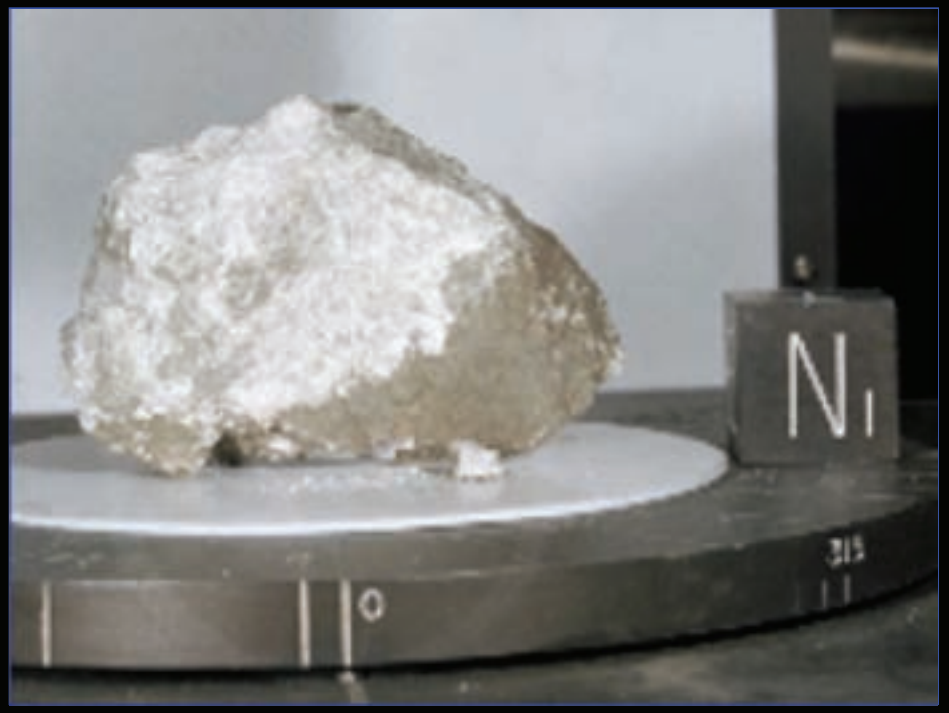
Lunar History



(From Jolliff et al., 2000.)
FeO (wt%) maps on the LEFT use a base image from Lucey et al. 1995. Th(ppm) maps on the RIGHT use Th concentrations from Lunar Prospector data, calibrated to landing site soils by Gillis et al., 2000.

Pixel size 60km (38 miles)

Highlands Lithologies

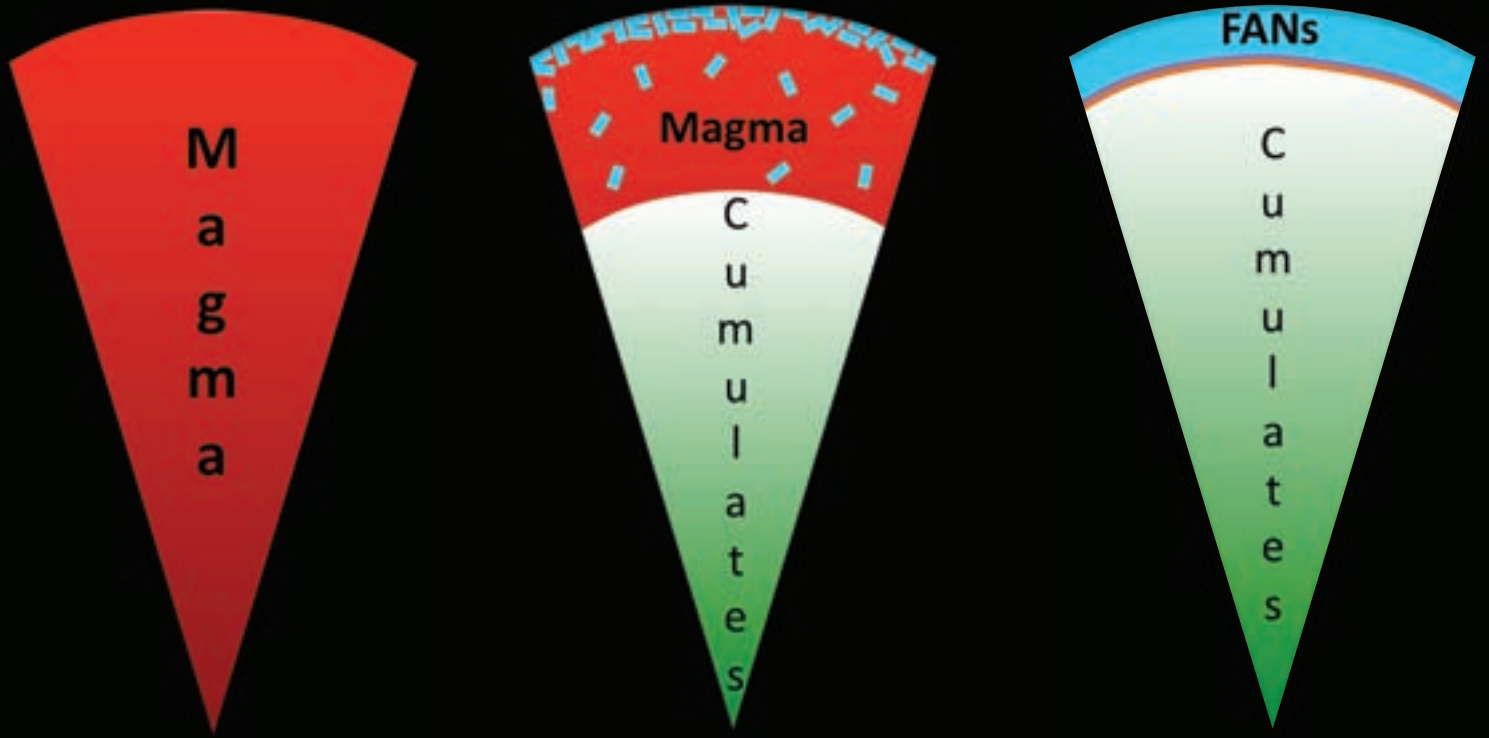


Anorthosite 15415
“The Genesis Rock”

Mg-suite norite
78236

KREEP

Ilmenite Cumulates

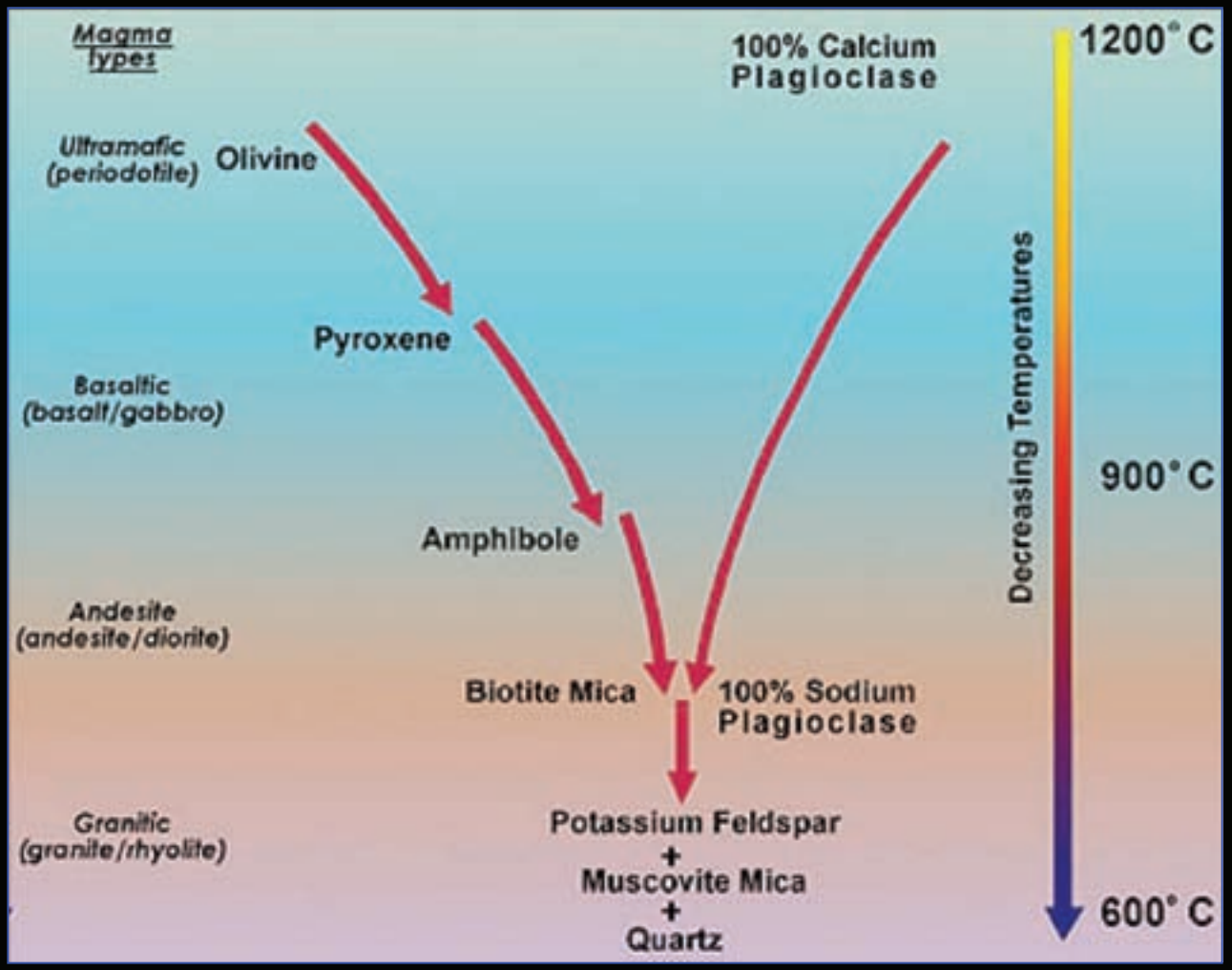


78 PCS

100 PCS

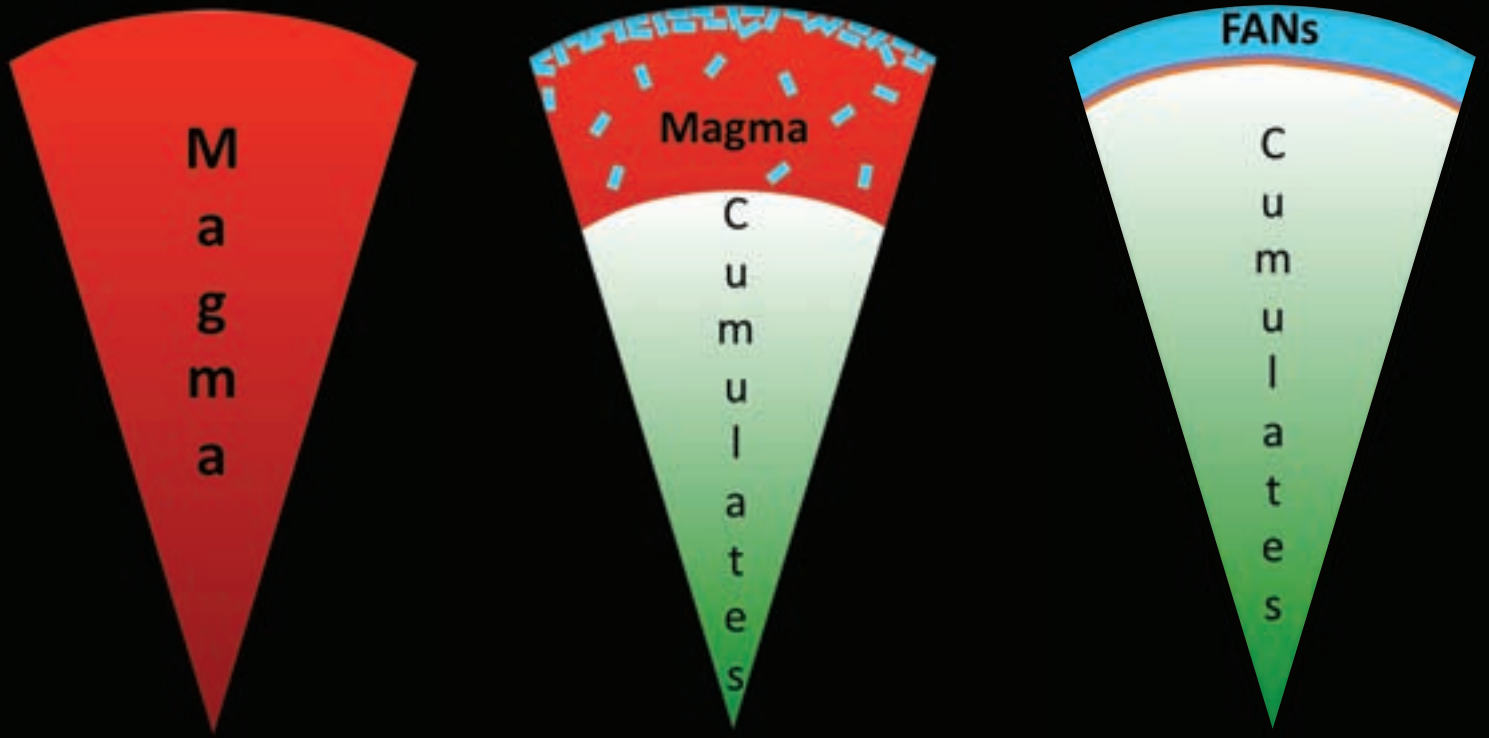
Snyder et al. (1992)

Bowen's Reaction Series



KREEP

Ilmenite Cumulates



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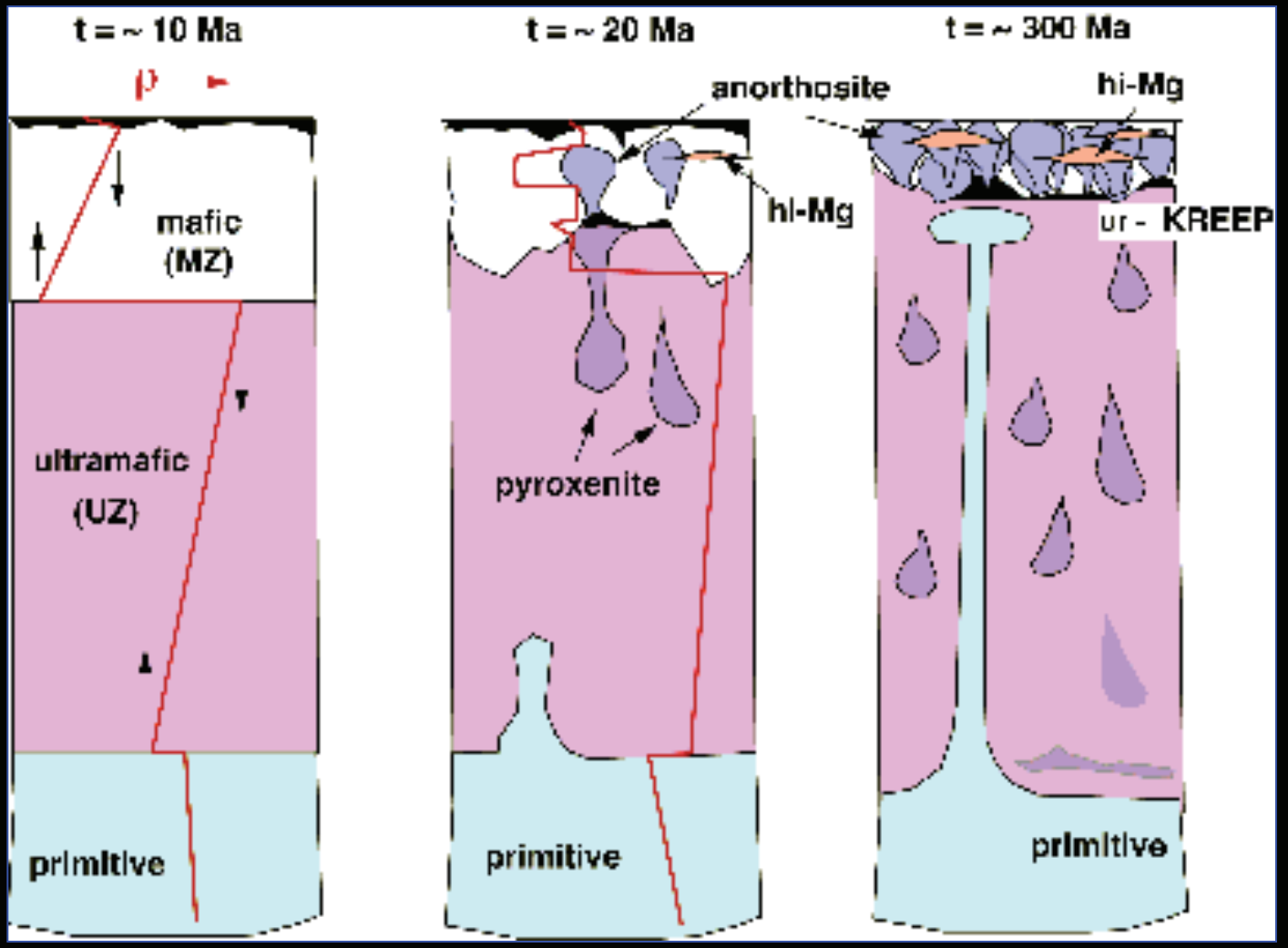
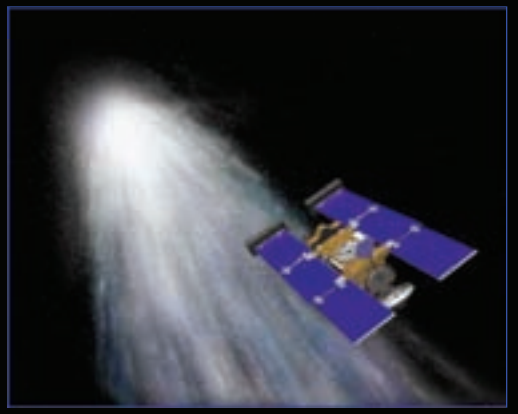
Snyder et al. (1992)

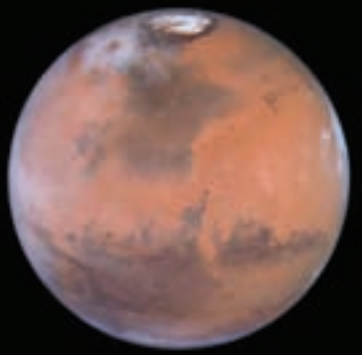
Lunar History

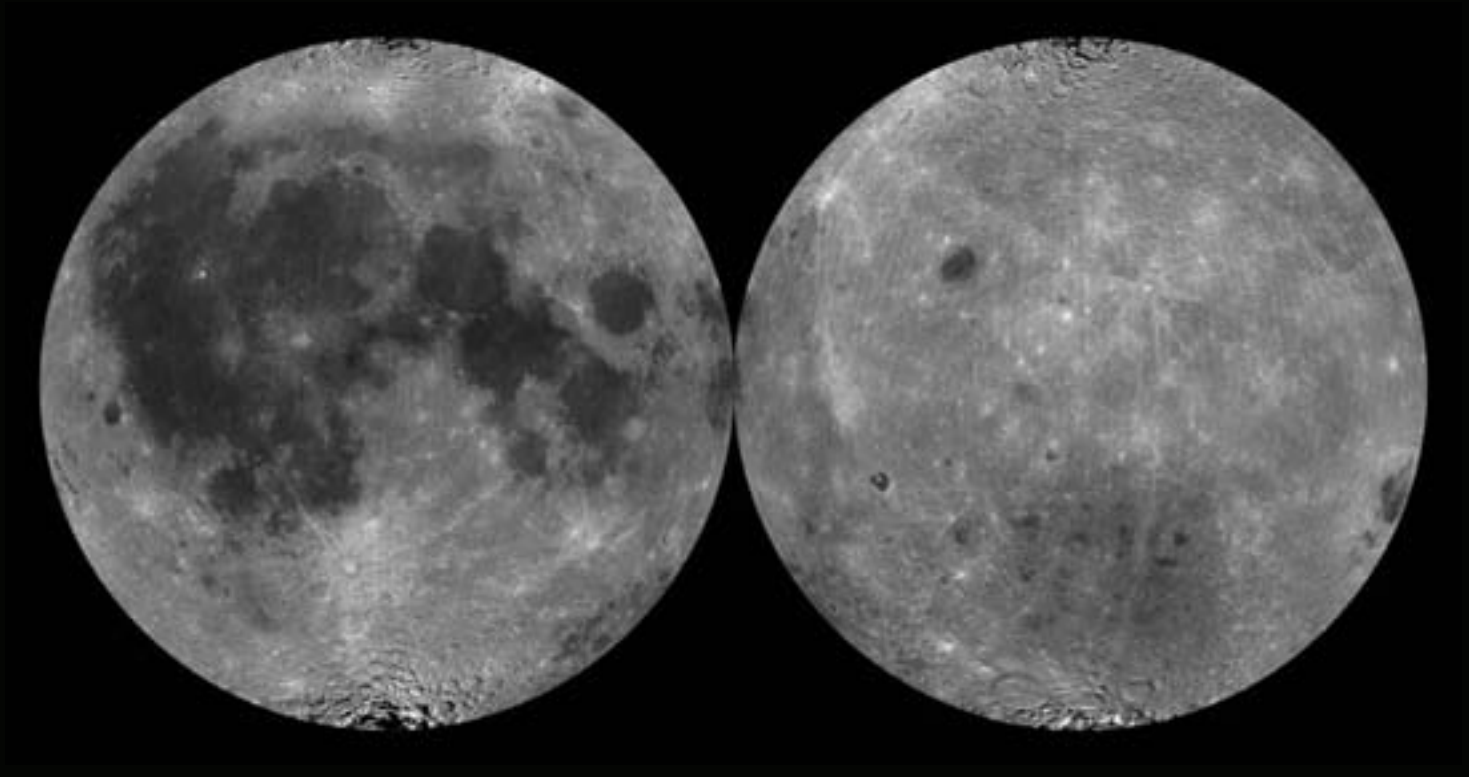


Longhi (2003)

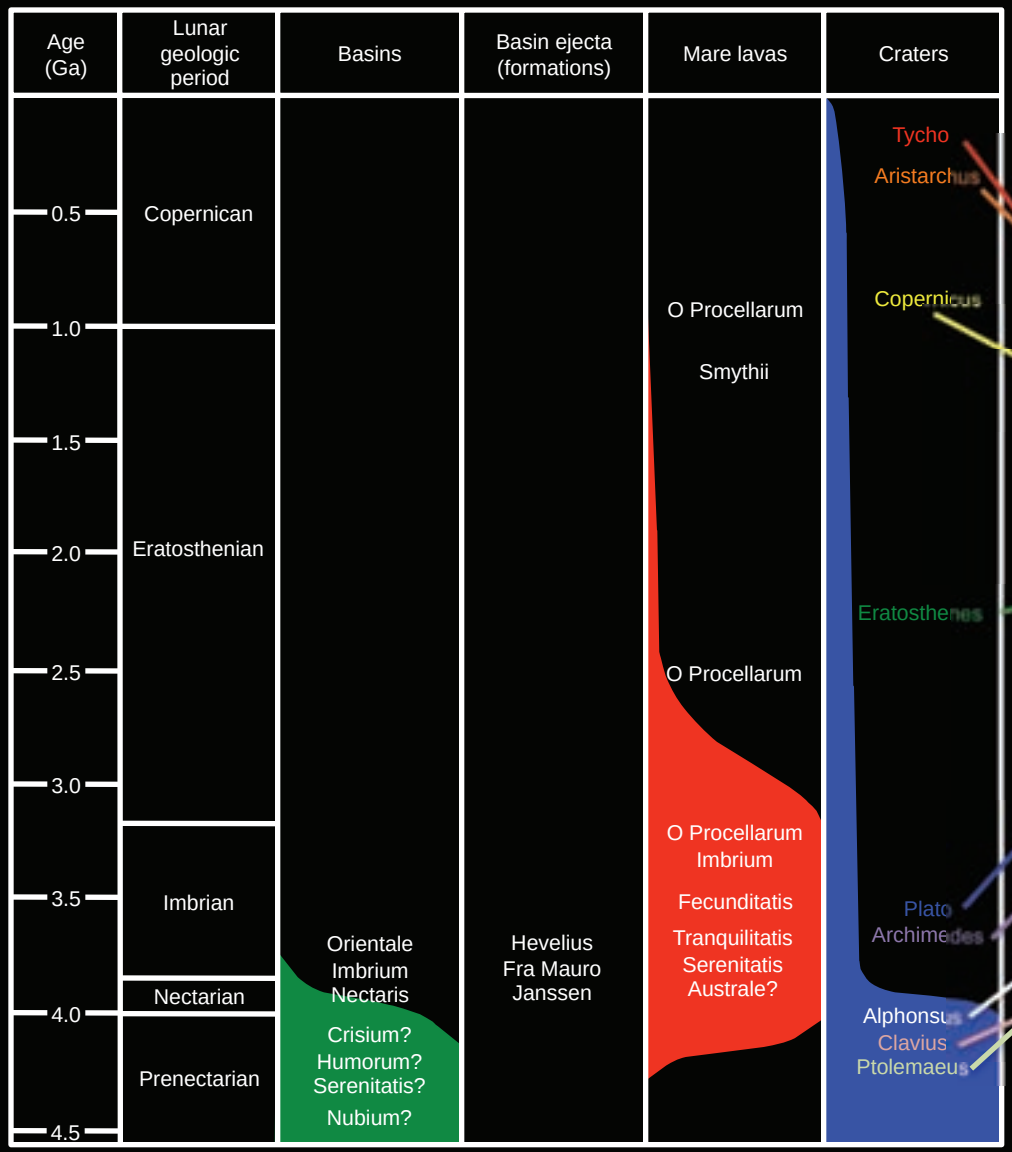
Lunar History

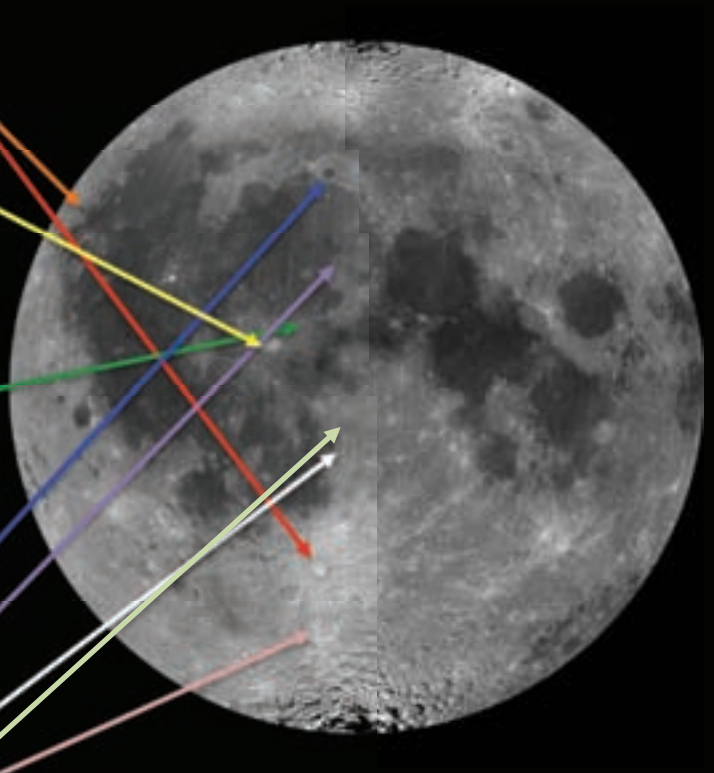




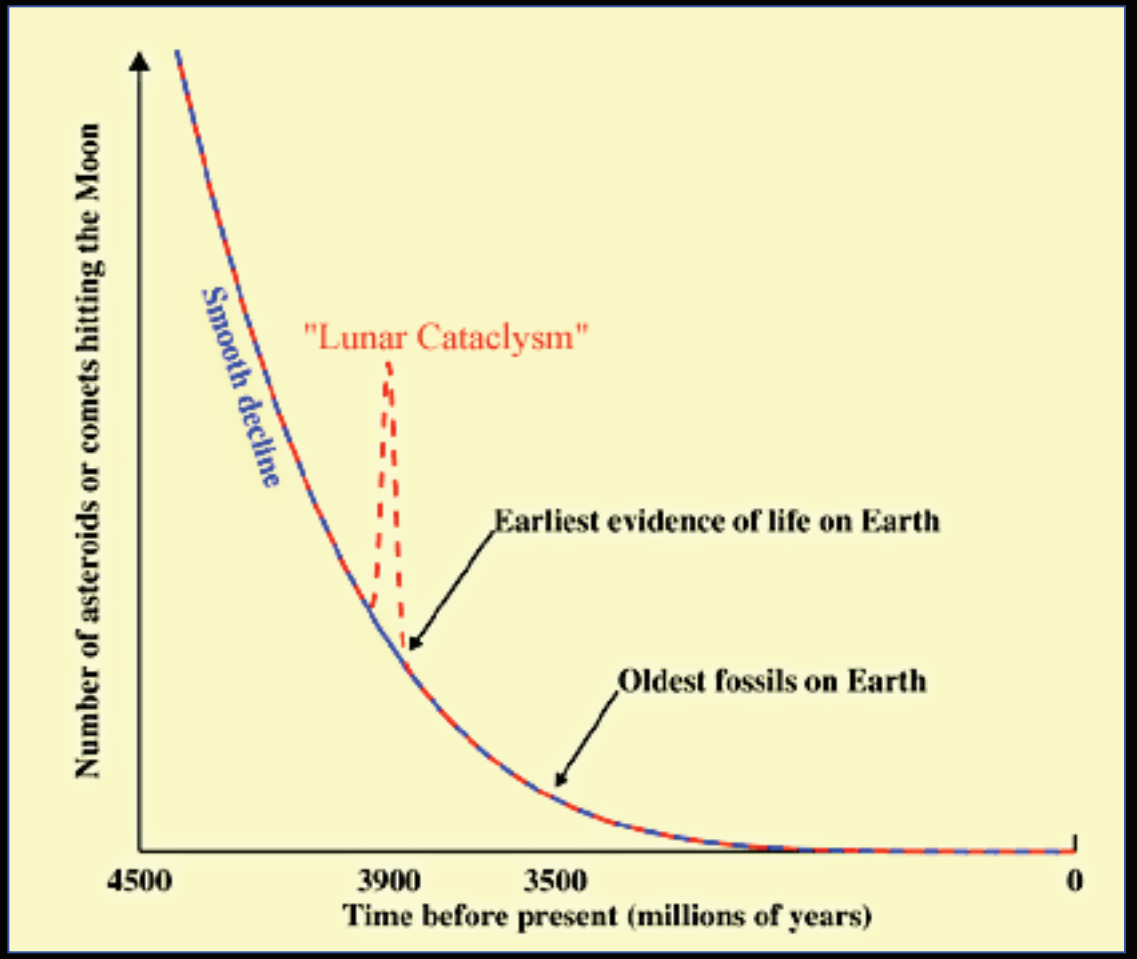


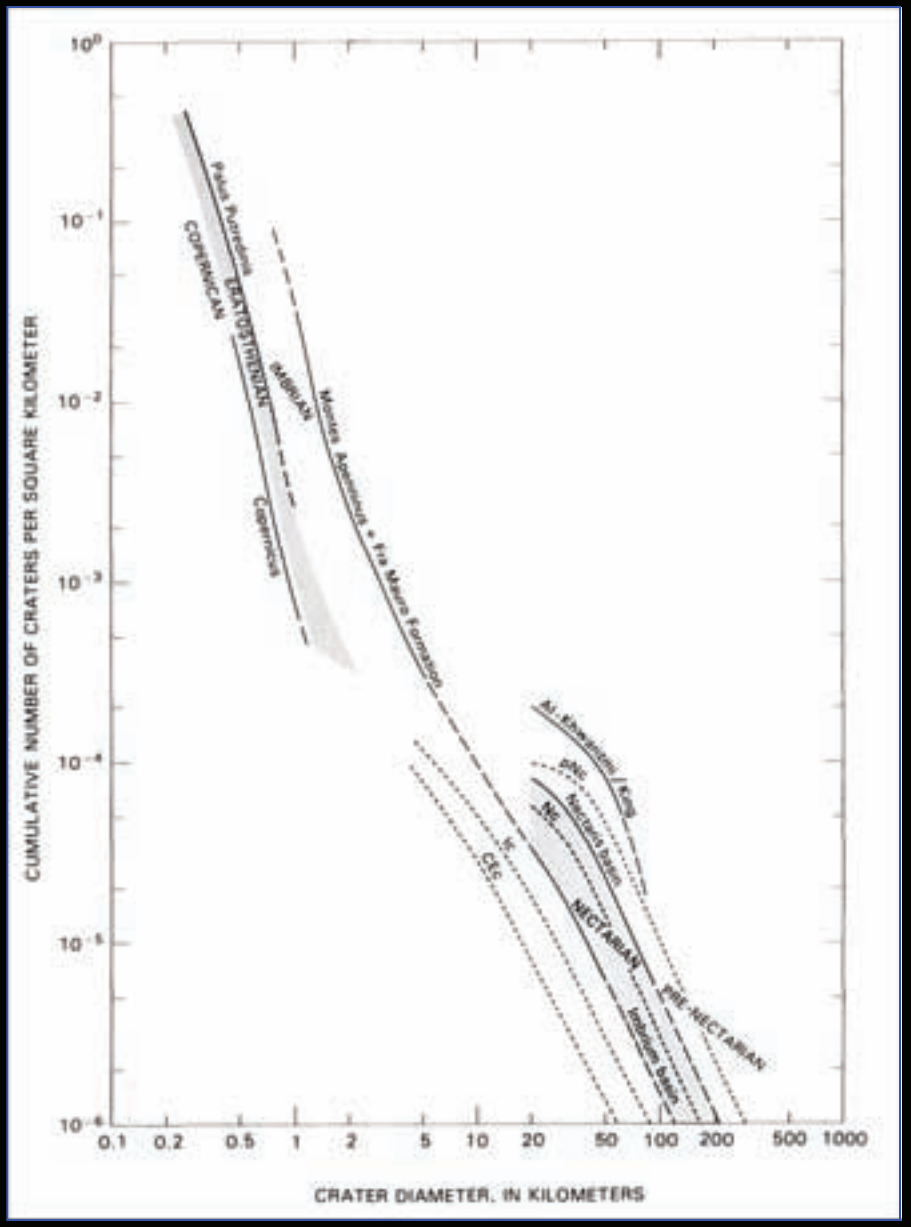
Lunar History





The Lunar Cataclysm

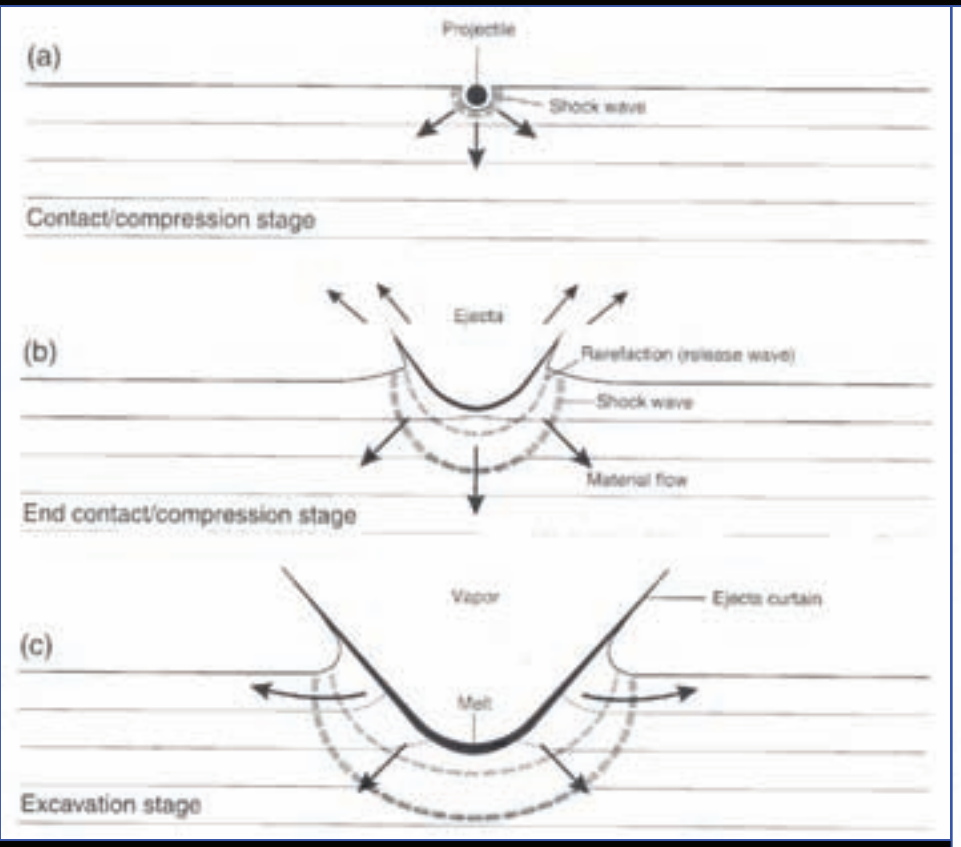


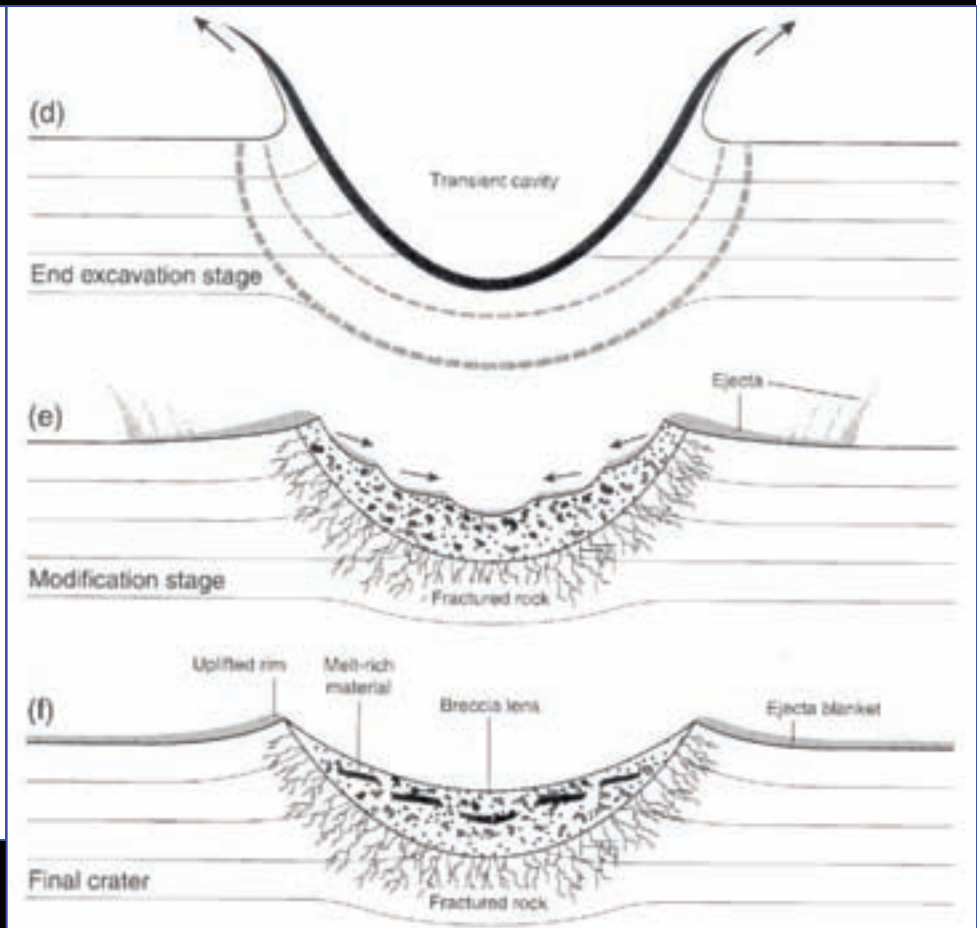


Size vs. Time

- The largest craters on the Moon were formed during its early history
- The size of impactors has decreased significantly over time

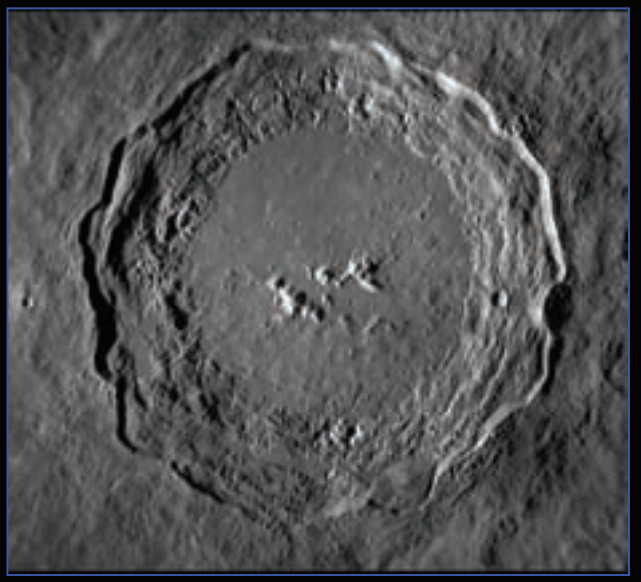
The Nature of an Impact (Simple Crater)

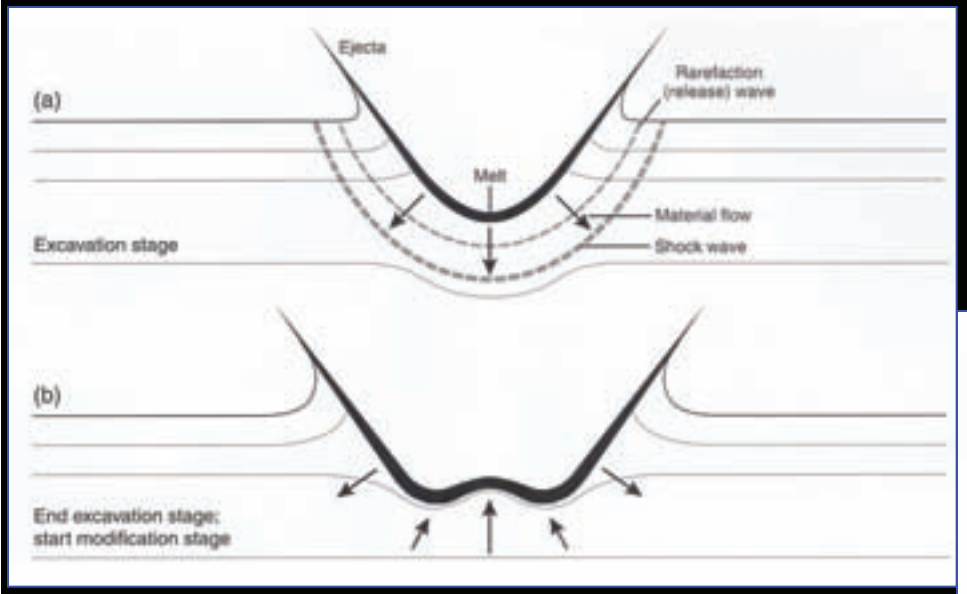


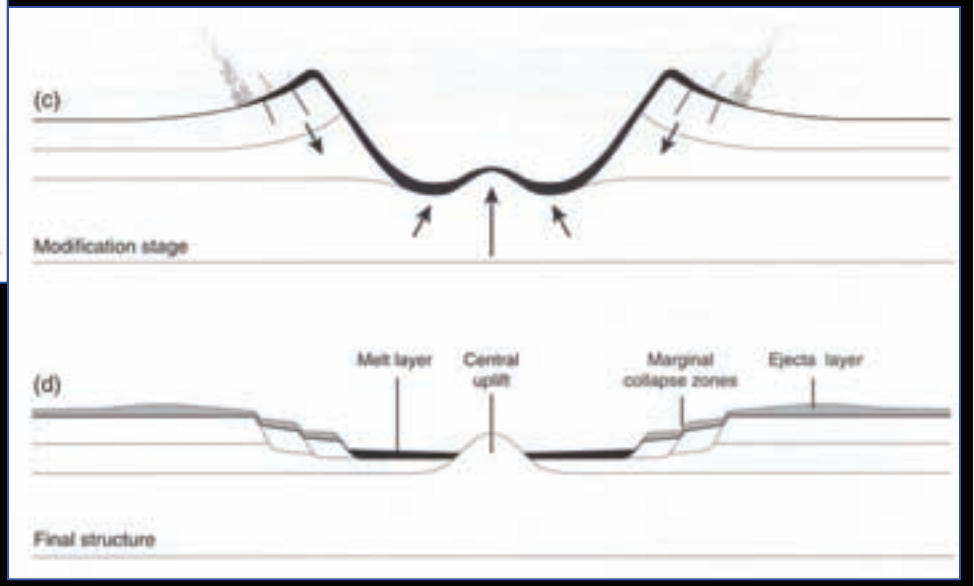


B. French (1998)

The Nature of an Impact (Complex Crater)

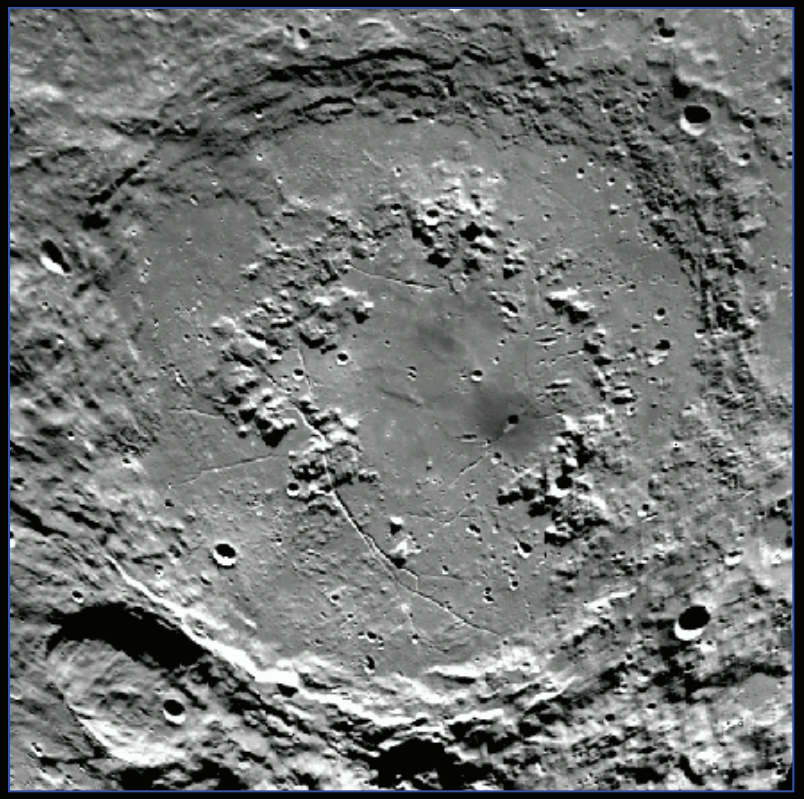




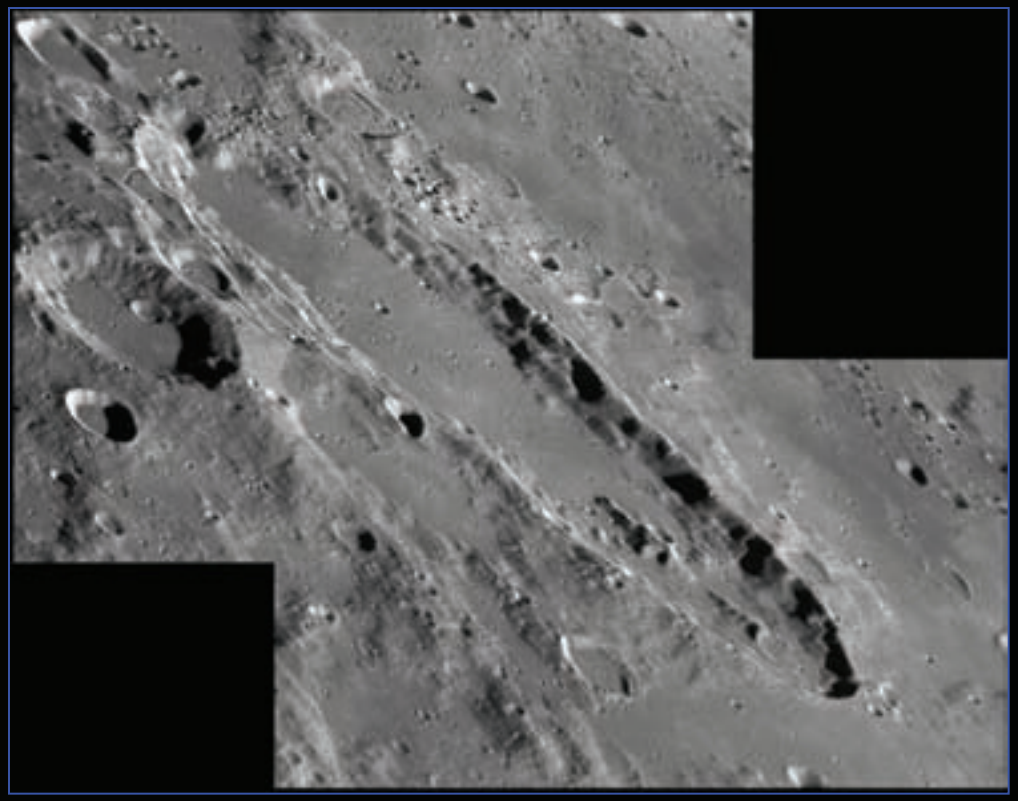


B. French (1998)

The Nature of an Impact



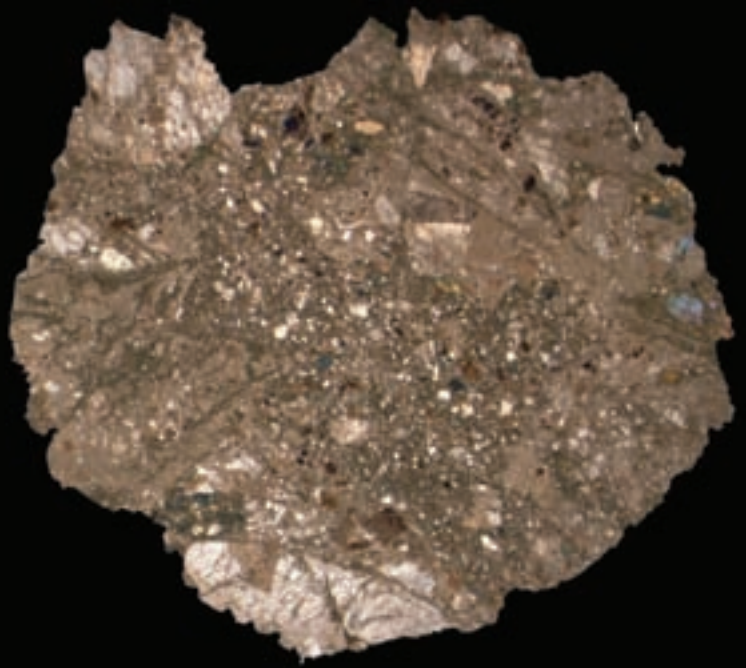
Schrödinger
Multi-ring Basin



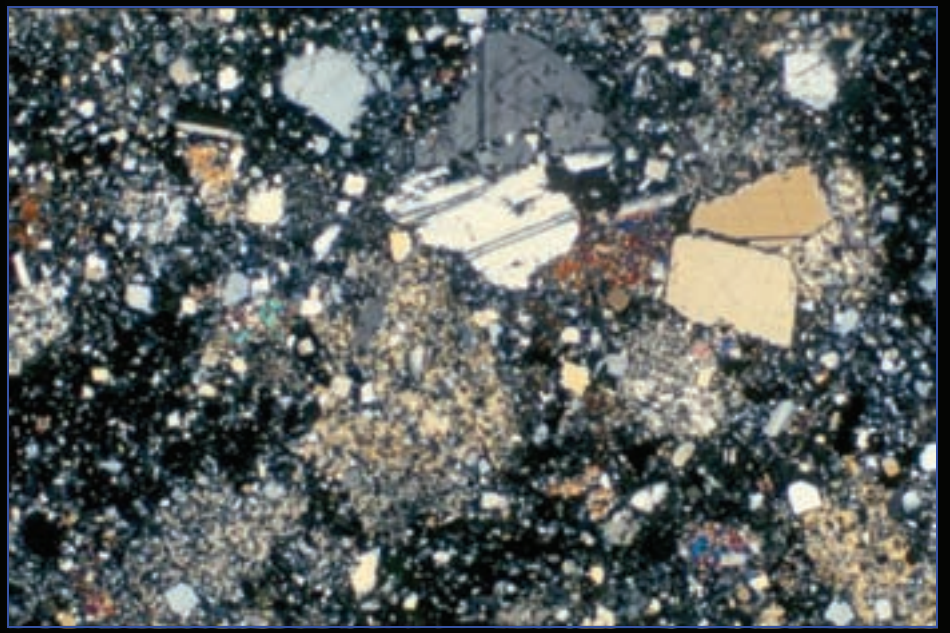
Schiller
Oblique Impact

Damian Peach

The Nature of an Impact

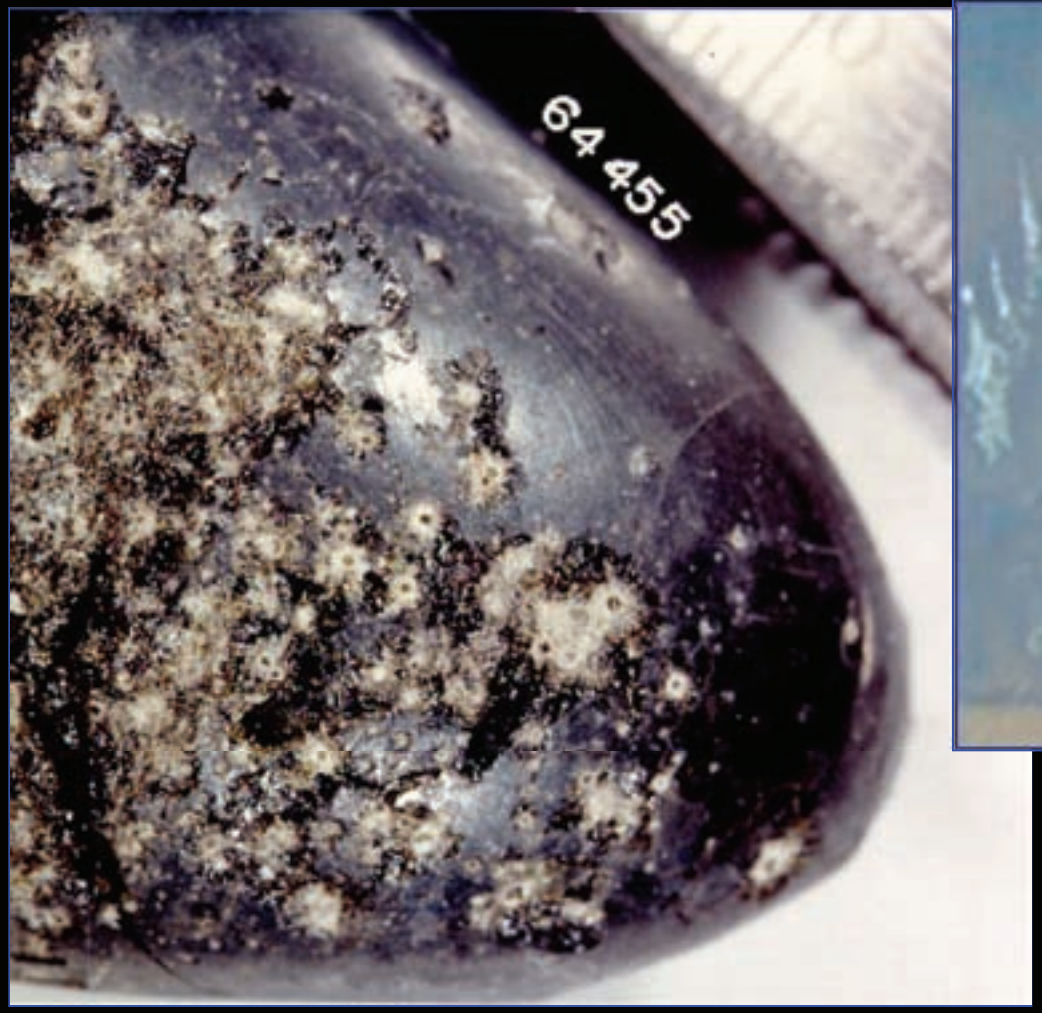


Apollo 17 Mg-suite Lithic Breccia 76335
J. Edmunson



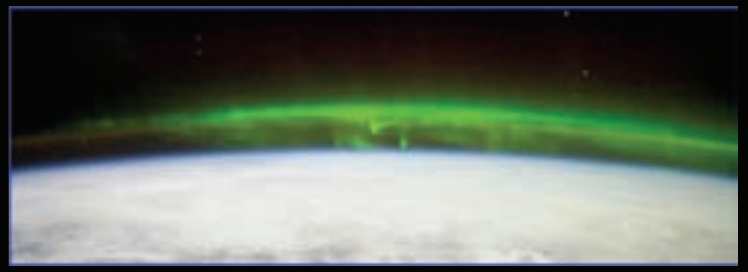
Apollo 16 Impact Melt Breccia
B. Jolliff

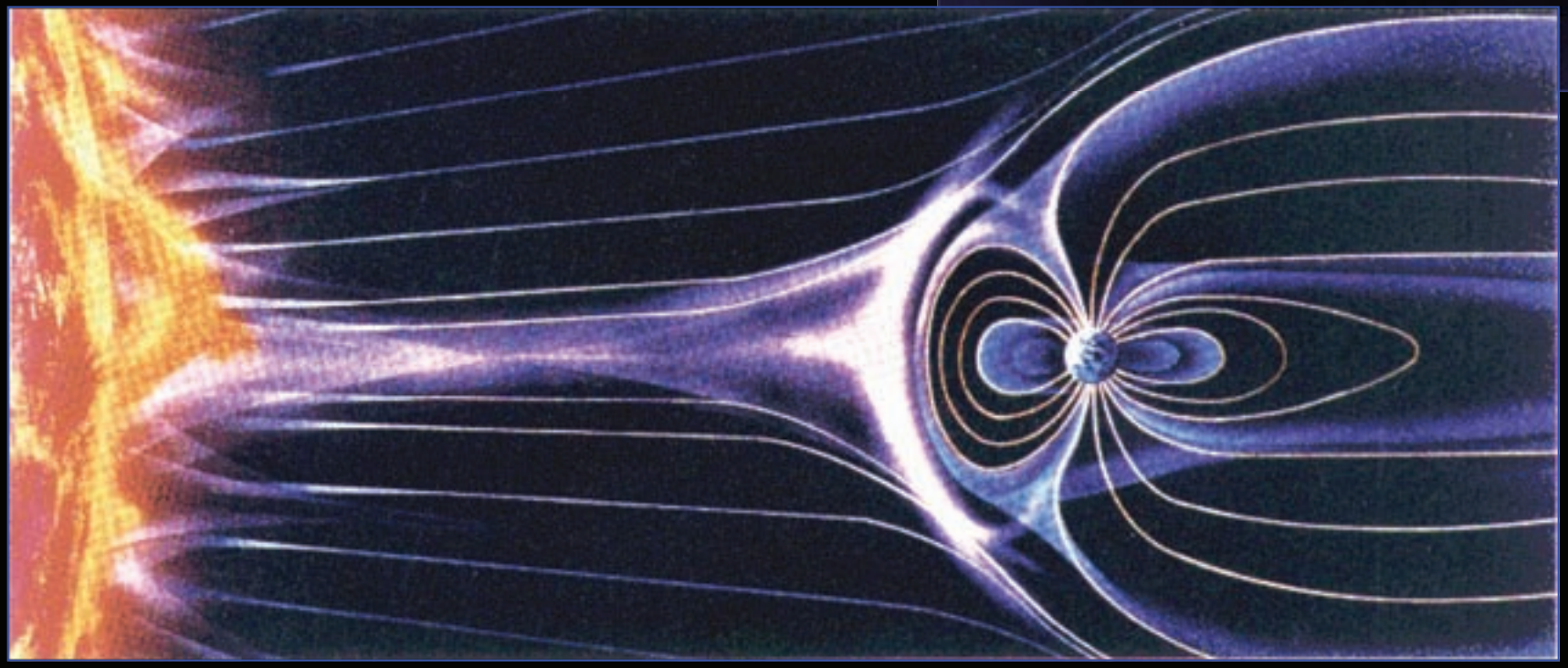
Continued Impacts



Micrometeorite Impact
Soviet Vostok-style Satellite
G. Clark

Solar Wind



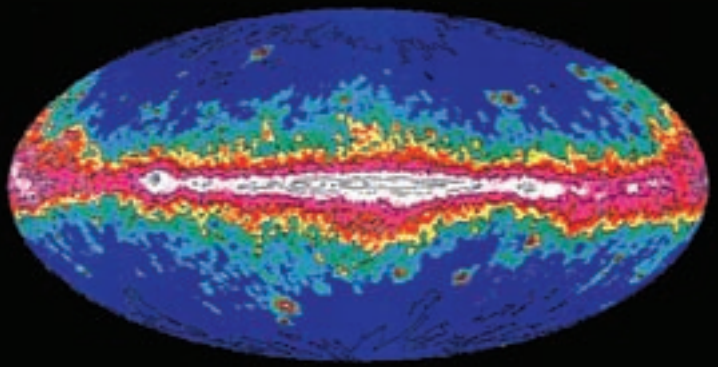


Solar Wind Implantation

- 1KeV protons, electrons, alpha particles, light volatile elements
- Implantation depth of a few tens of nanometers
- Energetic particles of 1-100MeV can be implanted up to 1cm in depth

Radiation (Galactic Cosmic Rays)

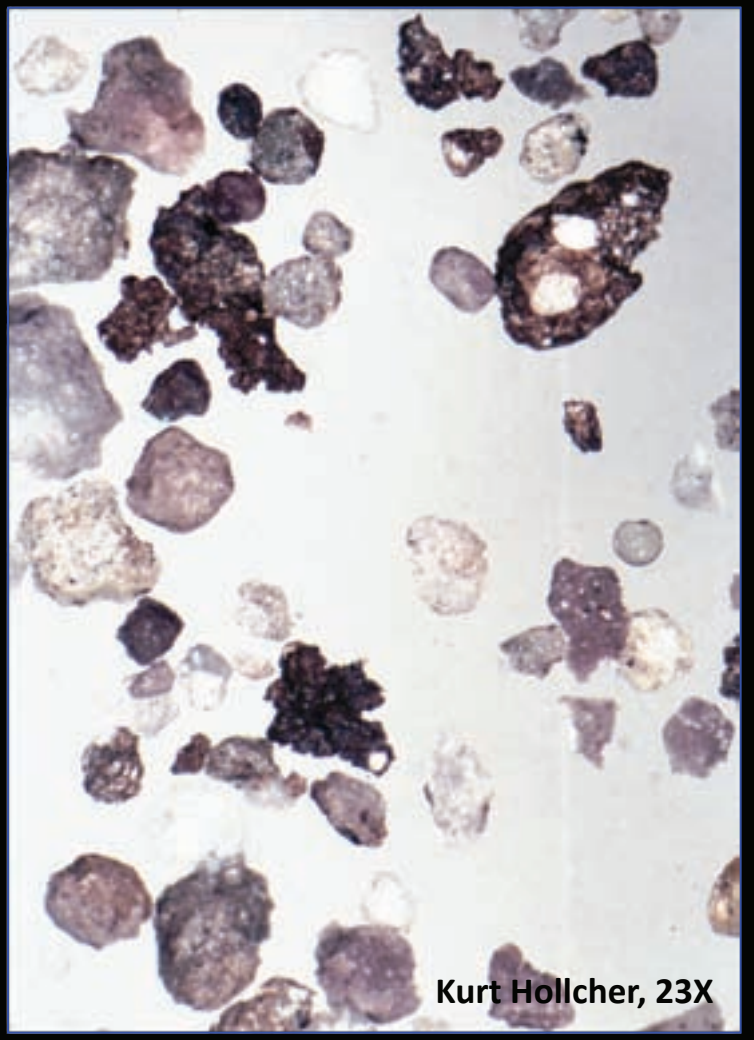
- 100MeV to 10GeV particles (87% protons, 12% alpha particles, 1% heavier ions)
- Emit gamma rays when interacting with the stellar medium (and lunar surface)
- Particles can change isotopic compositions through neutron capture and spallation
- Implanted meters in depth



Milky Way Cosmic Ray Background
EGRET/Carl Fichtel

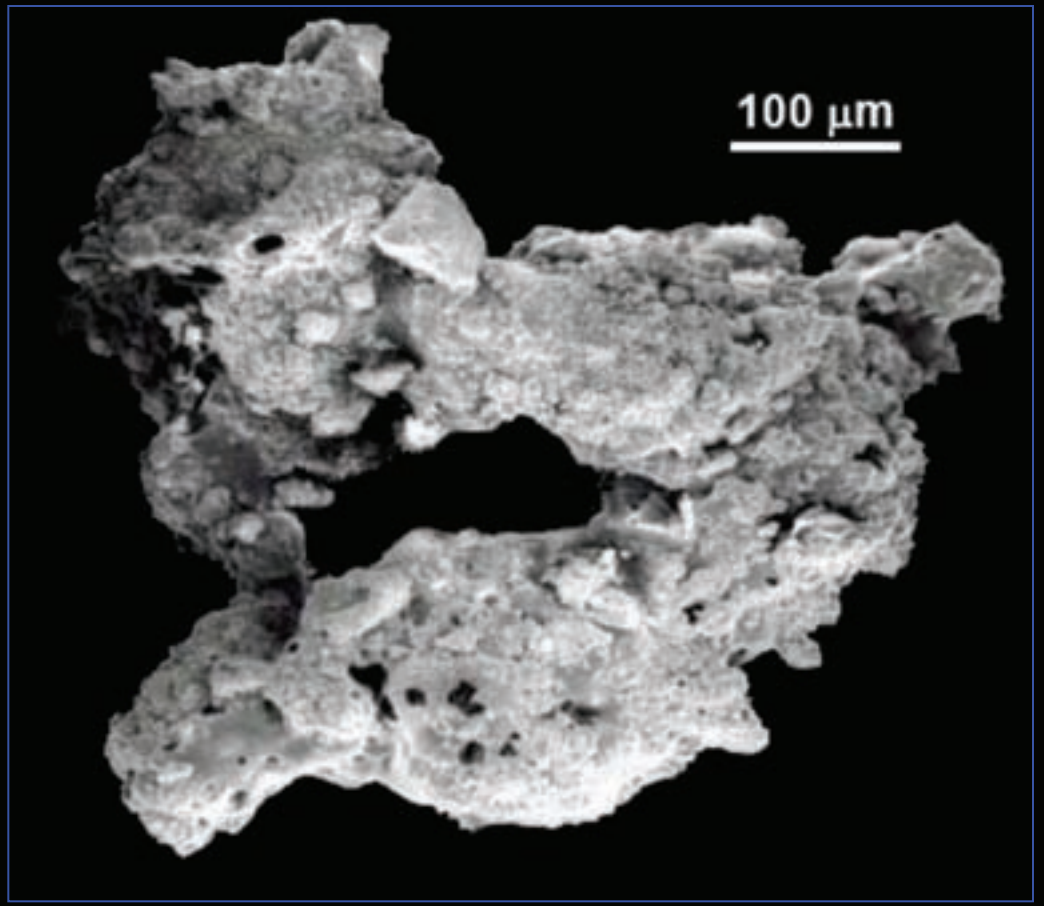
Generation of Agglutinates

- Regolith particles cemented together by vesicular impact melt glass
- Typically less than 1mm in size
- Formation via micrometeorite impact
- “Mature” soils can contain ~60% agglutinate by volume



Agglutinates

Kurt Hollocher, 52X



D. S. McKay

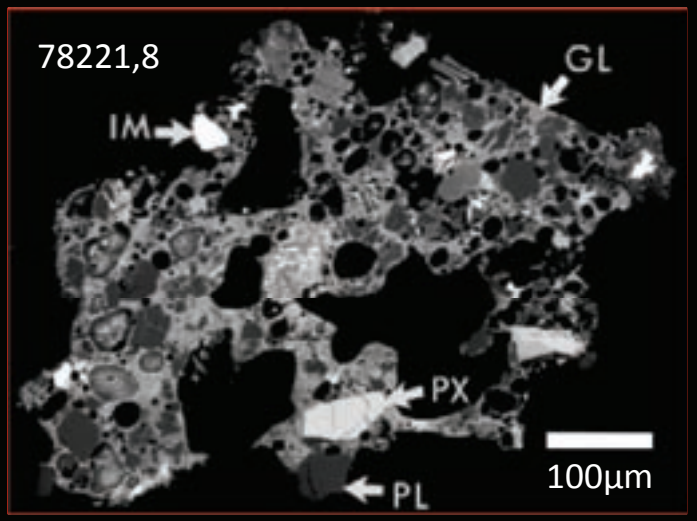
Sorting

Earth

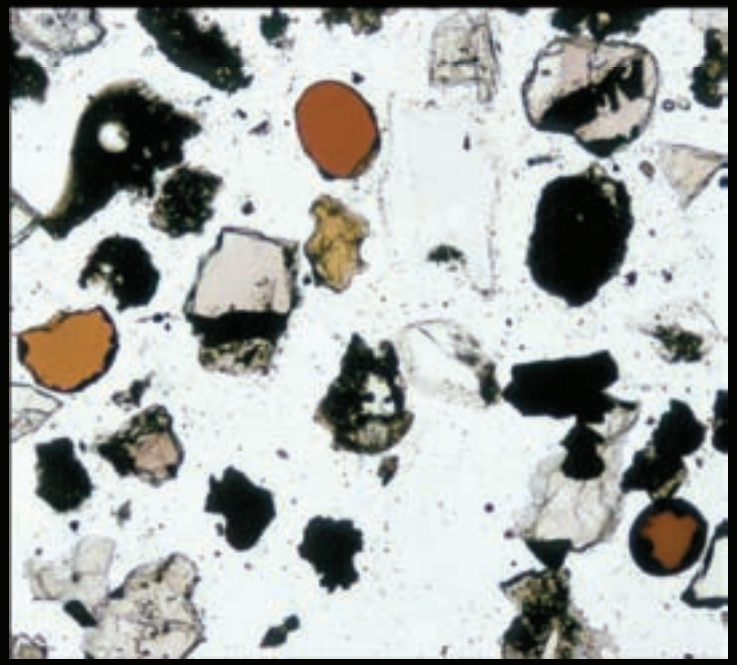
Third Beach Sand (Vancouver, BC)

Bobanny

Moon



Lunar History



Fine Regolith Particles
Apollo Sample 70181,88
Grain Mount:
Agglutinates
Glass Beads
Brecciated Minerals
Kurt Hollocher, 100X