

The Lunar Regolith



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Outline

- What makes lunar soil/regolith unique?
- What is lunar soil composed of?
 - Particle types
 - Size distribution
- How does it evolve?
 - Space weathering
 - “F³ model”



Lunar soils ≠ terrestrial soils

Earth

- Rounded by wind and water
- Sorted by wind and water
- Broken down by wind, water, chemically, biologically

Moon

- Sharp edges, fresh fractured surfaces
- No sorting
- Comminuted by meteorite impact, solar wind sputtering
- No organic material

Lunar Soil

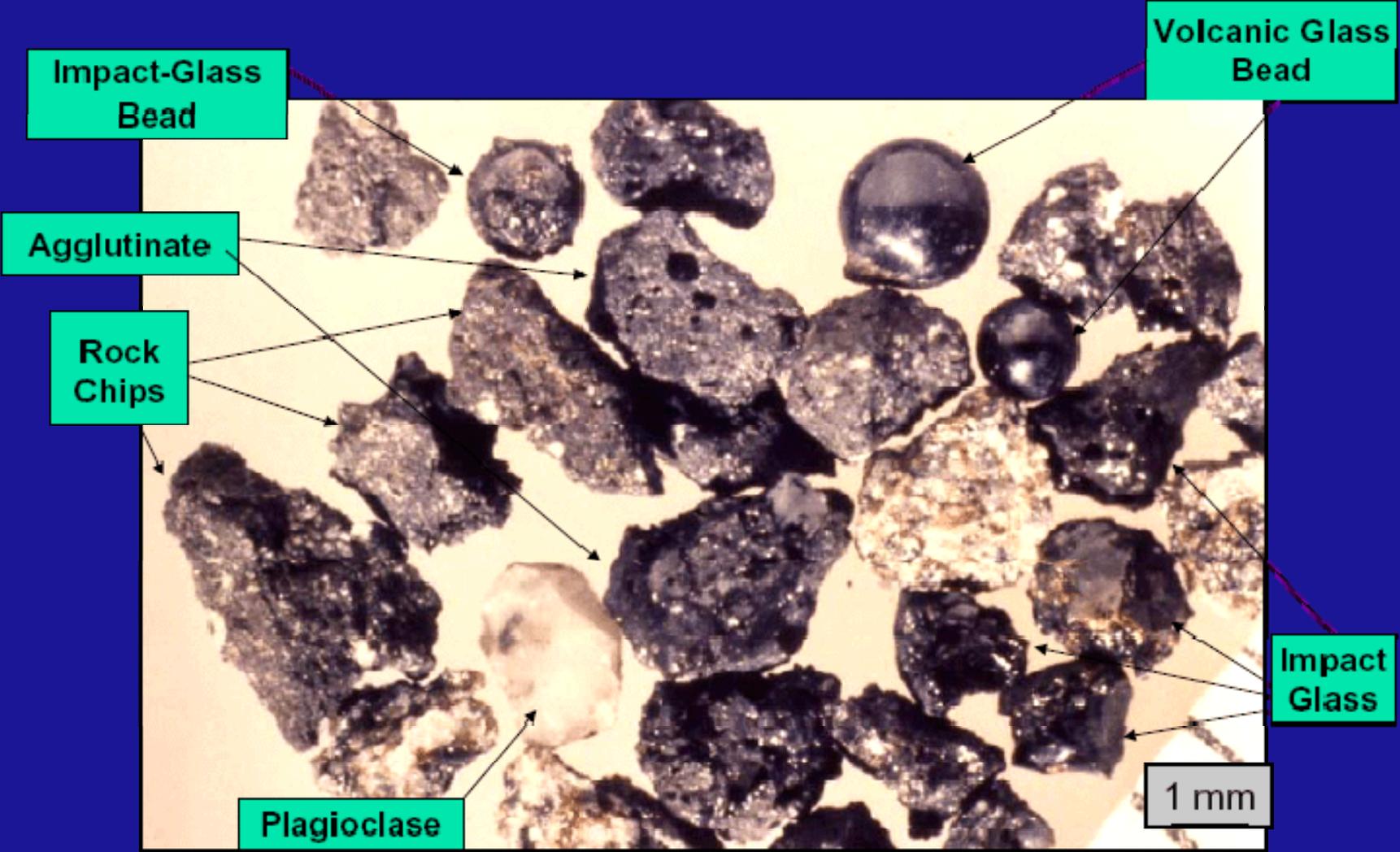
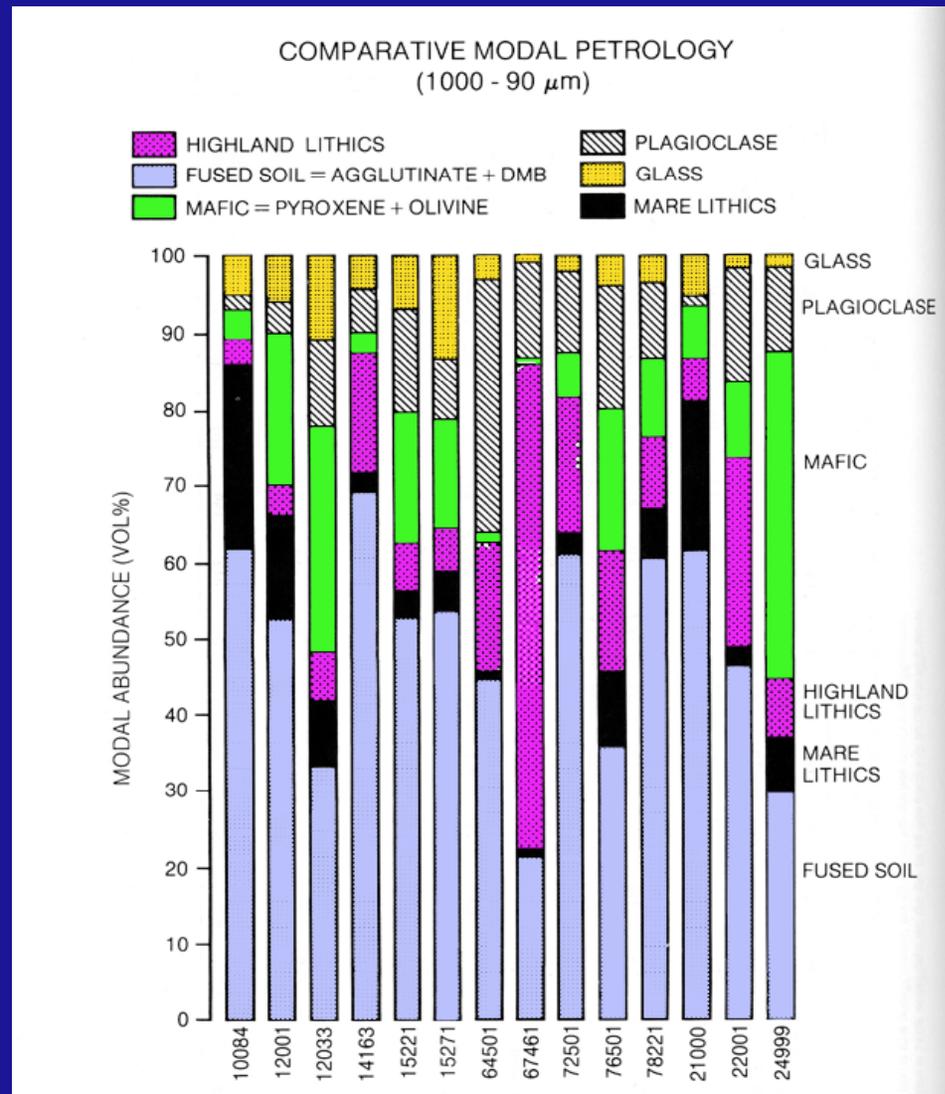
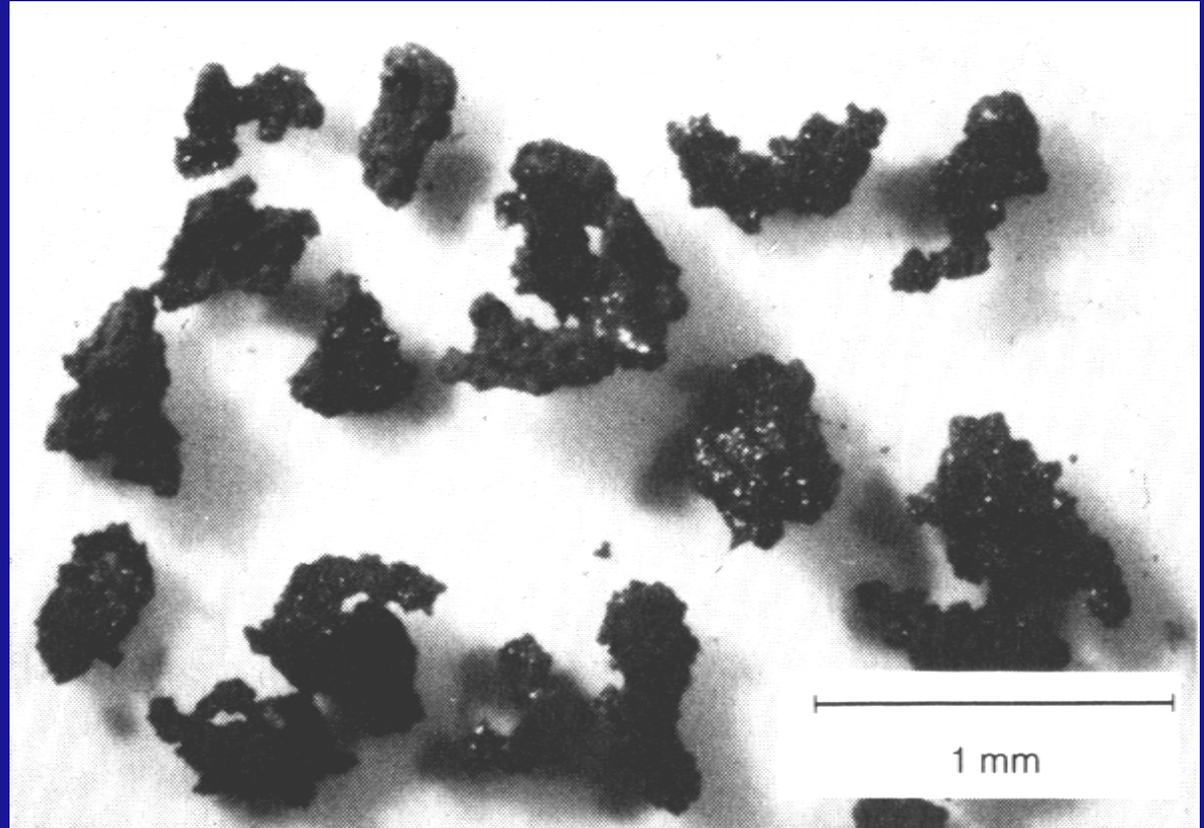
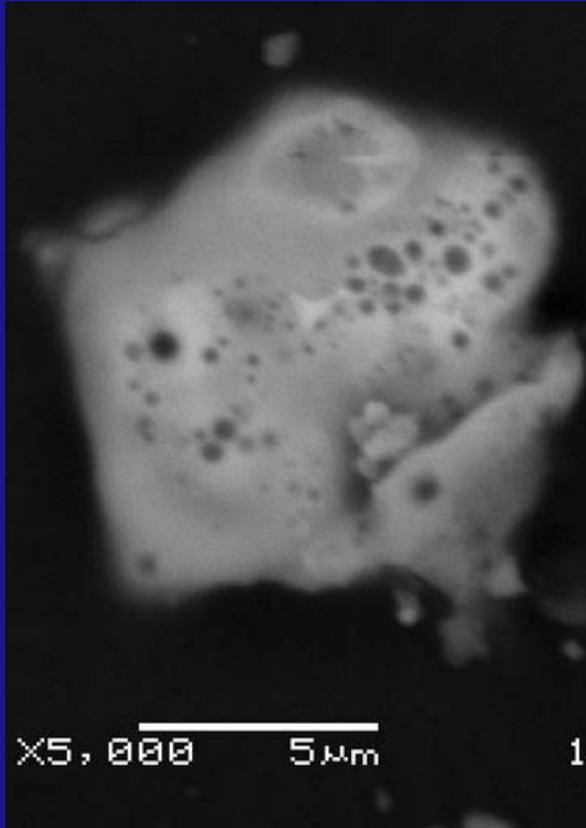


Image courtesy: L. A. Taylor, Univ. of TN

Mineral Distribution

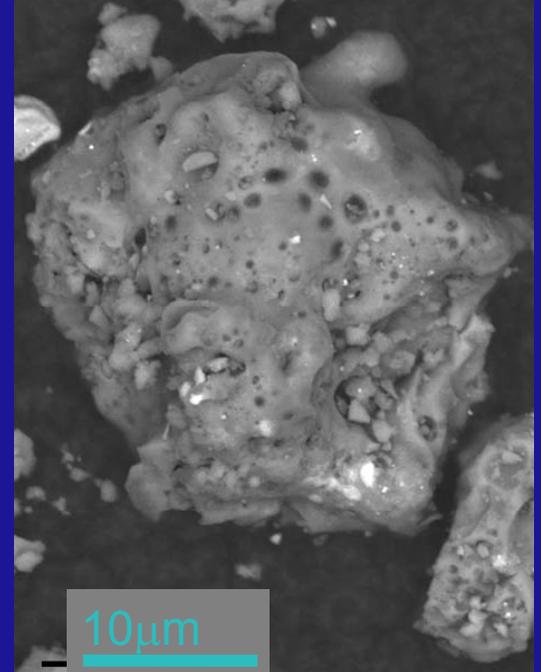
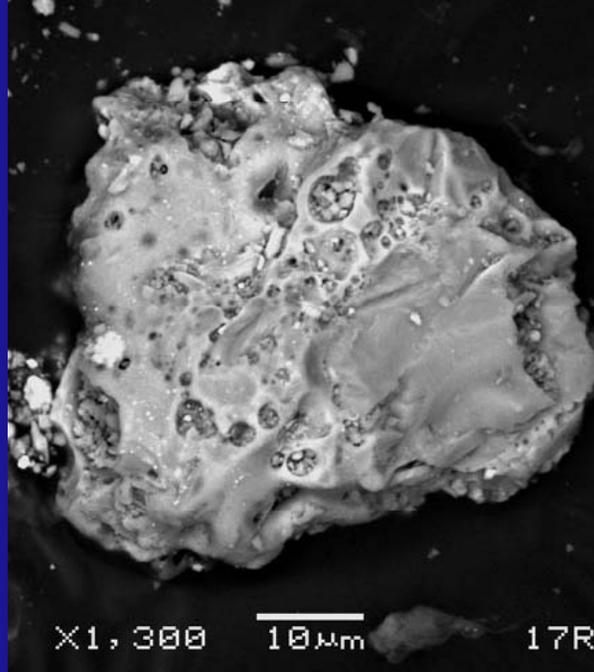
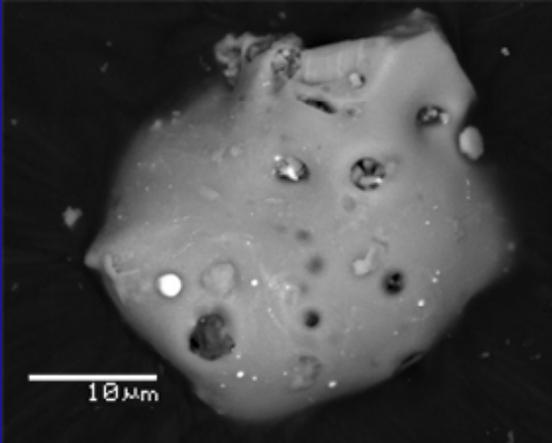
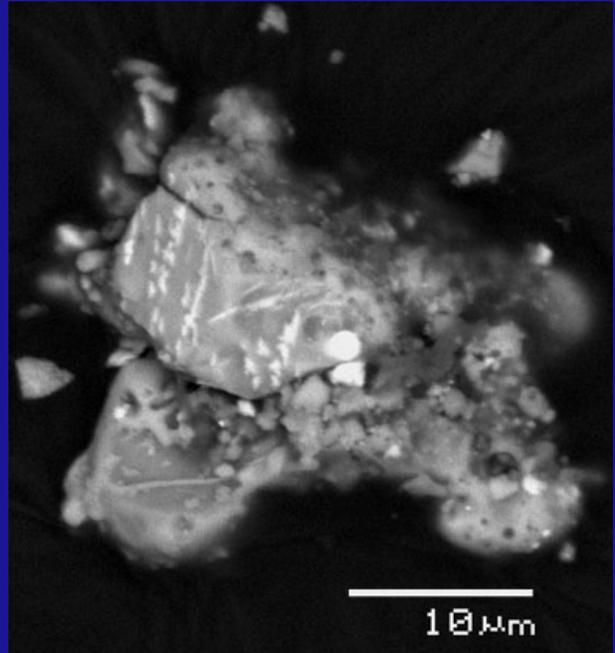
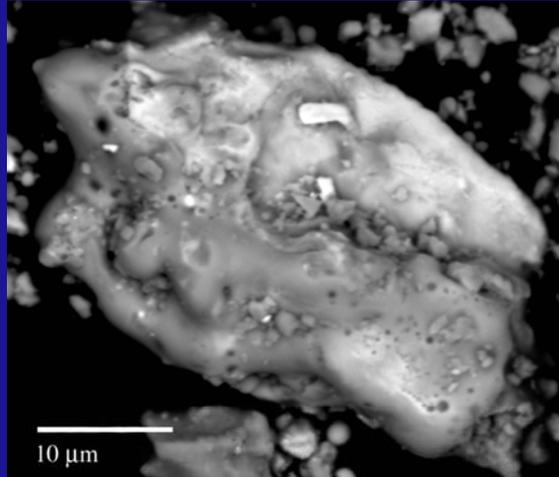
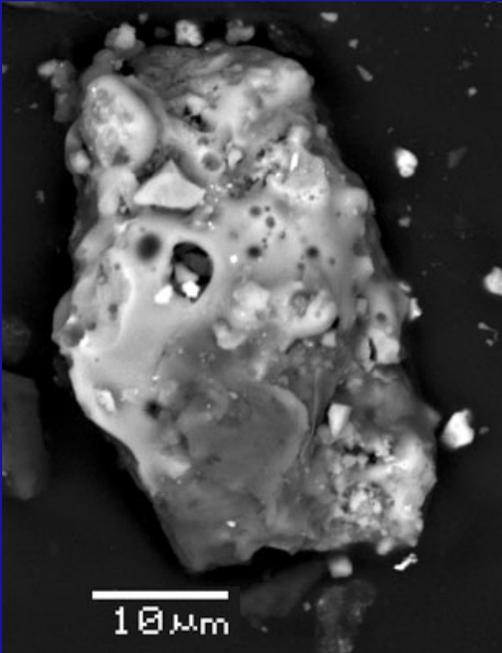


Agglutinates



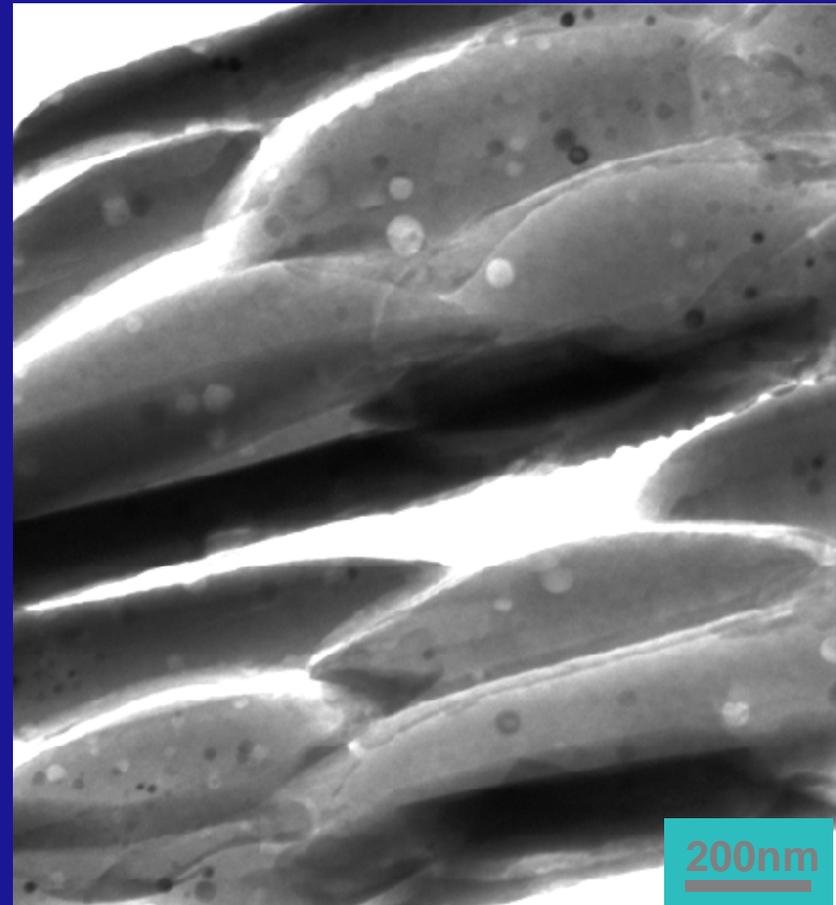
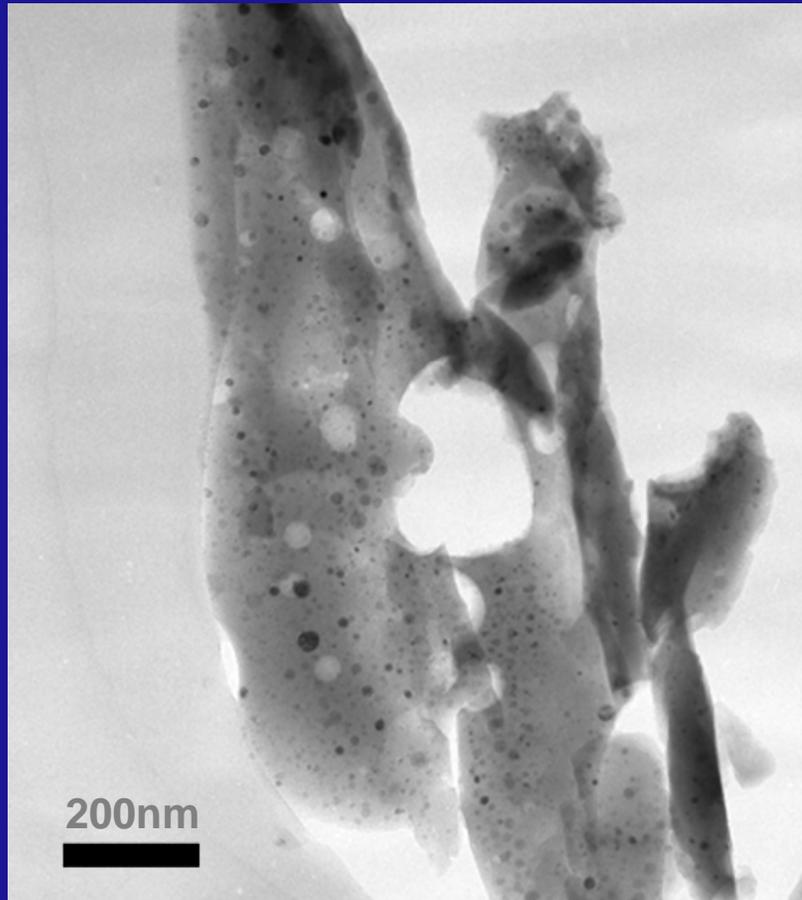
Agglutinates come in all sizes from submicron to over a millimeter, though the average is around 30-60 microns.

Agglutinates



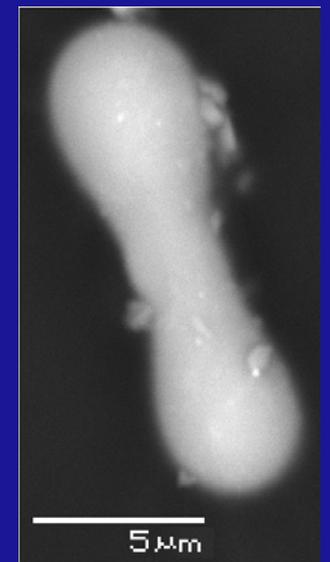
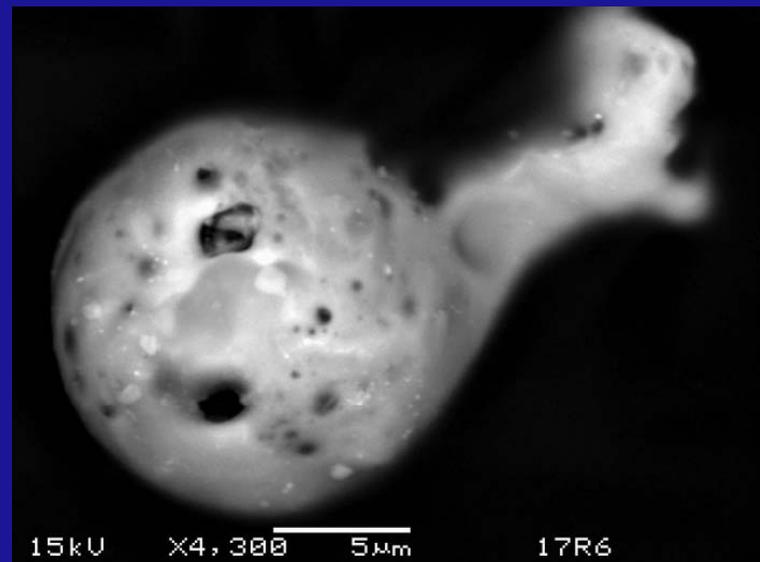
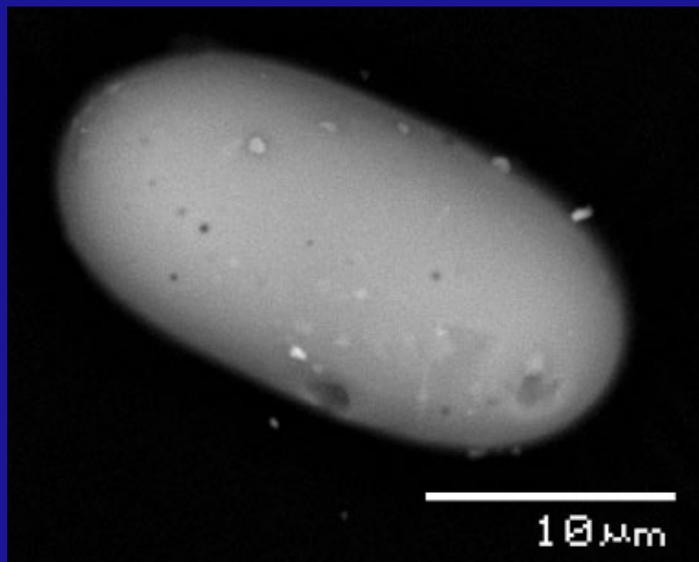
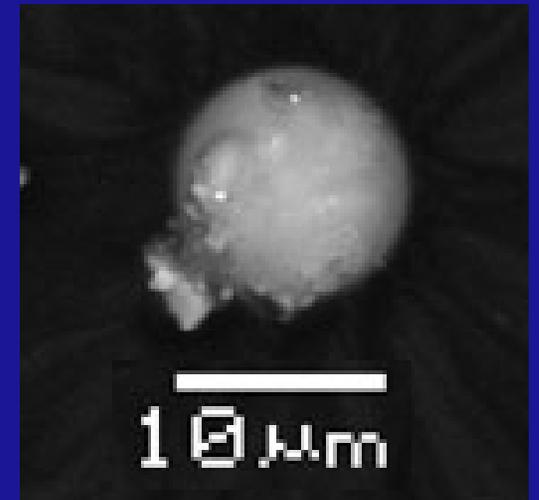
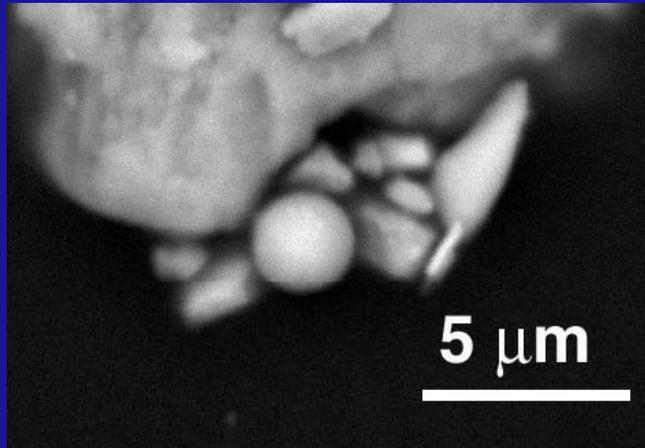
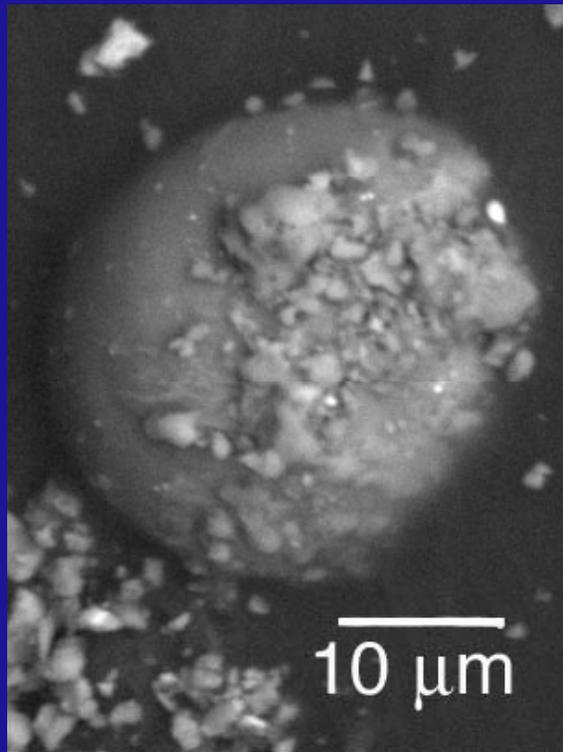
They can constitute from ~5% to over 60% of a soil.

Agglutinates

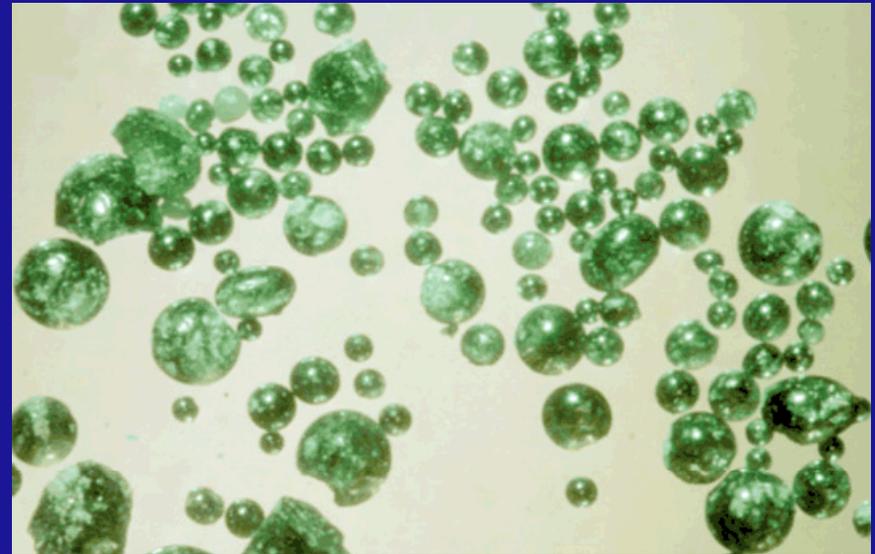
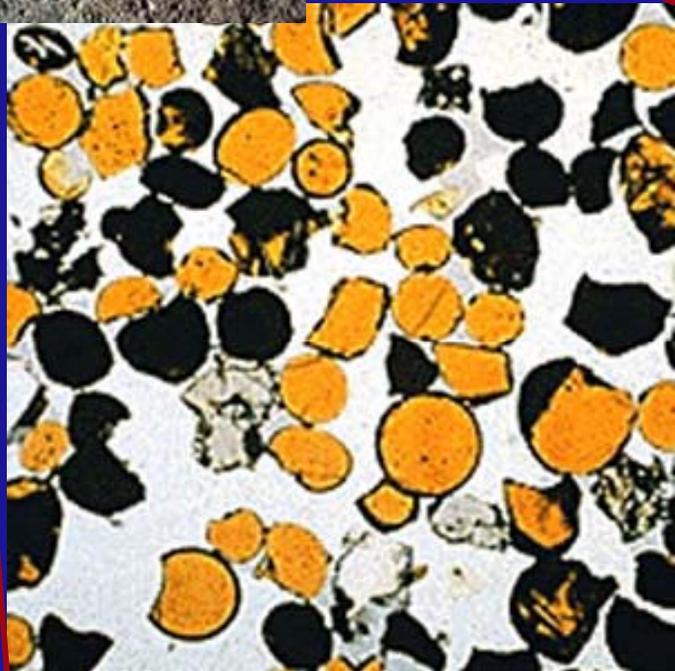


Agglutinates are vesicular (holey) and full of nanophase iron

Spherules



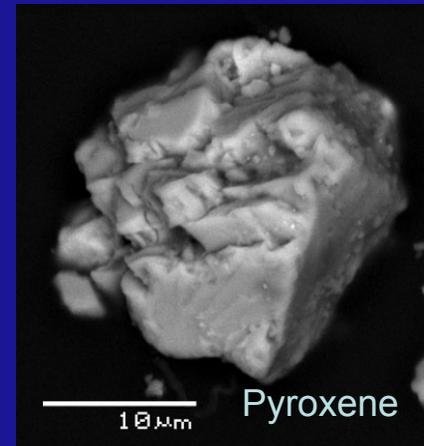
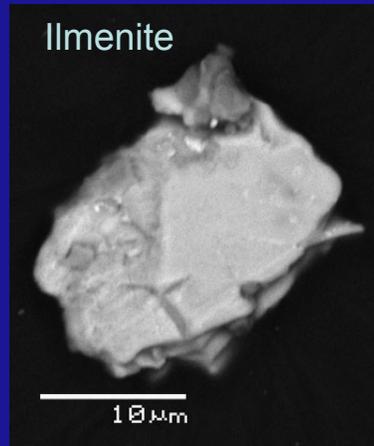
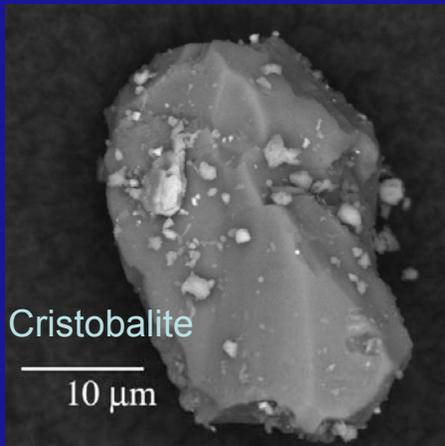
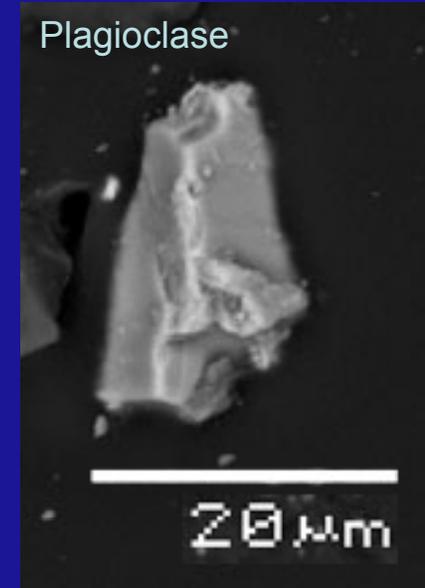
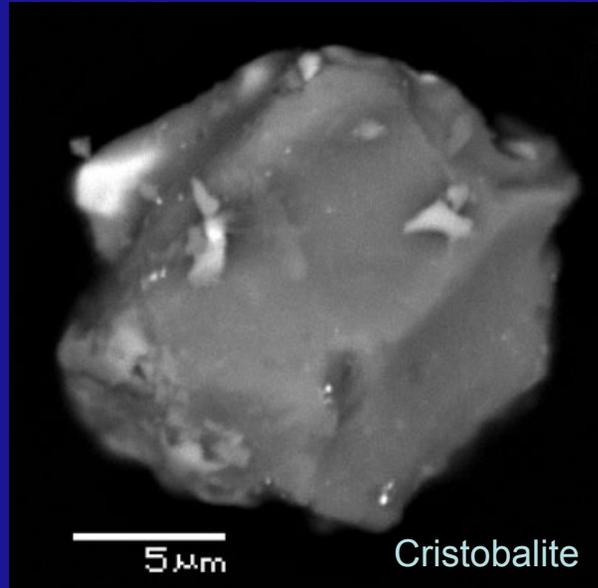
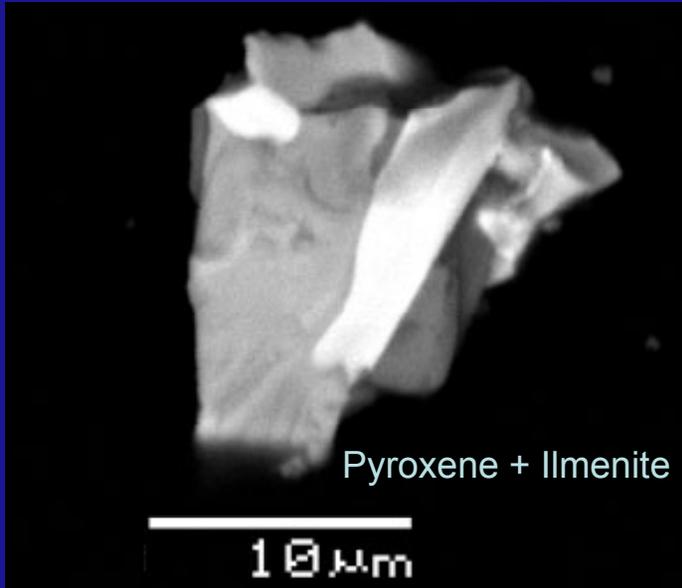
Volcanic glass beads



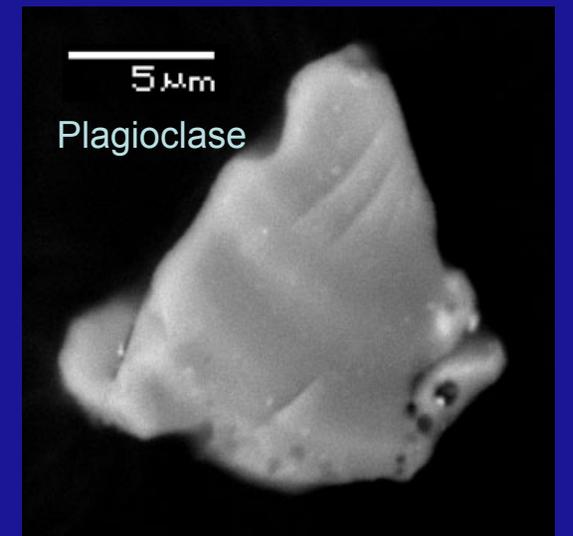
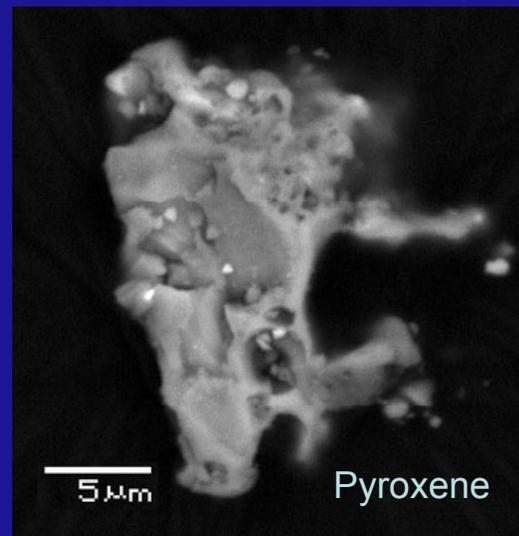
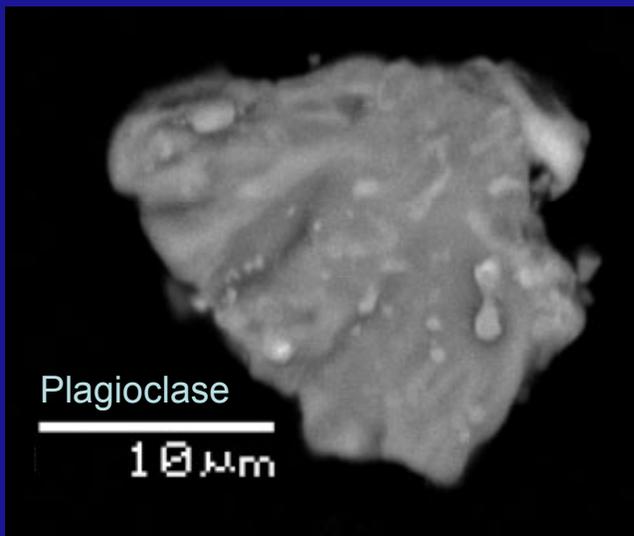
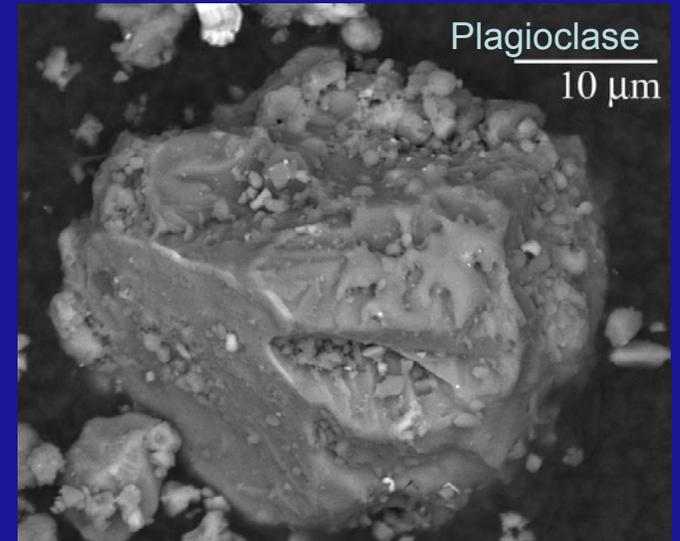
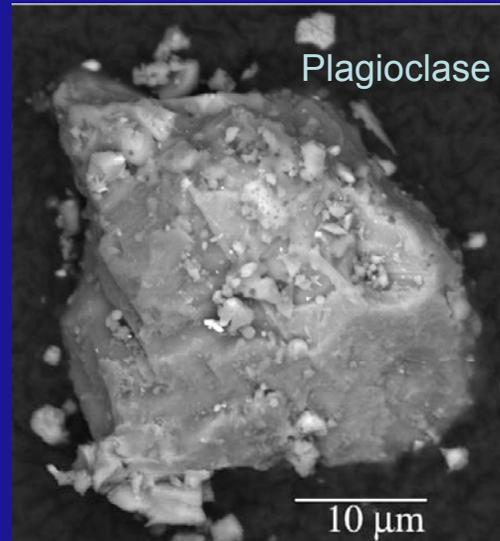
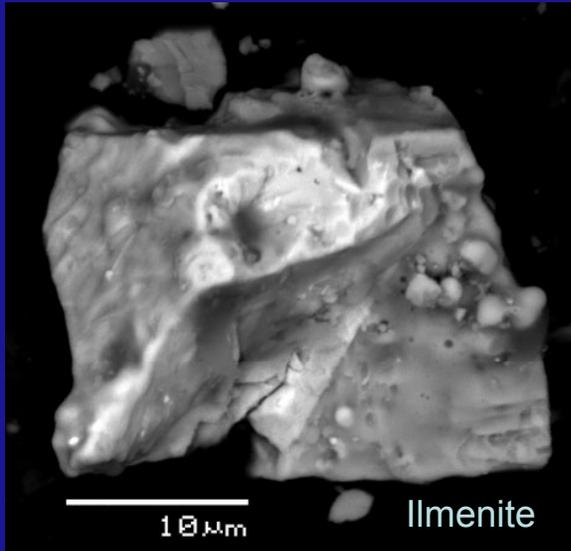
Apollo 15 green glass

Apollo 17 orange glass

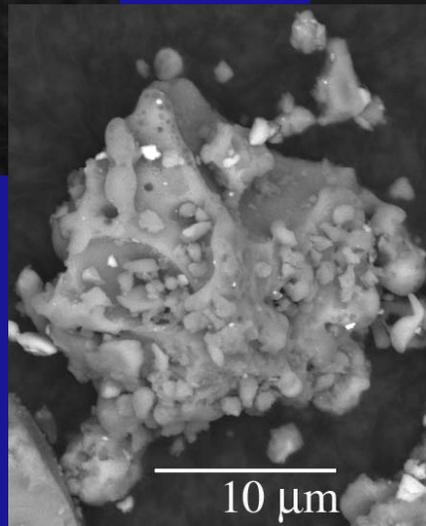
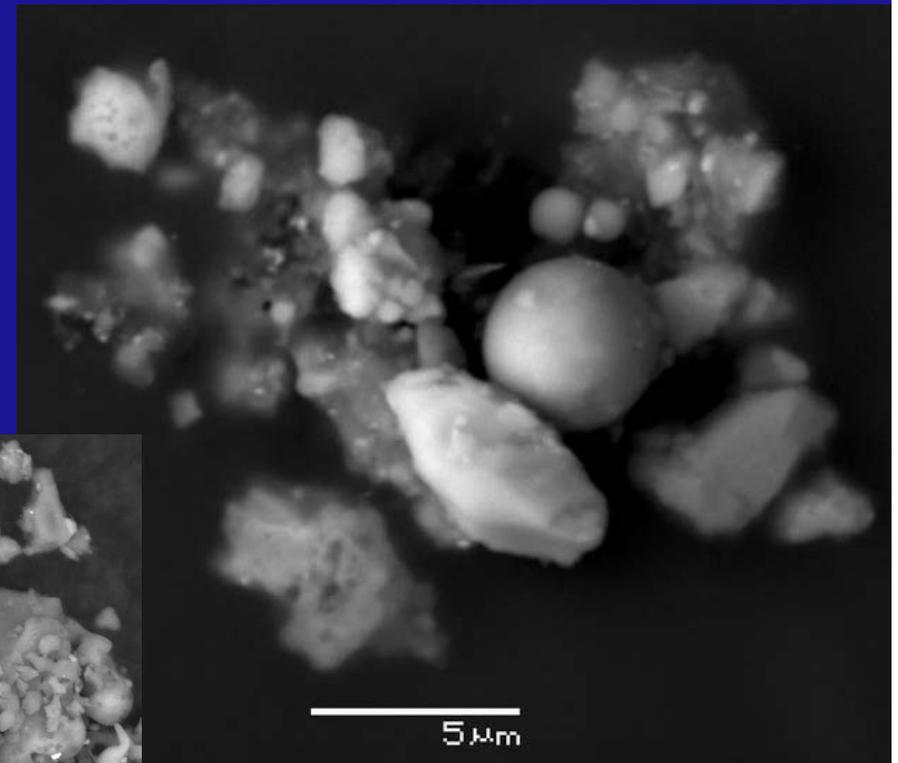
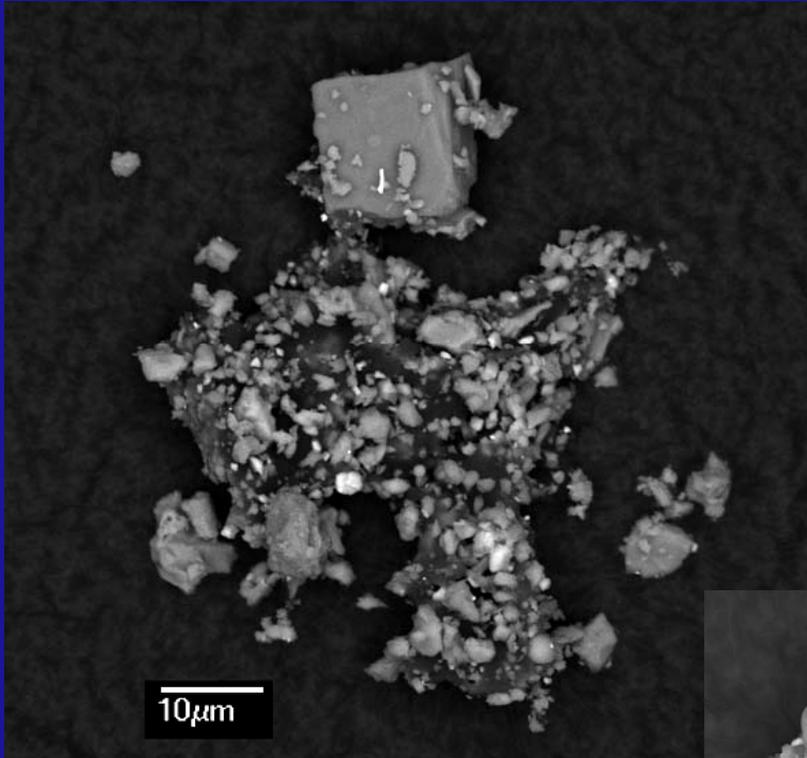
Mineral Fragments



Mineral Fragments

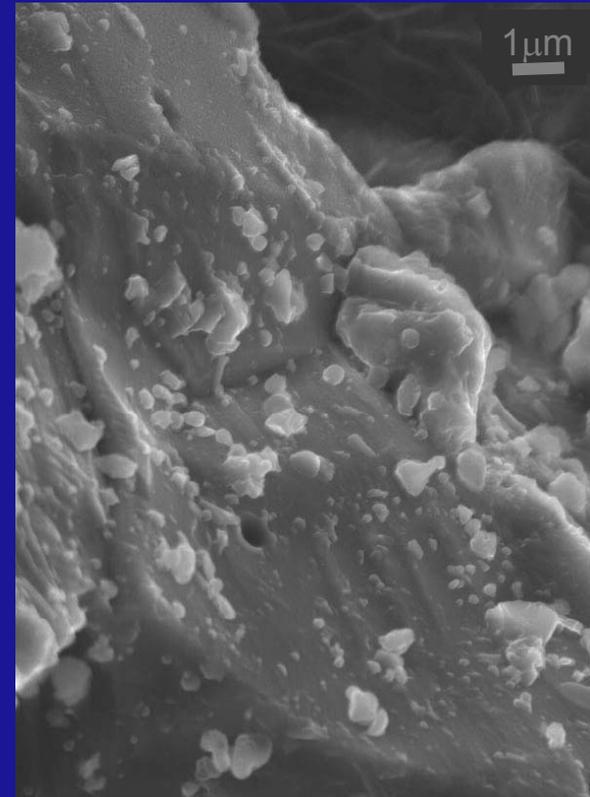
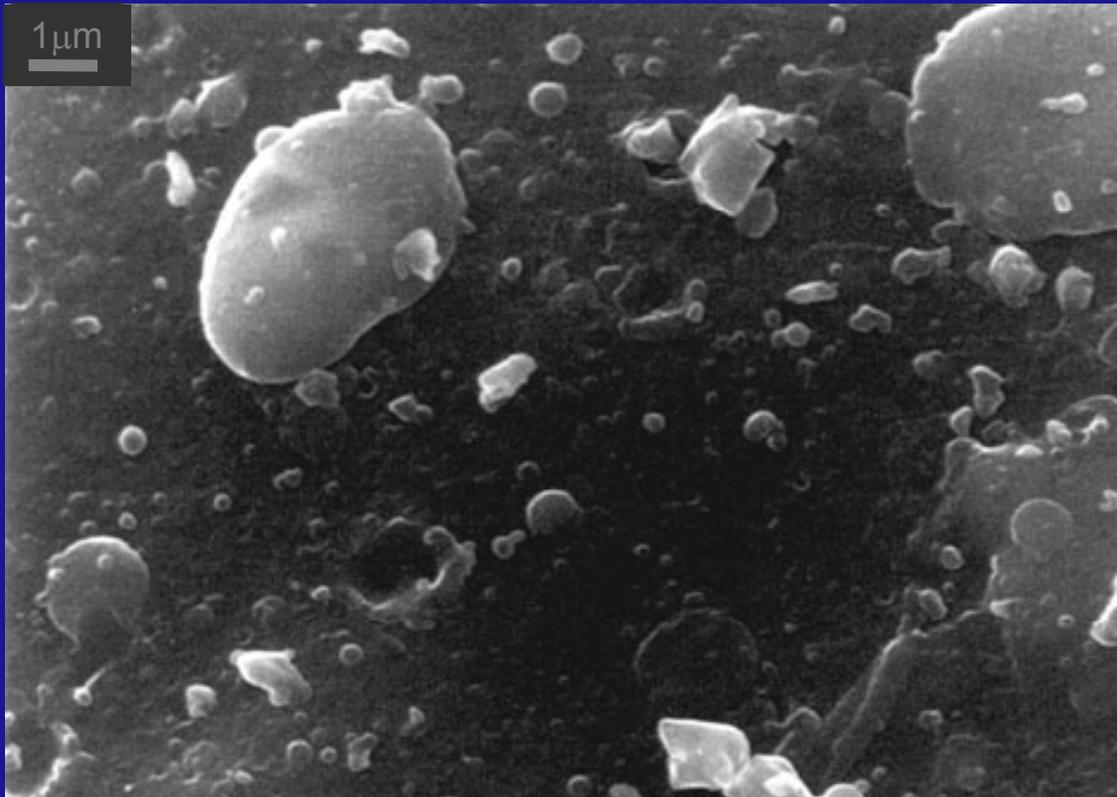


Lunar soil is “sticky”



Small grains “stick” to large ones -
electrostatically or
glass-welded

Surfaces are coated



Pancakes, Microcraters, Glass splashes

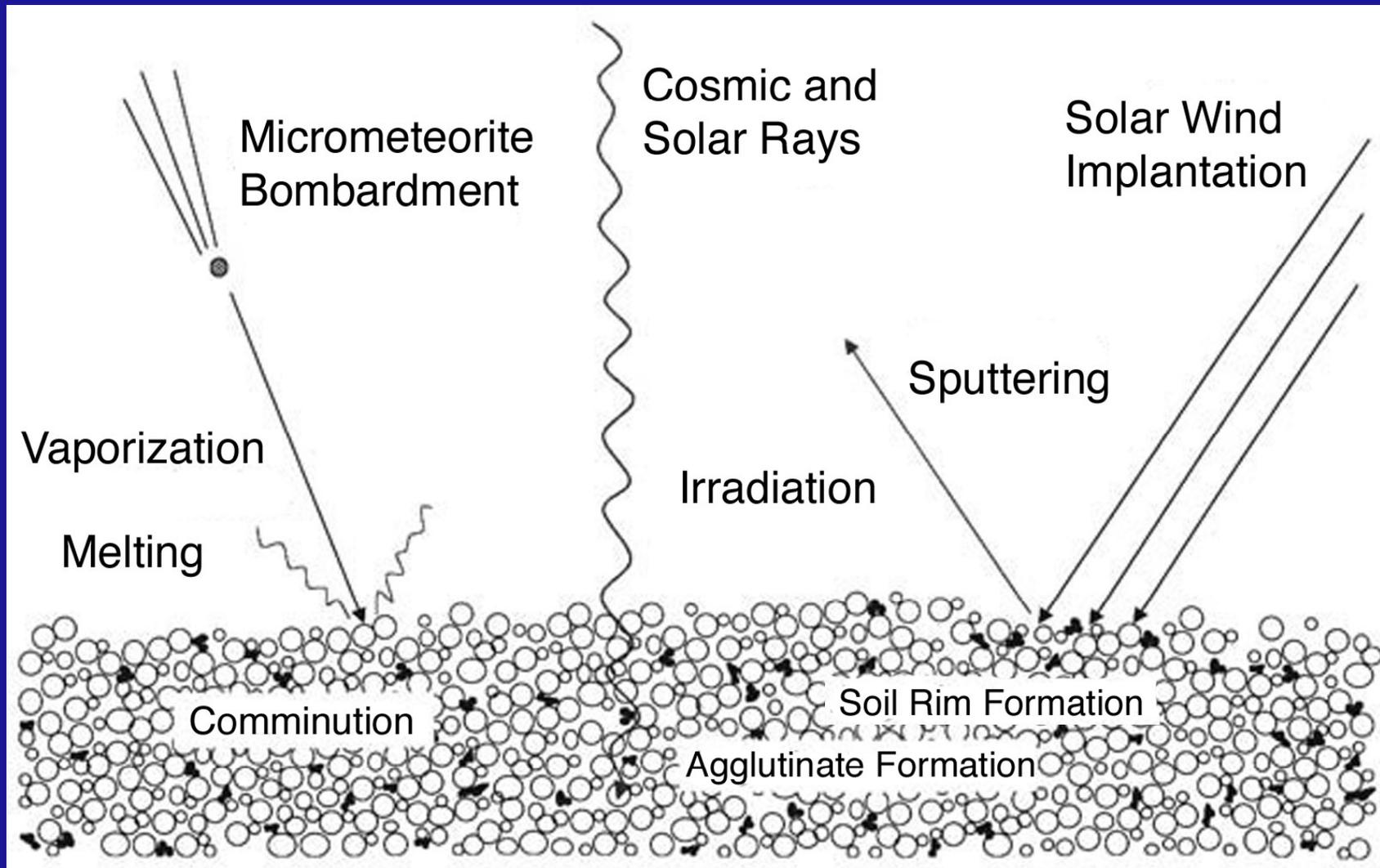


Regolith evolves over time

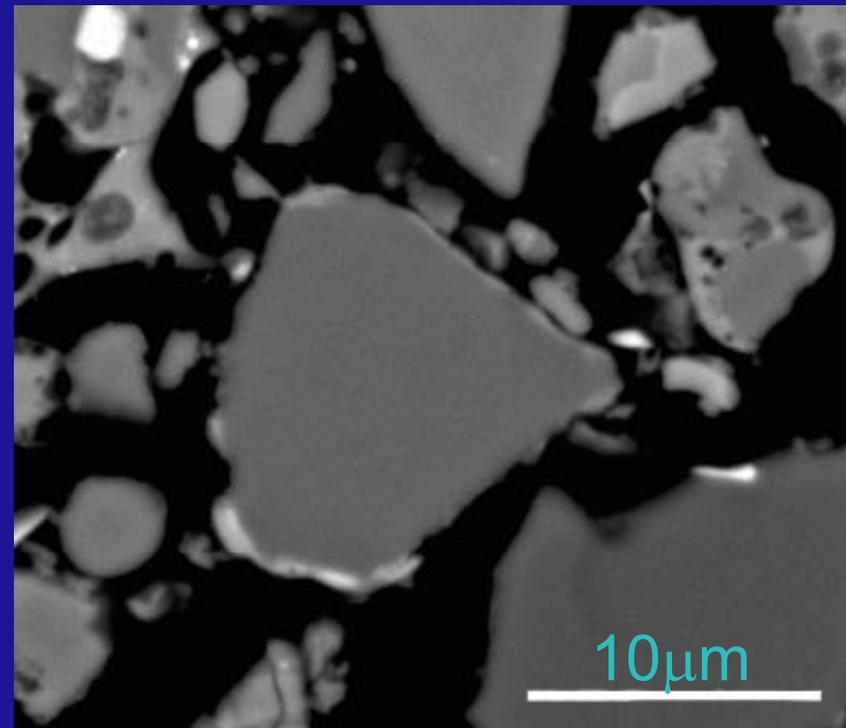
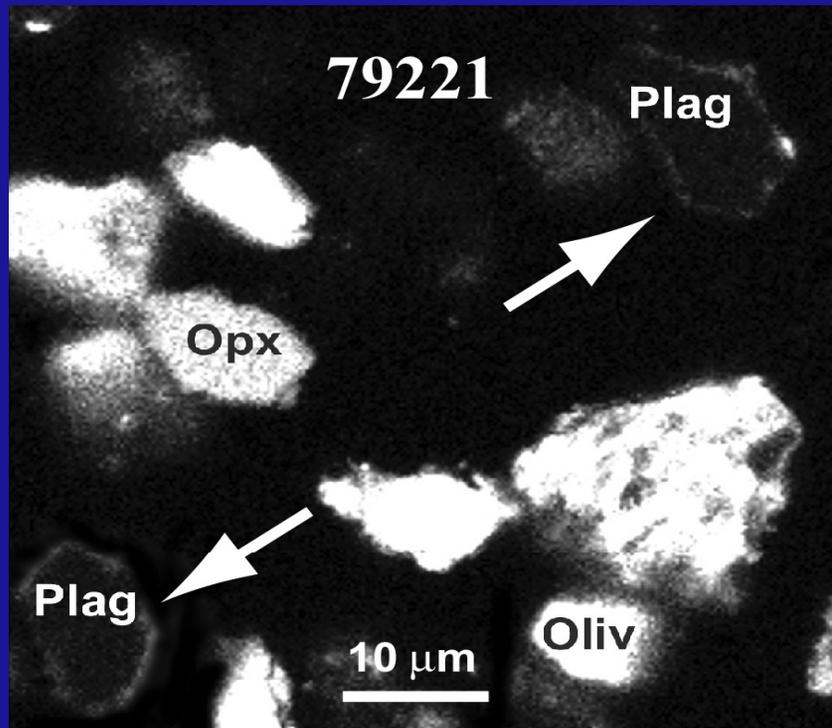
This process is referred to as
“maturing”

*fresh craters are bright

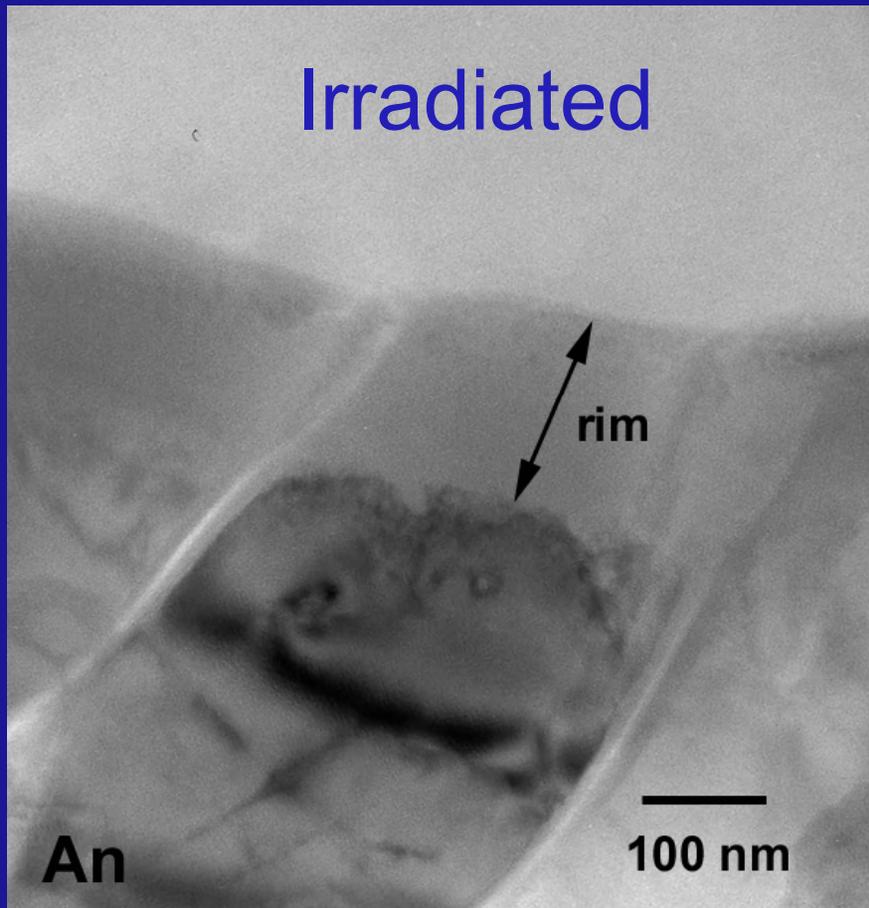
The causes of space weathering



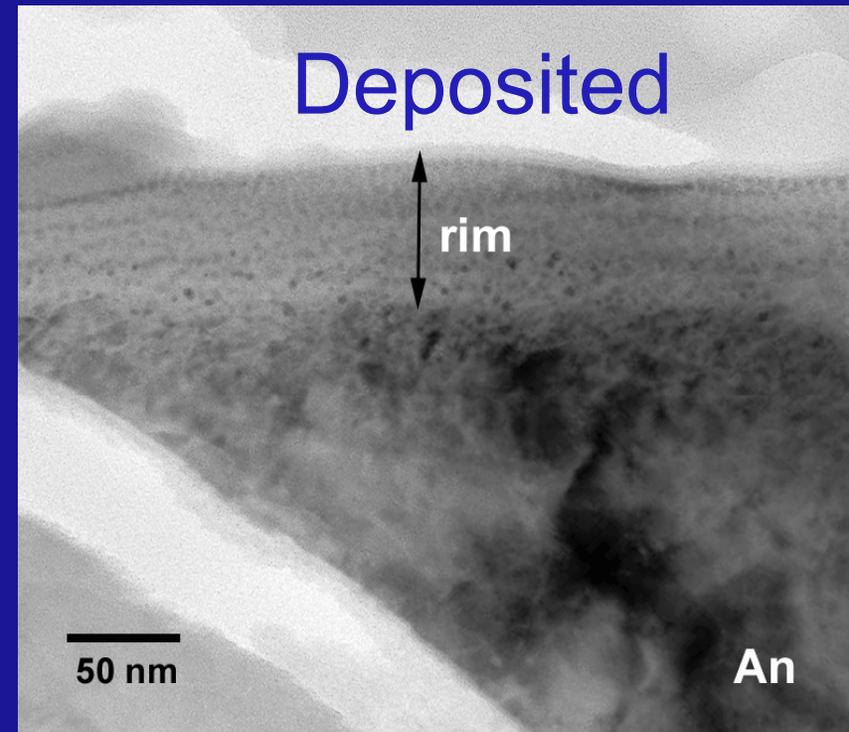
Grain rims



Two kinds of rims

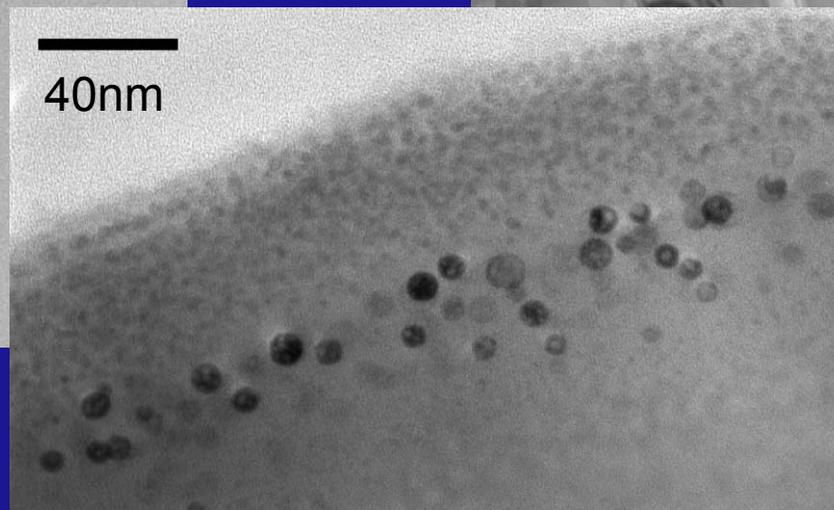
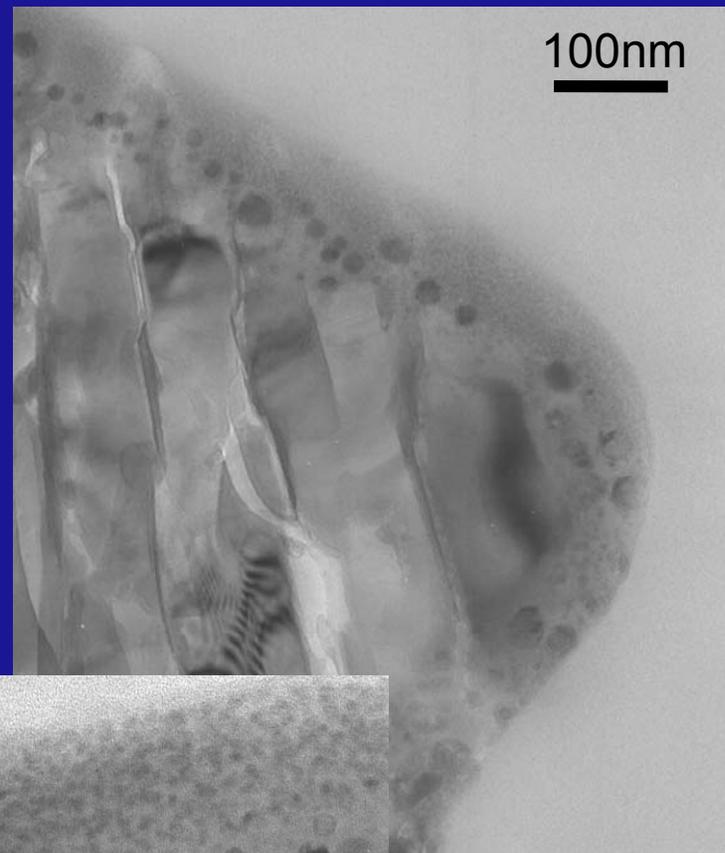
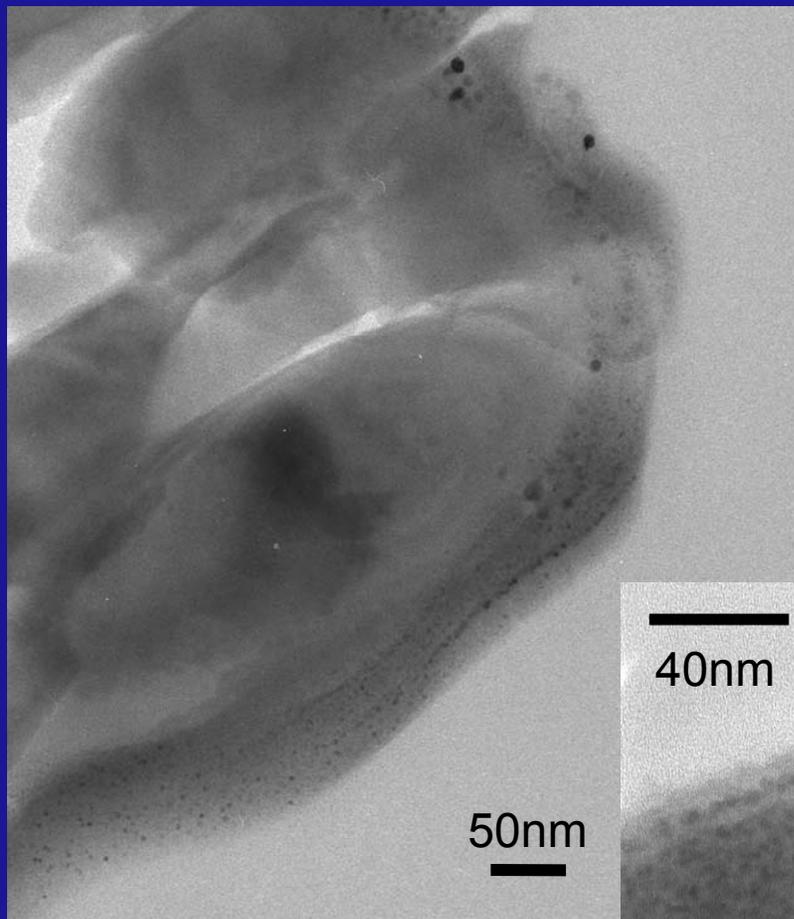


- Amorphous
- Show chemical heritage to host grain

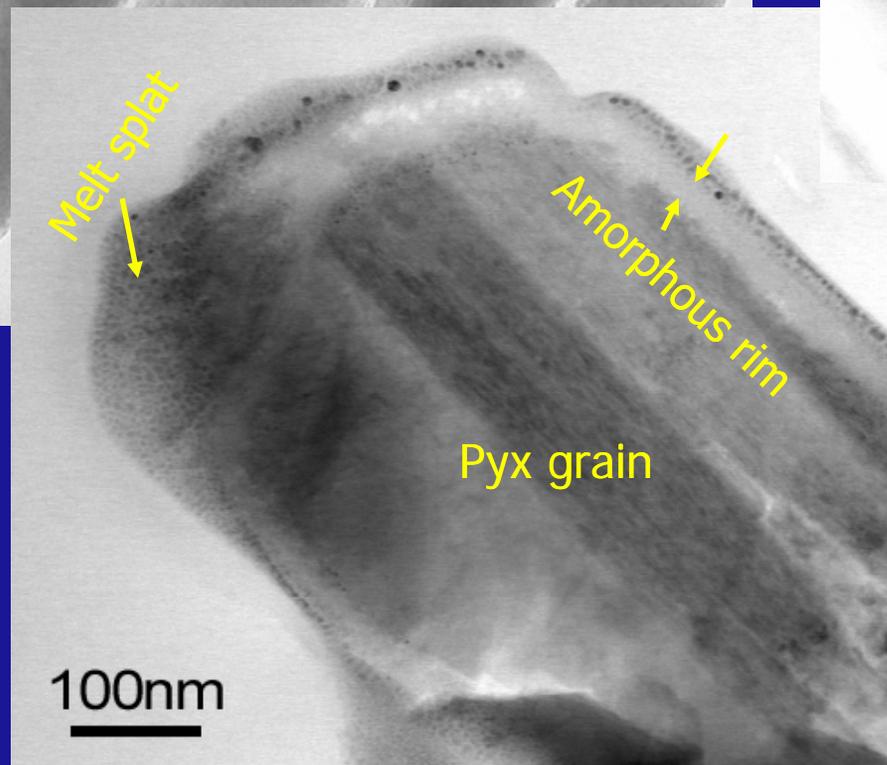
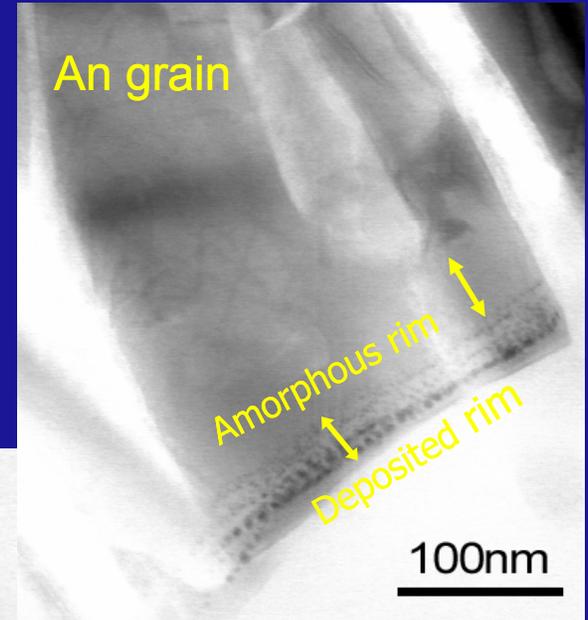
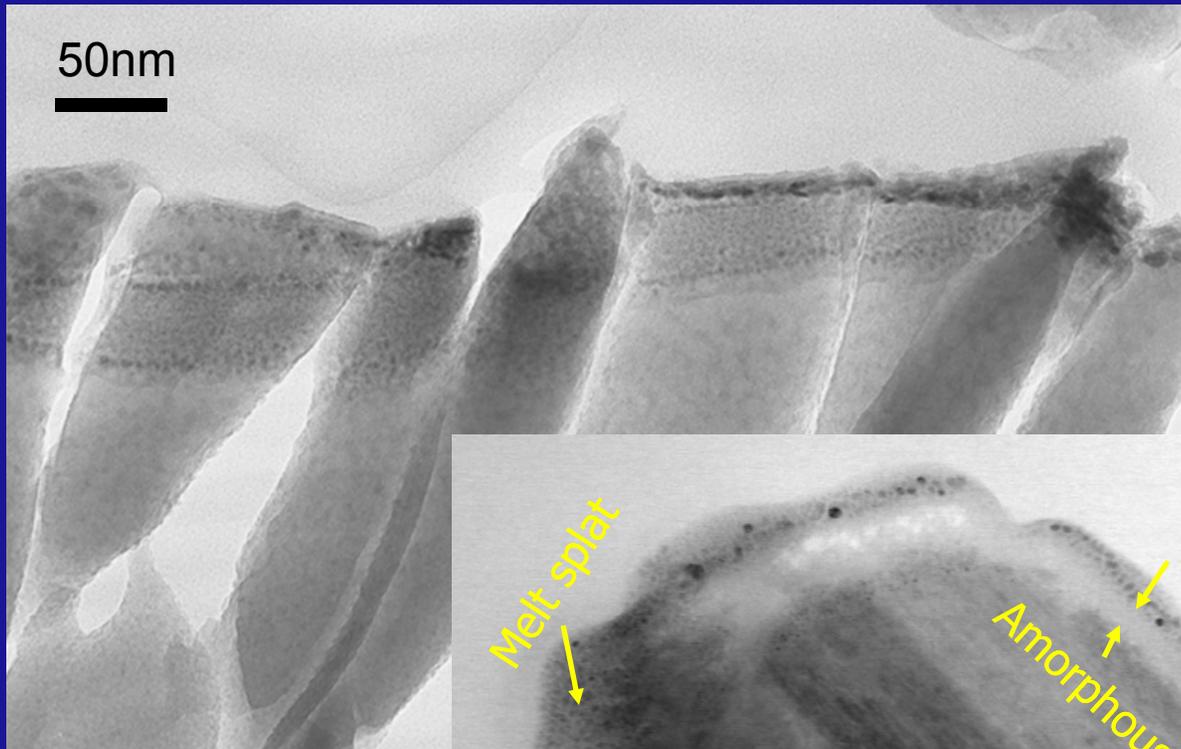


- Amorphous
- Compositionally distinct from host grain
- Layering is common
- Abundant npFe^0

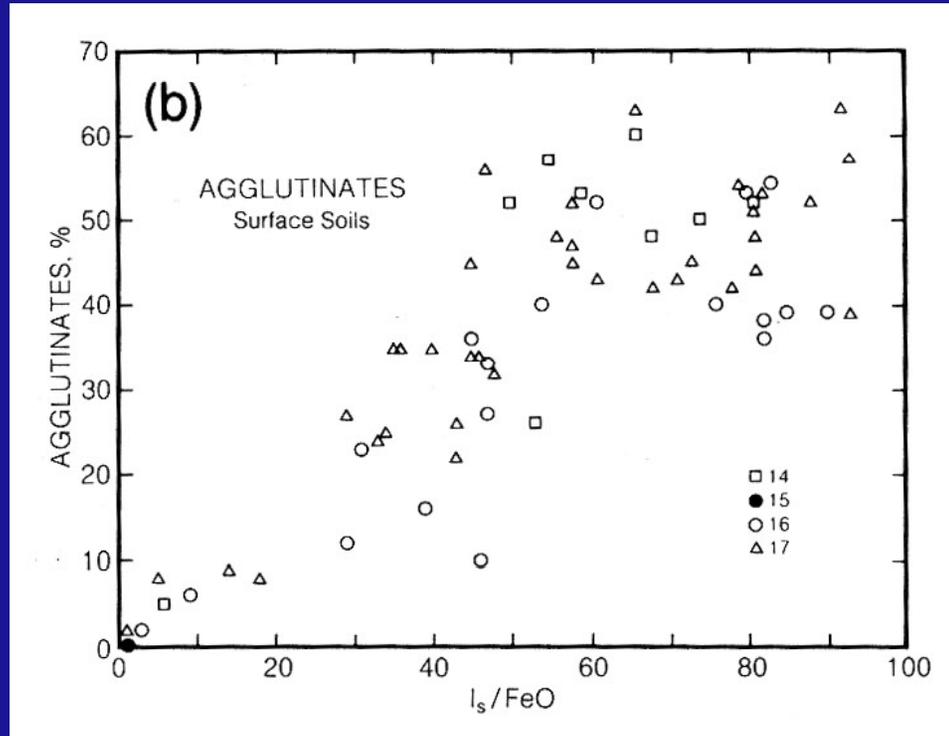
Deposited Rims



Complex Rims



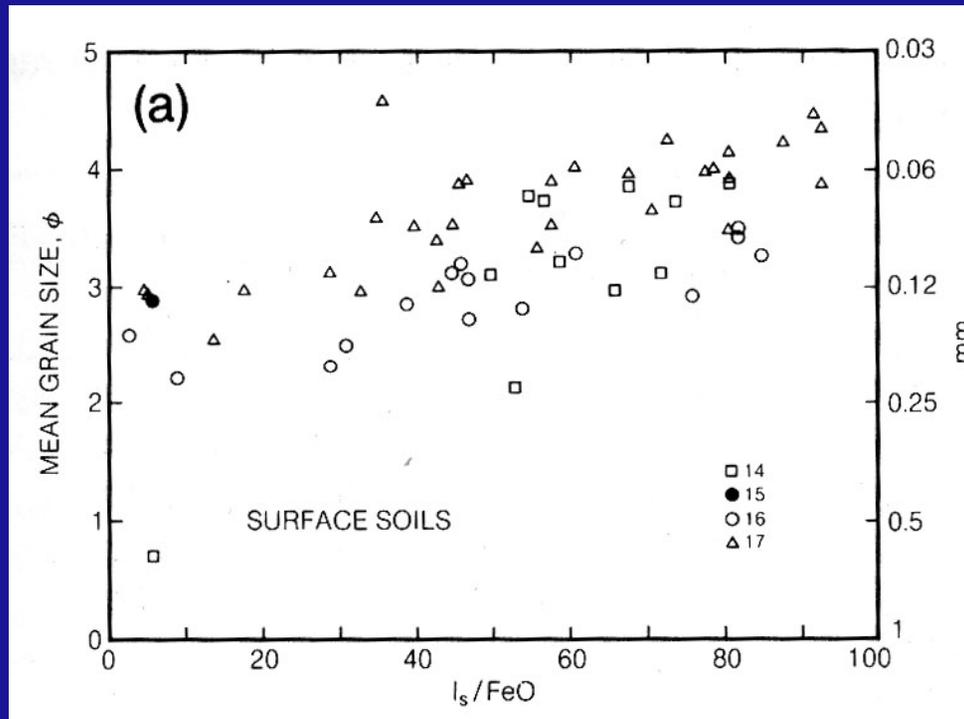
As a soil matures



Lunar Sourcebook

- I_s/FeO measures the amount of nanophase iron in a soil. This is the standard measure of maturity for lunar soils.
- Agglutinate content also increases with maturity.

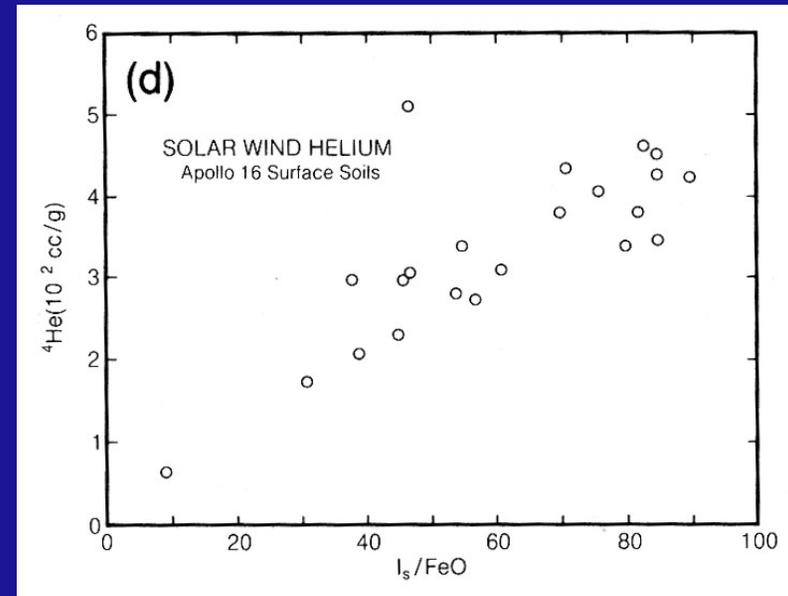
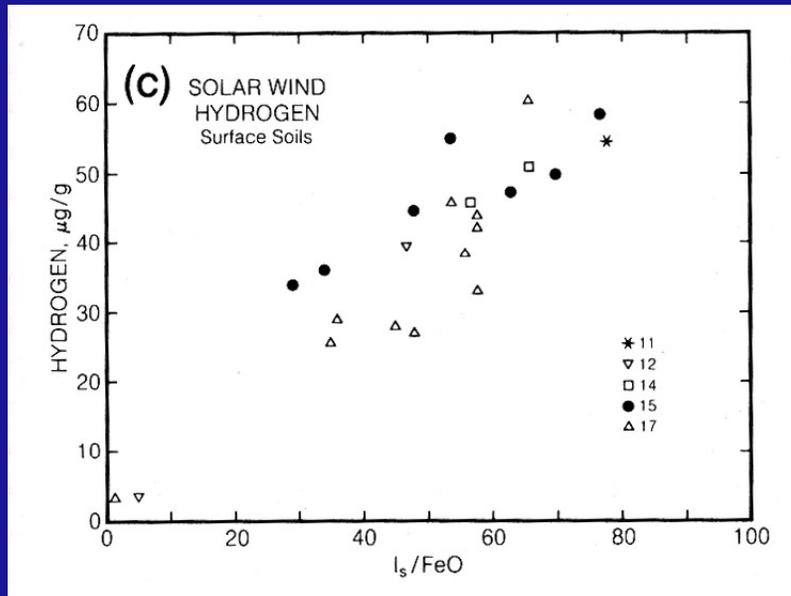
As a soil matures



- Mean grain size decreases as a soil matures

Lunar Sourcebook

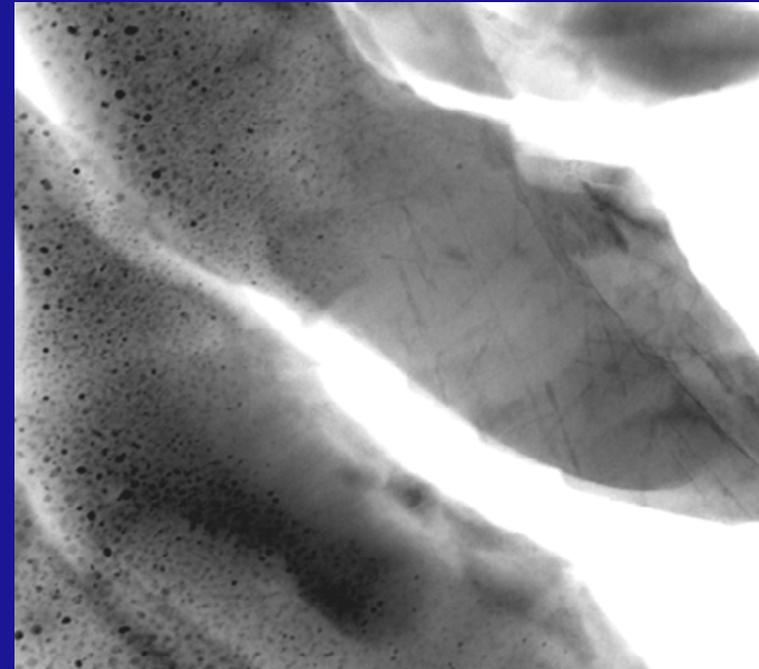
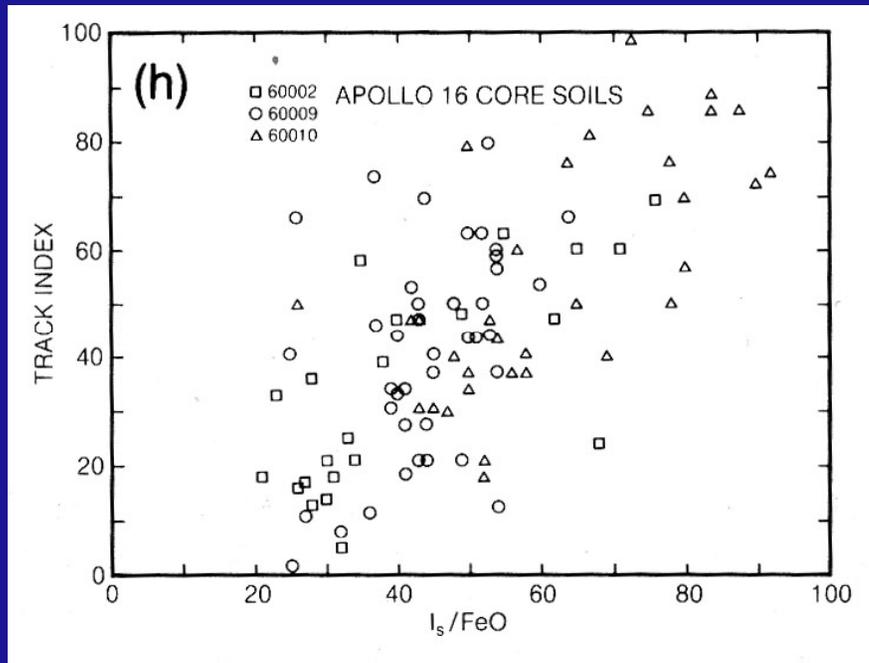
As a soil matures



Lunar Sourcebook

- Implanted solar wind ions increase as a soil matures

As a soil matures



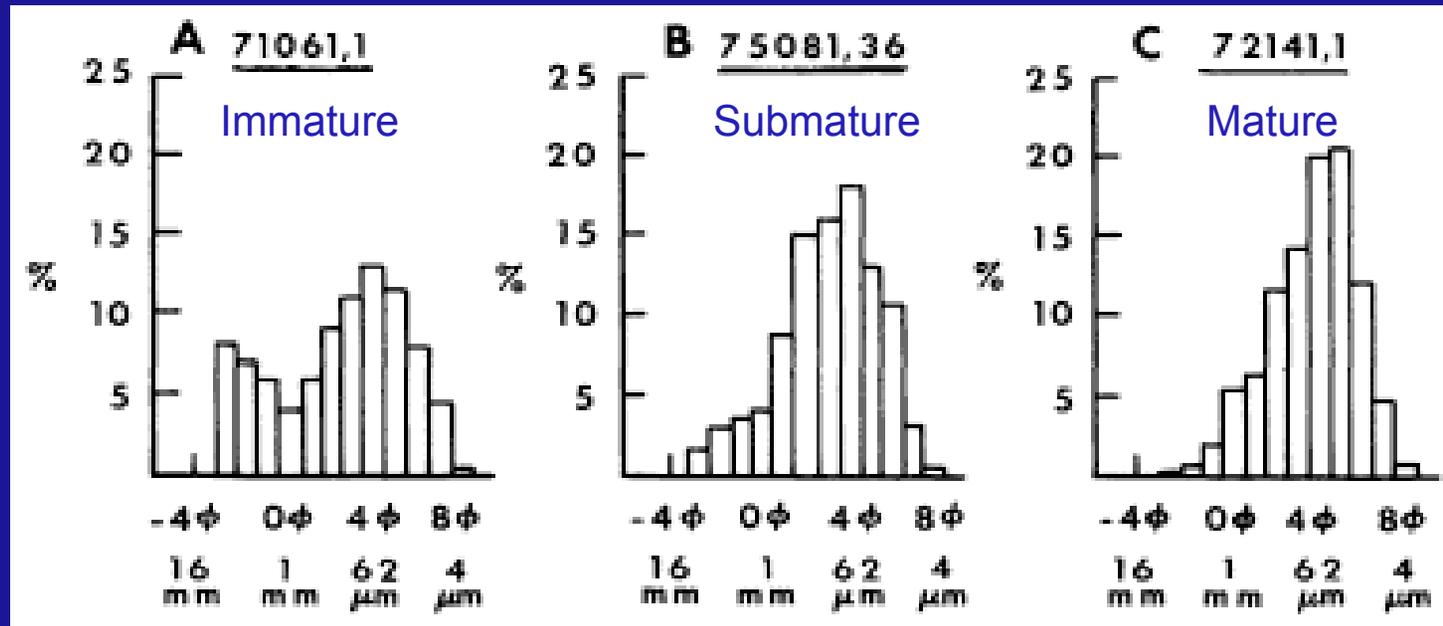
Lunar Sourcebook

- High energy electrons, positrons, and other subatomic particles traveling at near light speed leave behind tracks in soil grains that can also be used to estimate maturity.

As a soil matures

- It accumulates agglutinates
 - Immature 5-20%
 - Submature 15-50%
 - Mature >40%
- It accumulates rims
 - Immature $I_s/\text{FeO} < 30$, few grains have rims
 - Submature $I_s/\text{FeO} 30-60$, many grains have rims
 - Mature $I_s/\text{FeO} > 60$, most grains have rims (90%)
- It becomes finer grained
- It acquires solar wind ions

Grain Size Distribution



McKay et al, 1974

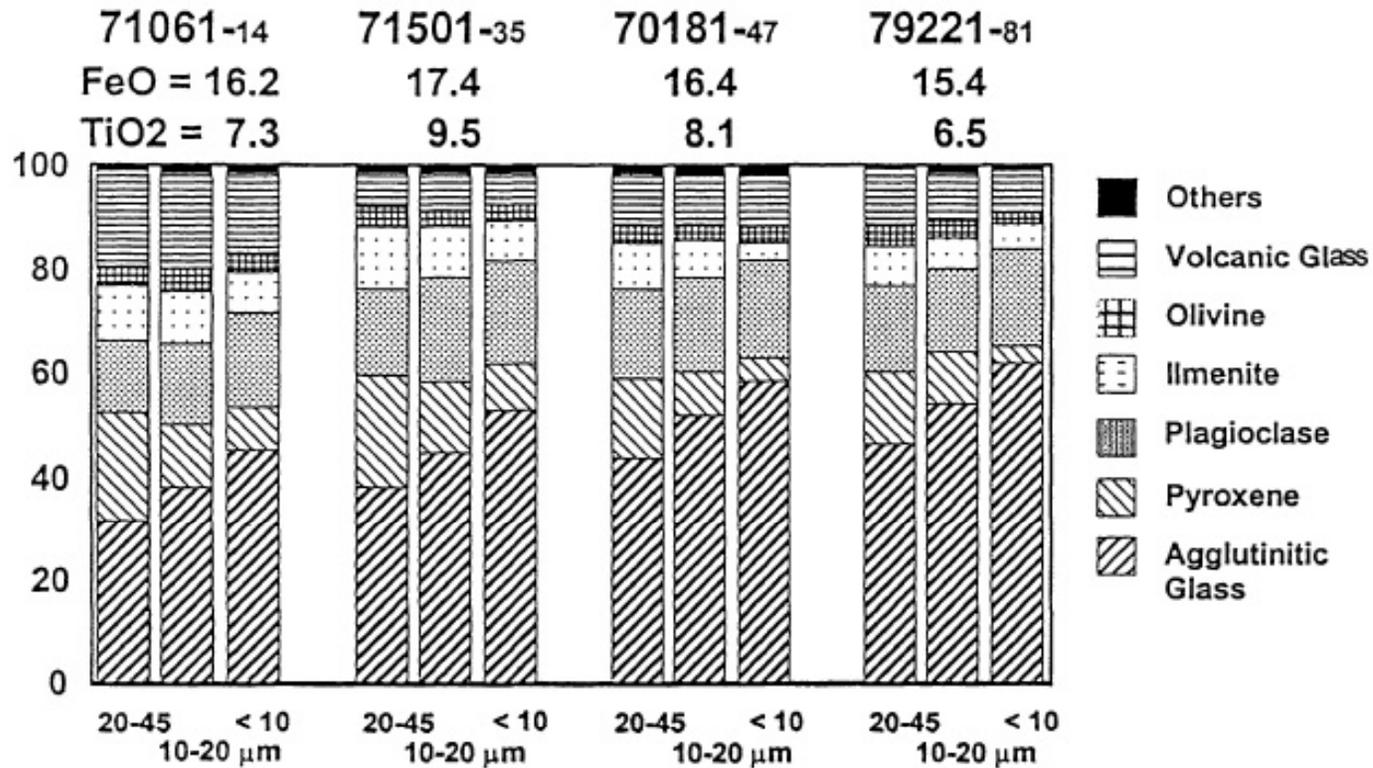
- About 10 percent of a lunar soil is greater than 1 mm
- 50 percent is greater than 100 microns
- 90 percent is greater than 10 microns

Soil Evolution

- Plagioclase and glass break down easier than the other major minerals in lunar soil (pyroxene, olivine, ilmenite, or cristobalite).
- The finest fractions of lunar soil are composed mainly of plagioclase and glass (Fusion of the Finest Fraction - F³)

Soil Evolution

Cumulative Modal Percentage of Apollo 17
Mare Soil Components (<10-45 μm)



Taylor et al, 2001

Important Stuff to Remember

- Lunar soils are unique
 - Not sorted (size, shape, or chemistry), sharp edges, agglutinates, rims, everything is coated, small grains stick to larger ones
- Lunar soils mature over time
 - Become finer grained, more agglutinates, more nanophase iron, implanted solar wind, finest fraction is mostly plagioclase and nanophase iron-bearing glass