RETURN OF A DIVERSE SAMPLE FROM MARS

D. A. Papanastassiou

JPL/CALTECH

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Mission Progression

- Observations from Earth, Flybys, Orbiters, Landers (in situ), Landers (sample return)
- There is excitement with every type of mission, at different stages of knowledge
- The explosion in understanding comes with successful sample return (meteorites, Apollo, STARDUST, GENESIS)
- Sample return would serve as the ground-truth for the design of follow-up orbiter and lander (in situ analyses) instrumentation
Examples of Mission Progression

• Spectroscopy of the lunar surface: all orbital observations required recalibration and reinterpretation
  – The presence in the soils of glass, agglutinates, and nanophase Fe (solar wind-reduced Fe) had been totally unexpected
  – The presence of breccias was unexpected
  – The same need for recalibration will be true for Mars
• Crater chronology and inferred lunar evolution had to be changed, based on the ages of the returned samples
  – Mars chronology (calibrated relative to the Moon) would change
• Chemistry provided by Surveyor (α-back-scattering) allowed preparation (on Earth) for the Apollo samples
  – However, only one isotope lab was adequately prepared for Rb-Sr on basalts, and almost none for U-Pb on basalts
  – Terrestrial labs are in much better shape for Mars sample return
• Apollo returned samples were key for understanding (and re-interpreting) prior observations and for dispelling myths
Preaching to the Choir?

- Coals to Newcastle?
- Owls to Athens?

Not quite!

- Some would persevere with orbiters and landers, avoiding sample return, due to perceived complexity and cost.
- Need to agree that ground truth, based on returned samples results in paradigm shifts.
- Without returned samples, interpretations are Earthcentric and potentially misleading.
Believe It or Not: Past Frequent Fliers

- Ranger 1  August 1961
- Ranger 2  November 1961
- Ranger 3  January 1962
- Ranger 4  April 1962
- Ranger 5  October 1962
- Ranger 6  January 1964
- Ranger 7  July 1964
- Ranger 8  February 1965
- Ranger 9  March 1965

- Surveyor 1  May 1966
- Surveyor 2  September 1966
- Surveyor 3  April 1967
- Surveyor 4  July 1967
- Surveyor 5  September 1967
- Surveyor 6  November 1967
- Surveyor 7  January 1968

- Luna missions (flybys, orbiters, landers, robotic sample return)
  - Luna 9  Jan 1966; first soft lander
  - Luna 16 (Sep 70), 20, 24 sample returns

- Learning curve with Ranger; lessons applied quickly to Surveyor Program;
- Quantum leap in understanding of the Moon came with Apollo lunar samples

- For Mars, we can not fly frequently; but we should avoid lingering with just orbiters and landers, because that fits in our comfort zone
The Apollo Legacy

• Creation of a multidisciplinary community of scientists
• The excitement of discovery (and funding) attracted a generation of then young scientists
• A key contributor to the birth of planetary science with contributions from physicists, chemists, geologists, biologists, astronomers, material scientists
• The development of new instrumentation and new analytical techniques
• A completely new way of doing science by focusing multiple approaches on specific science questions
• Adequate funding (larger teams) for a few years
• The Apollo experience allowed the development of modern geochemistry and of environmental science
Analytical Capabilities FOR Apollo

- Electron microprobes standardized and used
- SEMs available but not ubiquitous
- Ongoing developments of organic mass spectrometry
- High precision solid source mass spectrometry (Rb-Sr dating): only one instrument with sufficient precision
- Application of the then new technique of stepwise heating for $^{40}\text{Ar}^{39}\text{Ar}$ plateau age determinations
- Inadequate U-Pb measurements, given extremely low non-radiogenic Pb and high U/Pb in the returned lunar samples
- Rare earth element and siderophile element analysis mostly by neutron activation (low sensitivity)
- New chemistry and mass spectrometry for Gd, Sm for determining secondary neutron fluence on the Moon (maximum at depth of ~1.5m) and soil gardening on the lunar surface
  - Taking advantage of large thermal and epithermal neutron cross sections
Analytical Capabilities (Isotopes) AFTER Apollo

- TIMS - high precision commercially available (late 70s)
- SIMS - Ion microprobes developed for planetary materials, isotopes
- Sm-Nd dating technique developed, using lunar Gd and Sm methods
- U-Pb low contamination chemistry developed, leading, *inter alia*, to the recognition of and proposal for a Terminal Lunar Cataclysm
- NTIMS -- Re-Os dating and siderophile element determinations through negative ion TIMS, at greatly increased sensitivity (x10^5)
- Techniques revolutionized both cosmochemistry and geochemistry
- Microanalysis through MegaSIMS, Nanoprobe, SARISA/RIMS, Synchrotron XRF, new STEM
  - all with significant investment by the community and by NASA through SRLIDAP and the LARS Program, in connection with the GENESIS and STARDUST Discovery Program missions

*All this shows the persistent value of returned samples as analytical capabilities improve*
Important Apollo Fallout

• Meteorite paradigm shift: primitive meteorite studies using the tools for Apollo samples
  – Major attention on Allende (Fall, Feb 8, 1969) and on Murchison (Fall, 28 Sep 1969) followed the end of Apollo missions

• Geochemistry paradigm shift: Sm-Nd
  – Major importance of the Sm-Nd systematics to address terrestrial mantle evolution (recognized by a couple of Crafoord Prizes)
  – Traceable directly to developments for Gd and Sm for neutron effects on lunar samples
Mars Overview

• Local stratigraphy
  – Early phyllosilicates followed by more oxidizing conditions (sulfates, evaporites)
• Stratigraphy exposed by impact structures, with some degradation
• Current emphasis on collecting sediments, for higher probability of detecting evidence of life
• Desire to sample stratigraphic sequences
• Need to obtain diverse samples
Mars Sampling Considerations

• Emphasis on conditions for habitability and possible evidence for life (past or extant)
• Probability for life is low, and, furthermore, one would have to search during early Mars, before conditions became more hostile to life
• Detailed sampling of stratigraphic layers would yield correlated samples
  – If evidence for life is absent in a layer, then sampling several sequential layers, might be less productive
  – May run counter to the goal of sample diversity
Emphasis on Stratigraphy?

• There are no road cuts on Mars
  – Partially filled and degraded craters are not road cuts
  – One would not necessarily be sampling fresh outcrops
  – In situ analyses may not provide adequate recognition of diverse samples
  – If the probability of life on Mars is low, diversity of samples (with which to investigate formation and evolution on Mars) becomes important

• Emphasis should be on sample diversity not on samples correlated through stratigraphy
  – Least potential diversity for evaporite sequences
Sediments vs. Igneous Rocks

• Analytically we can handle both rock types
• Sediments, formed under low temperature conditions may yield model ages and their source provenance (crustal vs. mantle), not internal isochrons for a precise chronology
• If the probability of life on or near the surface of Mars is low, then the emphasis would be on the evolution of Mars, with the search for life having a lower potential impact
Concluding Comments

• If simplifying sample collection has a big influence on mission cost
  – A “Groundbreaking” mission, with limited mobility and very limited on-board instrumentation would receive close attention
  – Sieving soils to concentrate rocklets would be addressed
  – The key question is the nature of local samples (e.g., collected within 1 Km) and the extent of surface alteration of 1-4 cm diameter rocklets, before coring into rocks becomes a necessity