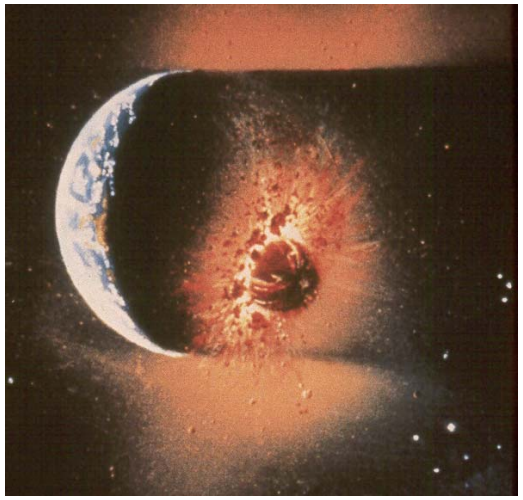
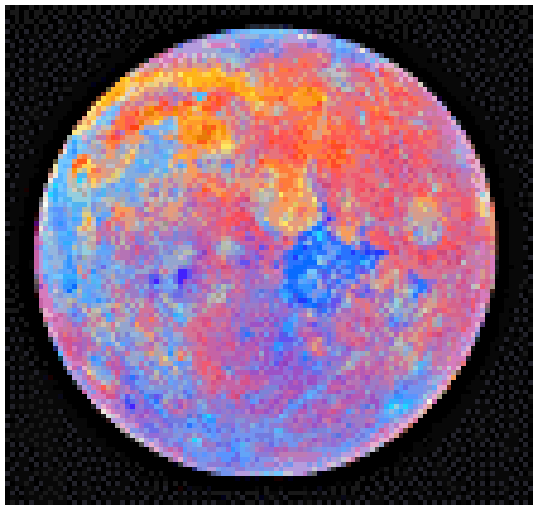
Past Studies of Lunar Science Activities and Fundamental Science Problems.

Chip Shearer
Institute of Meteoritics
University of New Mexico





Outline of Presentation

- To outline landmark fundamental scientific results from previous lunar exploration.
- To present examples of fundamental scientific problems that remain.
- To examine additional types of data that could be collected by a balanced program involving orbital, in situ, sample, human-collected data that would address these fundamental problems.
- To do this in the allotted time of 15 minutes.

Scientific Landmarks of Lunar Exploration I

- The Moon is a differentiated body.
  - It accreted very rapidly perhaps from debris resulting from a cataclysmic collision between Earth and another large body.
  - Planetary scale melting (LMO) was probably the mechanism behind the first stage of lunar differentiation.
- Realization that impact processes are fundamental planetary processes.
  - Large impacts produced all of the large lunar craters and a variety of impact lithologies.
  - Impact is a fundamental process for planetary formation and evolution.
  - Fundamental to development of Earth as an environment hospitable to life and the evolution of life.

Scientific Landmarks of Lunar Exploration II

- Lunar structure.
  - Estimates of thickness and mineralogical composition of the crust and mantle made from
  - Significant crustal asymmetry (KREEP, mare basalts) that reflects very early differentiation processes.
- Volatile reservoirs and transport.
  - Volatile transport in tenuous lunar atmosphere.
  - Discovery of possible volatile deposits at the lunar poles.
- Formation and evolution of the lunar regolith.
  - Regolith formation on airless planetary bodies (Moon, Mercury, asteroids).
  - Record of solar history.
  - Insights into the relationships between regolith characteristics and remotely gathered mineralogical-geochemical data.

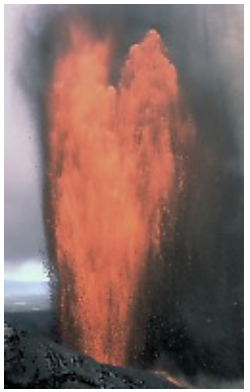
Scientific Landmarks of Lunar Exploration III

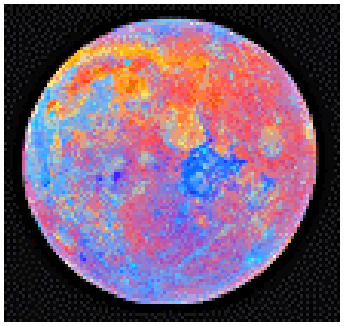
- Scientific and Technological Summaries:
  - New Views of the Moon (CAPTEM 2004).
  - Lunar Surface Exploration Strategy (LExSWG 1995).
  - A Planetary Science Strategy for the Moon (LExSWG 1992).
  - Geoscience and a Lunar Base (NASA Conf. Pub. 3070, 1990).
  - Many are on Lunar Return page of the LPI site.

Importance of the Moon in Understanding Fundamental Solar System Scale Processes

- The Moon preserves the remnants of primordial crust and early differentiated mantle.
- Moon has retained a record of the near-post accretional impact history of the inner solar system.
- Moon provides a type-locality for surface processes on a airless-planetary body.
- Origin of the Moon is tied to the earliest evolutionary stages of the Earth.
- Resource identification and processing in hostile environment.
- Develop planetary exploration tools (Planetary seismic net, remote drilling and sampling).

Remaining Lunar Problems





- Lack of understanding of the lunar interior.
- Nature of volatile reservoirs (lunar mantle and surface) and volatile transport on an airless planetary body.
- More complete understanding the thermal and magmatic history of the Moon.
- Fuller understanding of the bombardment history of the inner solar system.

Understanding the lunar interior I

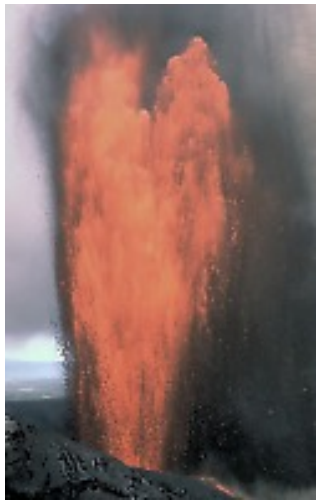
- Scientific Importance:
  - What is the bulk composition of the Moon?
  - What are the structural, compositional, and thickness variations of the lunar crust?
  - Are there distinct crustal and mantle structural domains? If so, do they mimic surface terranes and are the transitions between them abrupt or gradational?
  - Is garnet present in the middle and deep mantle?
  - Is the ~500 km discontinuity observed by Apollo a Moon-wide feature? Identification of this would allow an evaluation of the “magmasphere” vs. “magma ocean” hypotheses.
  - What is the lunar core made of, and how extensive is it?
  - Do “plastic zones” persist in the lunar core and mantle (i.e., are parts of the Moon still hot)?

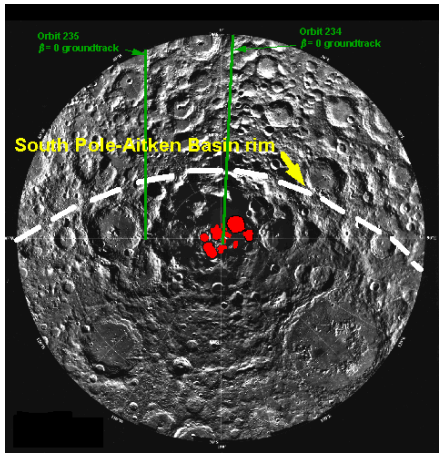
Understanding the Lunar Interior II

- Limitations of current data:
  - Apollo seismic data:
    - Seismographs clustered close together on the near-side.
    - Little data on variations in crustal structure & thickness.
    - Imprecise and ambiguous data for the deeper lunar mantle and core.
  - Samples are representative of a limited lunar terrane.
- Examples of required data:
  - Extensive, Moon-wide seismic network.
  - High-quality, Moon-wide topography and geophysical data sets.
  - Samples
    - primary basalts that represent melting in different mantle settings and over a more extensive periods of time.
    - Deep crustal lithologies from other lunar terrains.

Volatile Reservoirs and Volatile Transport I

- Scientific Importance:
  - Volatiles in the lunar interior.
    - What are the dominate volatiles in the lunar interior?
    - What are the volatile reactions that drive magmatic-volcanic processes?
    - How extensive are the lunar pyroclastic deposits?
  - Volatiles on the lunar surface?
    - Do H_2O ice deposits exist at the lunar poles?
    - What is the lateral extent of these deposits?
    - What is the vertical extent of these deposits?
    - Over what period of time are these deposits formed?
    - What volatile transport processes are active on the lunar surface?
    - Do these deposits record lunar surface and atmospheric processes?





Volatile Reservoirs and Volatile Transport II

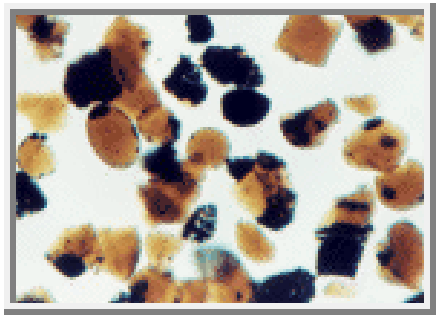
- Limitations of current data:
  - Samples of the pyroclastic deposits does not define size of deposits
  - Current orbital data on the nature and extent of H-rich deposits is open to interpretation.
- Examples of required data:
  - More detailed orbital compositional and mineralogical mapping of pyroclastic deposits.
  - Estimates the vertical extent of deposits.
  - More detailed orbital determinations of the extent of H deposits, their relationship to topography, and more conclusive orbital data that these deposits represent H_2O ice.
  - Robotic sampling and analysis of deposits at both surface and depth.
  - Robotic sample return of deposit.

Thermal and Magmatic History of the Moon I

- Scientific Importance:
  - Was there a lunar magma ocean?
  - If there was a magma ocean, what was its nature?
  - Is the magma ocean the dominate process by which all of the terrestrial planets differentiate?
  - How does lunar magmatism change with time?
  - How does this change is magmatism reflect mantle processes and evolution?
  - How does the lunar volcanic asymmetry reflect asymmetry in mantle processes?
  - How does lunar heat flow change with lunar geography and time?

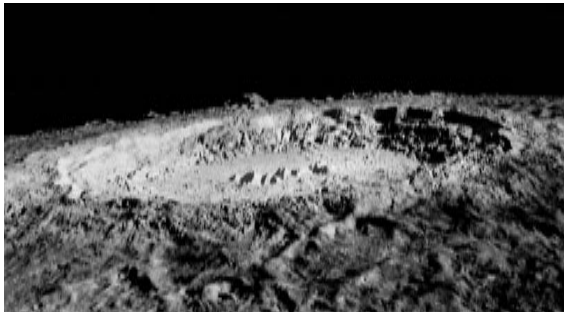
Thermal and Magmatic History of the Moon II

- Limitations of current data:
  - Apollo seismic data is ambiguous and regional.
  - Apollo heat flow data is regional..
  - Basalts are primarily samples from PKT.
- Examples of required data:
  - Extensive, Moon-wide seismic network.
  - Heat-flow measurements and thickness of regolith.
  - High-quality, Moon-wide topography geophysics.
  - Samples.



Bombardment History of the Inner Solar System I

- Scientific Importance:
  - Was there a substantial increase in the intensity of impact flux in the inner solar system at 3.9 billion years ago?
  - If it occurred, what role did this increase in impact flux have on the evolution of life on Earth?
  - What is the impact flux after 3.9 billion years?
  - Does the composition of impactor population change with time?
  - Does the impact flux change within the inner solar system?
  - What is effect of catastrophic impacts on planetary evolution?

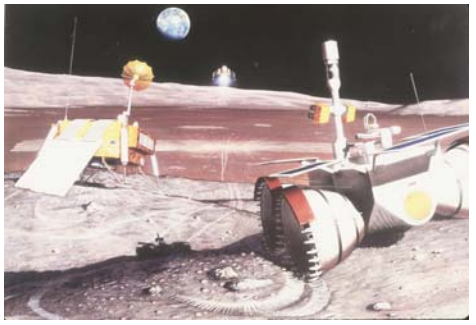


Bombardment History of the Inner Solar System II

- Limitations of current data:
  - Samples are representative of a limited lunar terrane.
- Examples of required data:
  - High-quality, Moon-wide topography and gravitational field data sets.
  - Sampling and dating of impact melt sheets associated with large basins and craters suspected to be products of the 3.9 billion year cataclysm.
  - Sampling and dating of impact melt sheets associated with craters suspected to be products impact after 3.0 billion year.

Science Activities During Manned Occupation of the Moon

- Geophysical surveys.
  - Setting up seismic stations.
- Geologic field work and sample collection.
  - Establish field relationships
  - Selection of important samples based on cognitive powers.
- Identification and processing of lunar resources.
- Astronomical observations.



Conclusions

- **Scientific goals of lunar exploration are consistent with a program of resource evaluation, data collection and technology development for human occupation of the Moon.**

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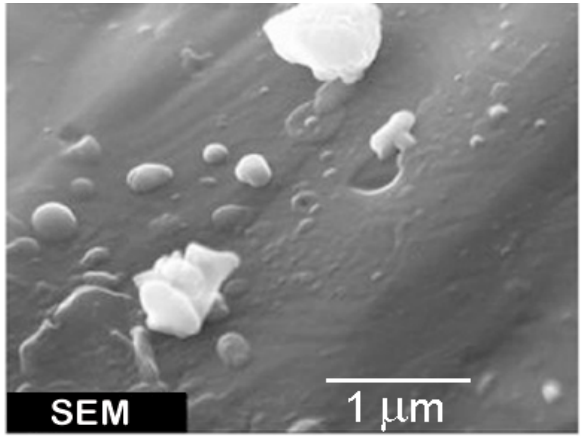
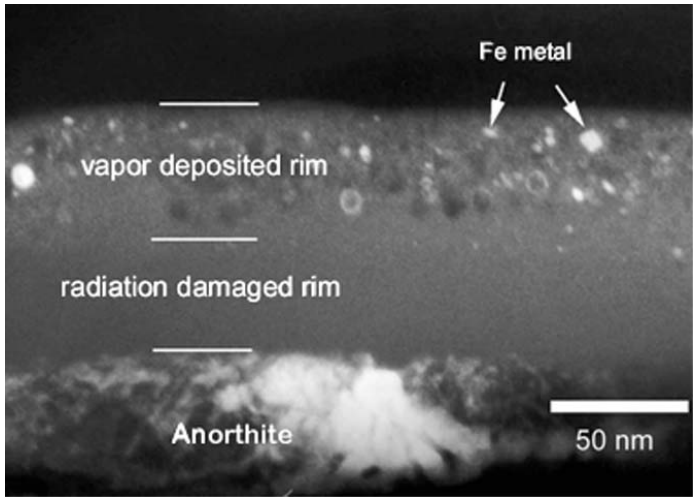
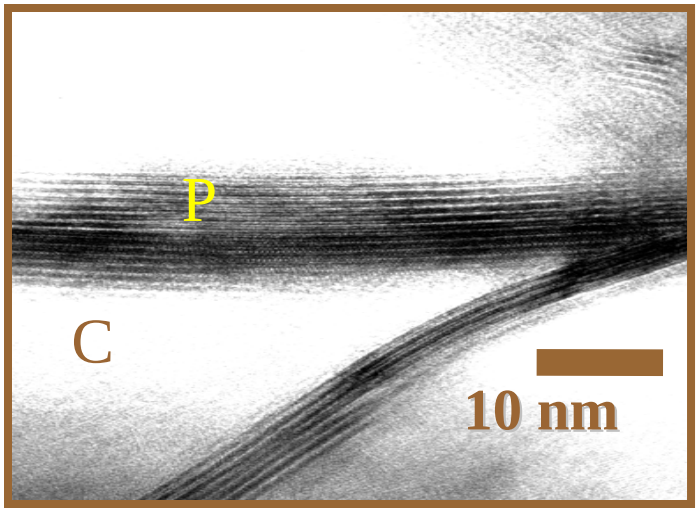


Volatiles on mineral surfaces.





Mineralogical fingerprints of water.