RETURN OF A DIVERSE SAMPLE FROM MARS

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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

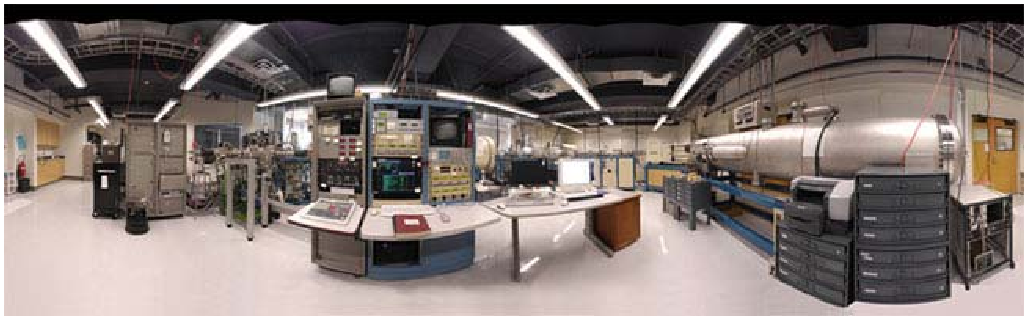
- Electron microprobes standardized and used
- SEMs available but not ubiquitous
- Ongoing developments of organic mass spectrometry
- High precision solid source mass spectrometry (Rb-Sr dating): only one instrument with sufficient precision
- Application of the then new technique of stepwise heating for ^{40}Ar-^{39}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

UCLA MegaSIMS



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