Exploring the Moon with Samples.

Scientific and Exploration Importance of Sample Return and Buying Down Risk and Cost of Sample Return Missions.

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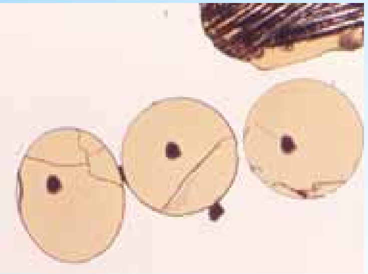
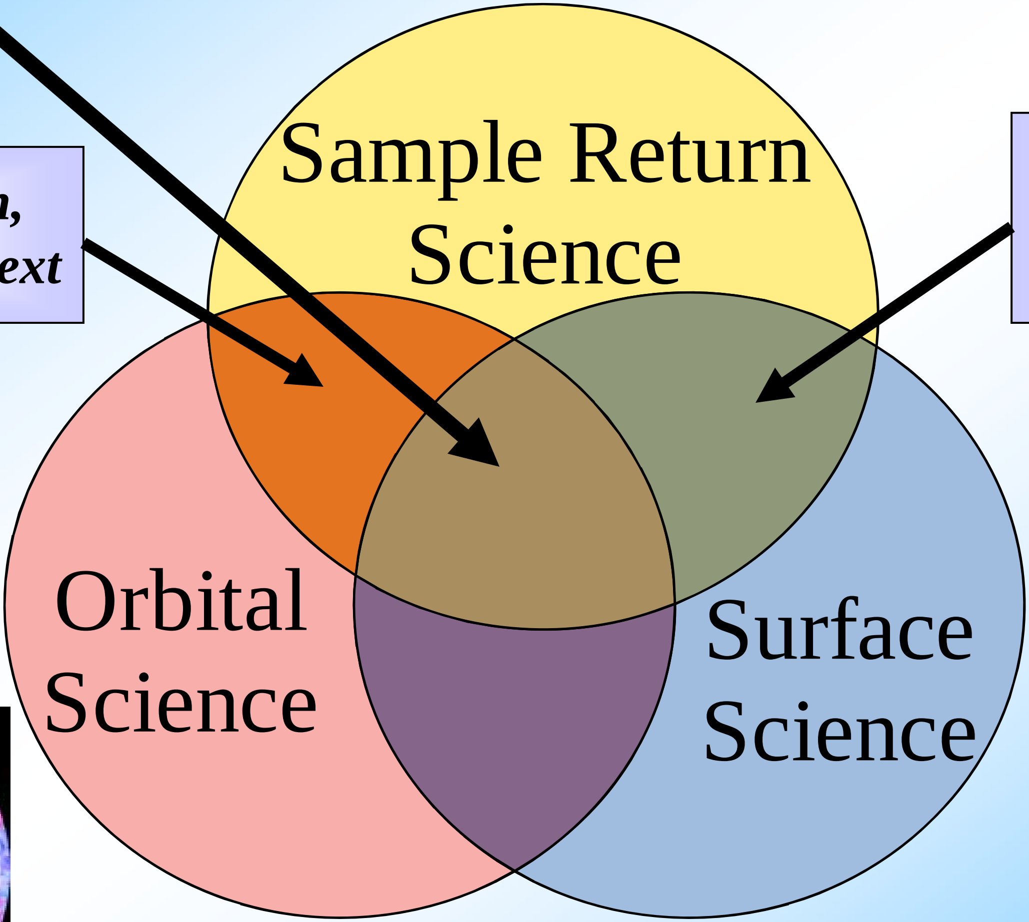
Outline

- Synergy between sample return and other types of lunar observations.
- Sample return, a unique scientific perspective.
- Linkages between sample return and compelling lunar-planetary science.
- Sample return within the context of lunar exploration architecture.
- Buying down risk and cost of sample return.

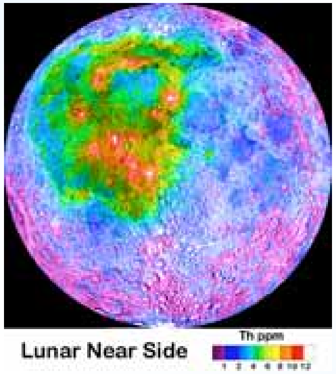
Richer understanding of the Moon, Earth-Moon system & Solar System

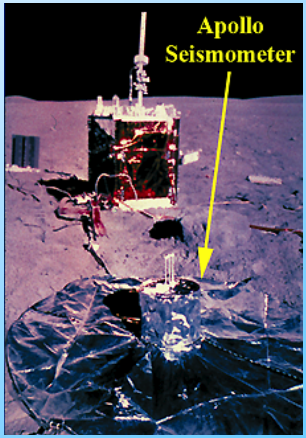




Ground Truth, Planetary Context

Ground Truth, Surface Sensitive Measurements

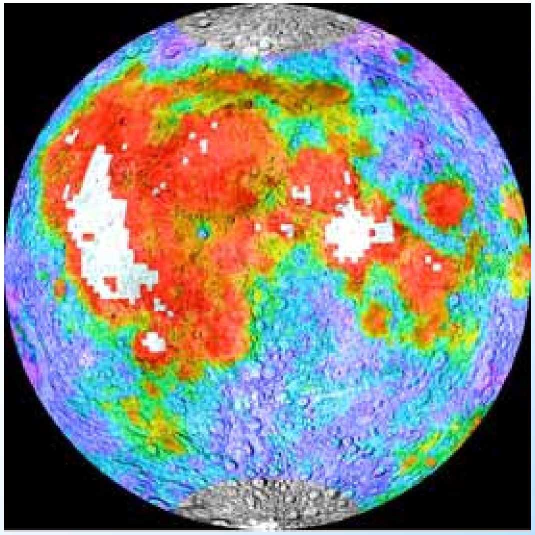


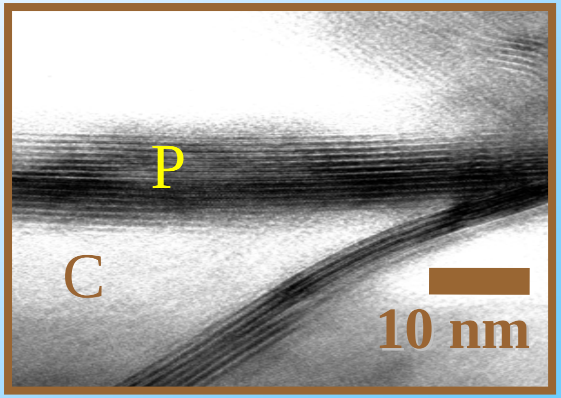


Significance of Sample Return I

Samples Provide a Unique Perspective

- Large Science Return.
  - The Moon is the best understood extra-terrestrial object because of the samples returned by the Apollo program.
- Relatively small samples often record planetary- and solar system-scale processes.
- Provides a unique perspective based on high spatial resolution and high analytical precision.

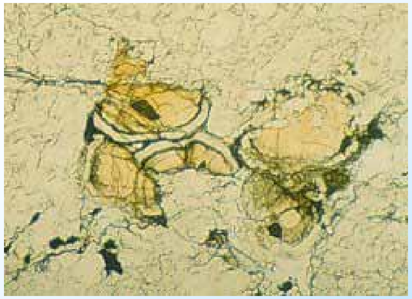


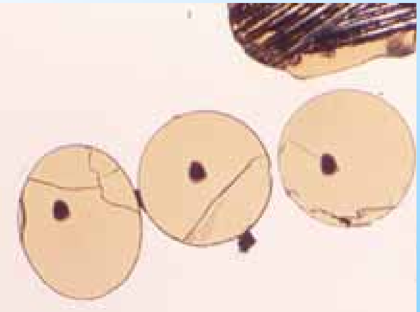


Significance of Sample Return II

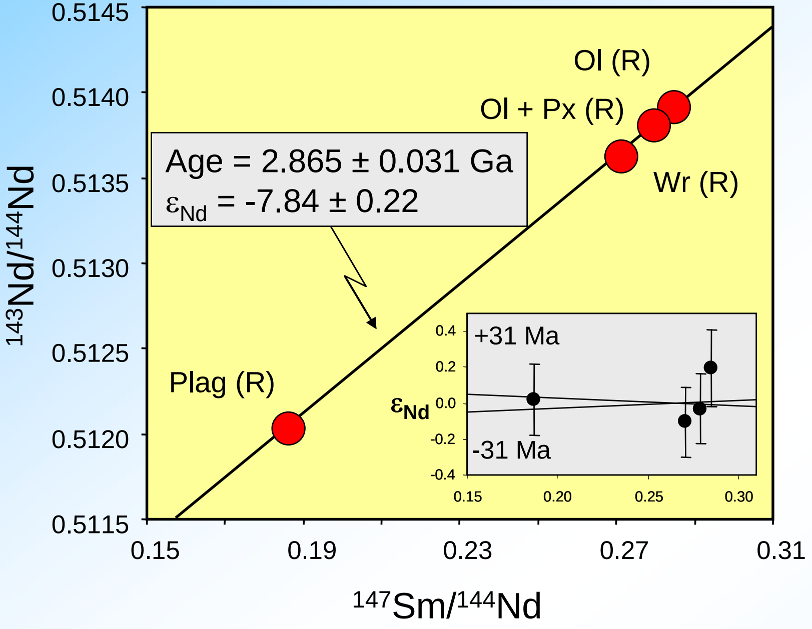
Sometimes a Lab is Better

- The best instruments can be used to analyze returned samples, not the best available at the end of mission design reviews.
- Instrumentation is not limited by mass, power, reliability, data rate, the requirement to work autonomously, etc. This results in much lower cost to do analysis.
- Analysis is iterative and not limited by preconceived ideas.
- Offers a high degree of sample manipulation and multiple analytical approaches.
- Unexpected or ambiguous result can be tested with additional measurements or modified experiments. <u>A new mission is not required to retest results.</u>
- The ability to modify experiments as logic and technology dictate over an extend period of time.
- "Samples are the gift that keep giving" to future generations of planetary scientists.



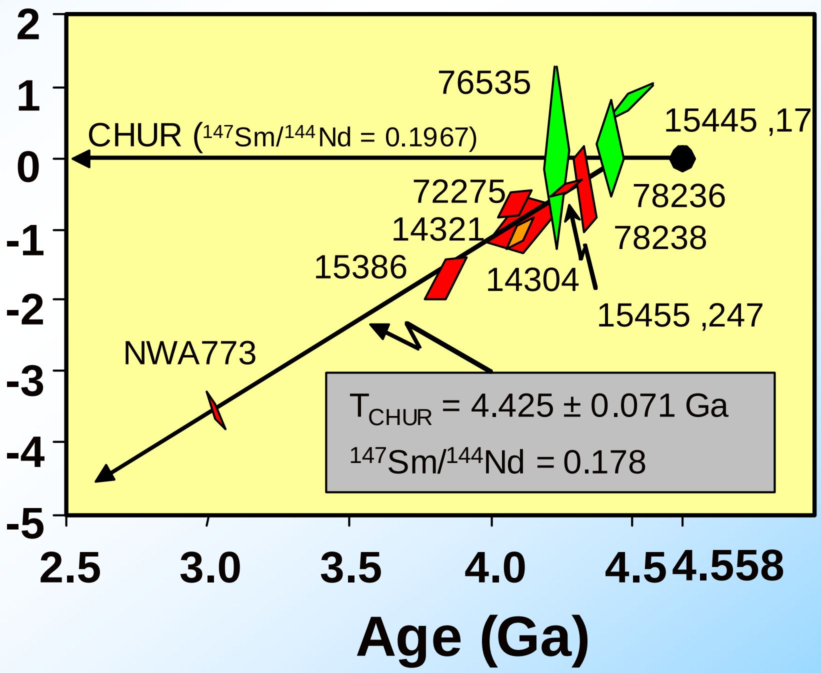


Example 1. High analytical precision and sample manipulation



NWA 773 Gabbro-norite clast (youngest dated lunar igneous rock)

Age = 2.865 ± 0.031 Ga
ε_{Nd} = -7.84 ± 0.22

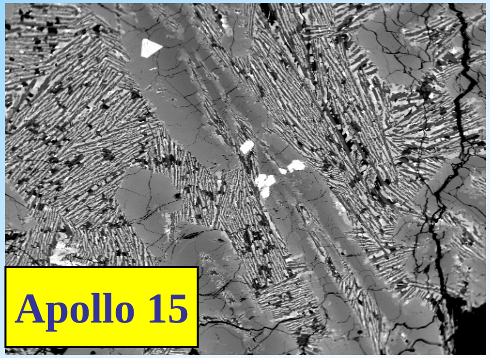


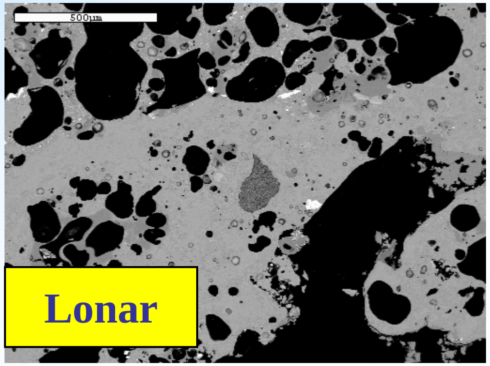
T_{CHUR} = 4.425 ± 0.071 Ga
$^{147}Sm/^{144}Nd$ = 0.178

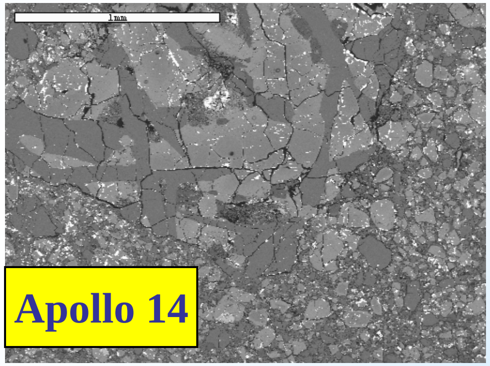
Significant sample processing-manipulation and analytical precision required

Not only a crystallization age that can place surface events into a historic context, but information relevant to mantle composition and evolution

Example 2. A matter of precision & petrologic context



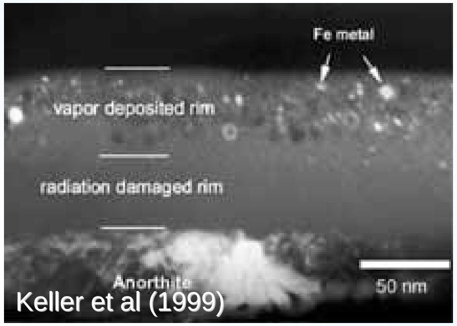




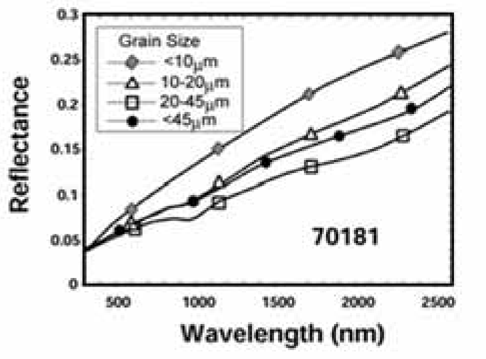
COMPOSITION:	**Basalt**	**Basalt**	**Basalt**
MINERALOGY:	**plagioclase pyroxene Fe-Ti-oxides glass**	**plagioclase pyroxene Fe-Ti-oxides glass**	**plagioclase pyroxene Fe-Ti-oxides**
***PETROGENESIS*:**	**Mantle melting**	**Impact Melt**	**Basaltic Breccia**
AGE:	**Crystallization or reheating event**	**Impact event**	**Crystallization, assembly, or mixing**

Example 3. A matter of scale

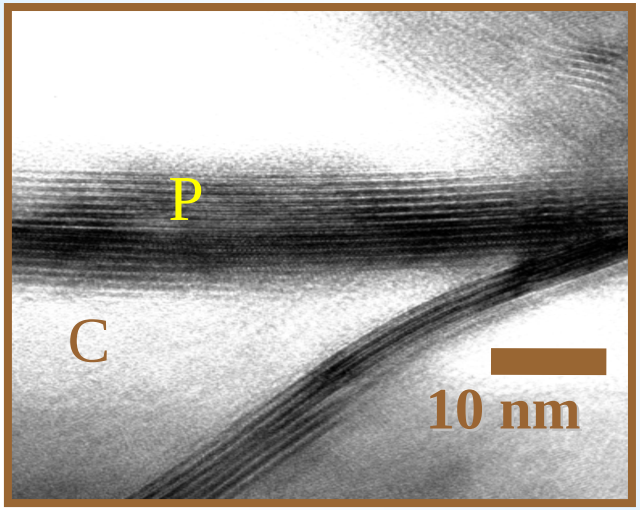
- All grain surfaces are altered by radiation damage and vapor deposition.
  - Very fine grain size chemistry, mineralogy, and grain surface alteration dictate reflectance spectra.
  - Studies of the very fine fractions of lunar soils show how to interpret reflectance properties of planetary objects that have little or no atmosphere.



Keller et al (1999)



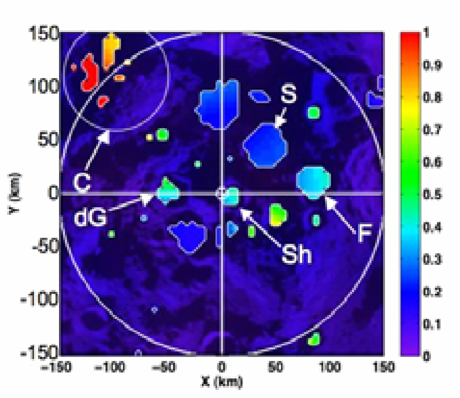
Lunar Soil Consortium



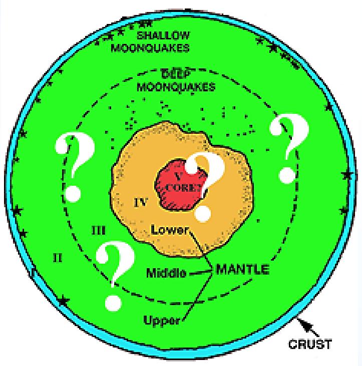
- Part of the lunar volatile record is preserved at this scale on mineral-glass grains.
  - Endogenous volcanic volatiles.
  - Volatile transport during impact processes.
  - Interactions between polar deposits and regolith?

Compelling Lunar Science and Sample Return

mGEO7: Characterize impact flux over the Moon's geologic history, to understand the impact history of the inner solar system.



mGEO13: Characterize transport of volatiles to understand the processes of polar volatile deposit genesis and evolution.



mGEO1: Use passive seismic data to determine the internal structure and dynamics of the Moon to constrain the origin, composition, and structure of the Moon and other planetary bodies.

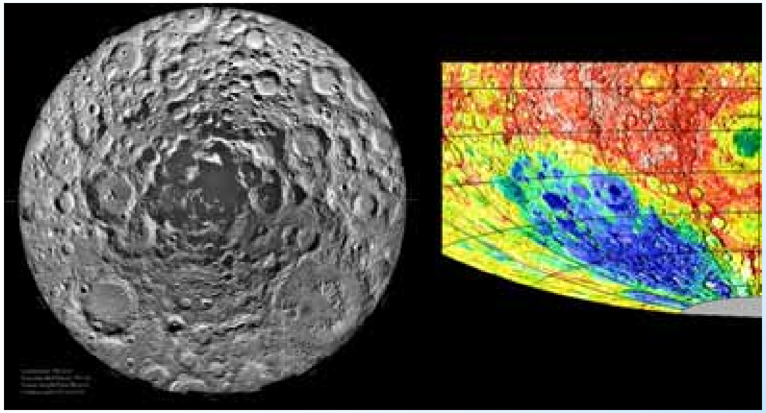
Sample return in lunar exploration architectures I.

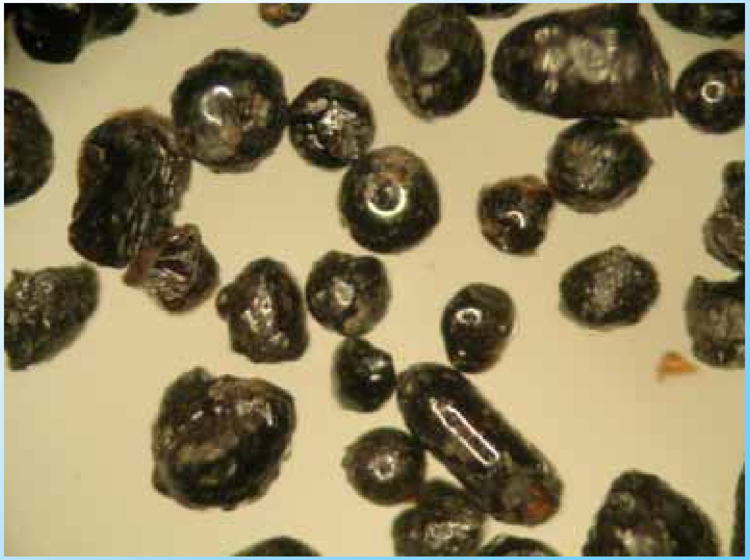
- Robotic sample return from unique lunar locations.
- Human sample return.
  - One lunar site.
  - Missions to mult.iple site.
  - SR capability 250-300 kb
- Robotic-Human Integration
  - Rover sampling and return to lunar outpost

Sample return in lunar exploration architectures II.

Role in the utilization of lunar resources

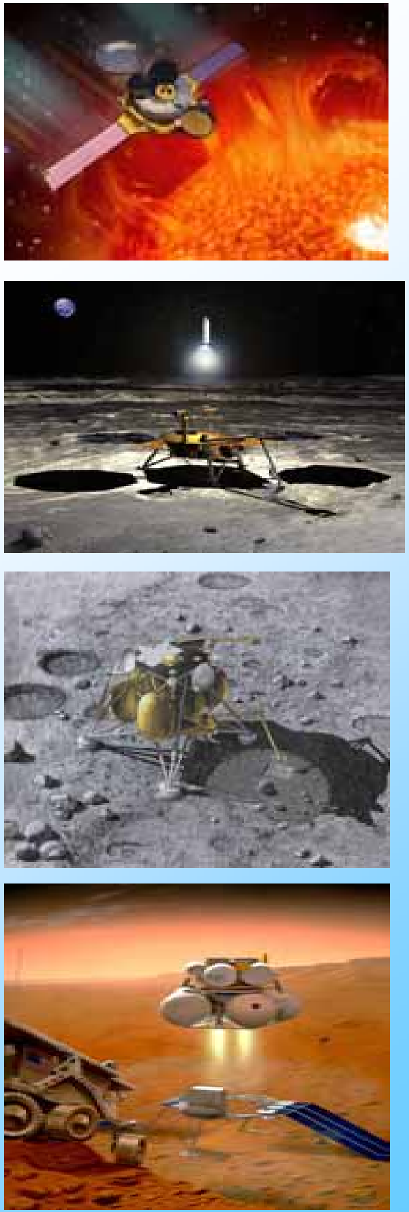
- Validation of orbital observations in terrains outside of the Apollo sites.
- Evaluation of potential resources.
  - High-Ti pyroclastic deposits.
  - Nature of H resources.
- Better definition of the geology at potential lunar base sites.
  - Structure of regolith.
  - Local resources.
  - Transmission of seismic energy.





Buying down risk and cost of sample return

- Risk and cost of SR missions are perceived as having a higher risk and cost than other planetary exploration missions.
- Are there technology linkages among different styles of SR missions at system and subsystem levels? Examples:
  - Precision landing and hazard avoidance
  - Sample containment and preservation.
  - Coring and sample manipulation.
  - Clearly differences: Surface launch vehicles.
- Entrepreneurial development of SR subsystems which have technology commonality (NASA Challenge).
- SR linked to other lunar surface activities.
- International cooperation on SR missions.



Key Ideas

- Sample return is an exceedingly important component of lunar exploration.
  - Samples provide a unique data set that is critical for understanding the Moon.
  - Information about large scale planetary-solar system processes can be extracted from the robotic return of small sample volumes.
  - Sample science and sample return has a symbiotic relationship with orbital science, surface science, and resource utilization.
  - Samples placed within a planetary and geologic context by orbital and human observations is extremely valuable.
- Sample return fits within a variety of exploration architectures and surface activities.
- Risk and cost of sample return missions are perceived as being higher than other planetary missions. How can we buy down risk and cost?
  - Technology linkages. Reduce risk through flying similar SR technologies.
  - Entrepreneurial development of SR subsystems.
  - International collaborations.