Mars Sample Return

The Apollo Perspective

D. A. Papanastassiou
Science Division, Jet Propulsion Laboratory

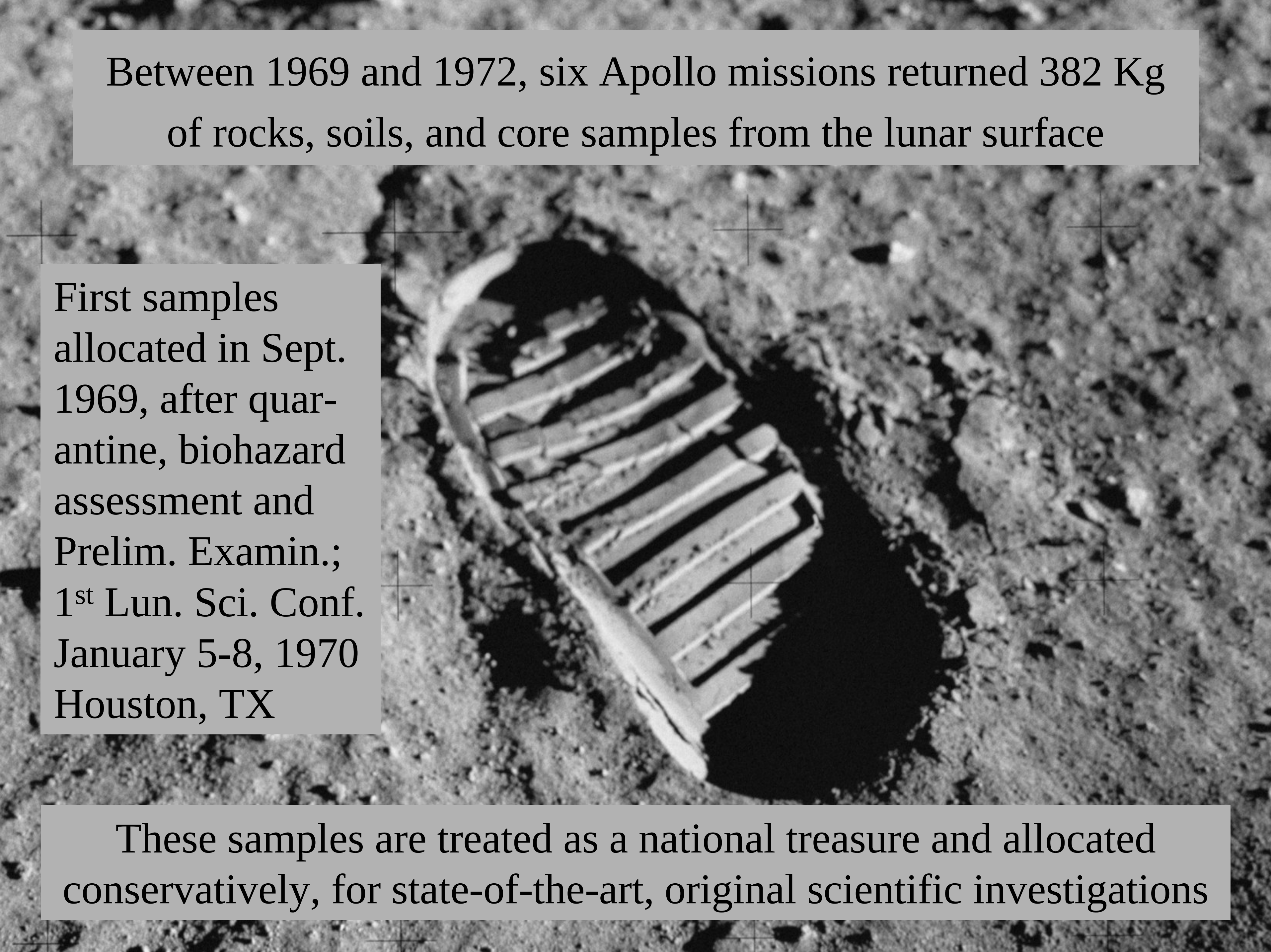
Ground Truth from Mars, Albuquerque, NM, April 21-23, 2008

Purpose

- Share some of the excitement of the Apollo returned samples
- Share the excitement of addressing lunar evolution from hard data and lifting the veil of estimates, guesses and theories
- That many “facts” prior to Apollo were wrong does not diminish the importance of earlier orbital and in situ data
- Wish the same excitement in your lifetime

Overview of Conclusions

- Prior to sample return, we interpret wonderful orbital and in situ observations of other planets in terms of our very detailed terrestrial experience
- For the Moon, Apollo samples demonstrated that our interpretations and theories were inaccurate
- This will be reasonably true about Mars too
- Hence, applying our terrestrial interpretations to Mars and requiring earth-centric, detailed sample collection processes may over-constrain MSR
- It is important to identify which scientific questions and which part of Mars' evolution, should actually be addressed by the first MSR and get on with it



Between 1969 and 1972, six Apollo missions returned 382 Kg of rocks, soils, and core samples from the lunar surface

First samples allocated in Sept. 1969, after quarantine, biohazard assessment and Prelim. Examin.; 1st Lun. Sci. Conf. January 5-8, 1970 Houston, TX

These samples are treated as a national treasure and allocated conservatively, for state-of-the-art, original scientific investigations

MARS

- We will have to work with much, much less returned material from a far more complex planet
- But after many orbital and detailed, in situ missions, it is time to bite the bullet, and seek the ground truth provided by returned samples
- Need to choose with care a landing site and processes to be addressed
- The time scale of processes on Mars is key
- If some of my statements are like bringing owls to Athens, it is deliberate, in the interest of keeping it simple, lower risk, and affordable

Ground Truth for the Moon

- From the Apollo 11 contigency soil
  - Anorthositic fragments => anorthositic crust
  - Luny Rock 1 => granitic component (=> KREEP)
  - Magic (Rb/Sr) component in soils vs. high-K basalts
  - Glass shells, spheres, dumb-bells, zap pits, agglutinates
  - Breccias
  - Pristine, coarse grained rocks
- On Mars it is harder and we can not count on serendipity
  - Sample rocks (igneous, metamorphic, sedimentary; in that order)
  - Sample soils
  - Sample evaporites, modern or ancient brines?
  - Do not sample the detailed stratigraphy of soil-like “outcrops” of siliciclastic matter plus chemical sediments, especially if dealing with an incomplete or not in equilibrium evaporite sequence

Meridiani Outcrops; B. C. Clark et al. (2005) EPSL 240, 73.

If this was Apollo again

- Prior to Apollo
  - Photography of lunar surface
  - Crater counting chronology: erroneous, based on assumption of constant cratering flux
  - Expectations for very young Moon or very old Moon
  - Surveyor landings on the Moon, essentially every two months, for Surveyors 3-7; chemical compositions from Tony Turkevich's alpha back scattering instrument
    - Implications of high Ca addressed (crust and planet density)
    - Implications of low K not adequately recognized
  - Extensive VIS-IR spectroscopy from orbit needed to be recalibrated and reinterpreted based on the presence of glass, agglutinates and "space weathering"
- Apollo returned a grab (contingency) sample, rocks, breccias, soil, for the ground truth

Prior Knowledge or Lack of It: Moon

- A plethora of scientific expectations and predictions prior to sample return, including the possibility of sinking through the lunar soil
  - Scientific expectations not confirmed by returned samples
- Completely unanticipated processes
  - Glass and agglutinate formation on airless surfaces, exposed to micrometeorites
  - Amorphous soil grain surfaces, due to irradiation
    - Reduction of Fe by solar wind hydrogen; darkening of Fe-bearing minerals
    - Overall modification of spectroscopic properties (VIS-NIR)
  - Completely unanticipated impact crater-age relationships
  - Completely unexpected regolith gardening processes, e. g., depositing 2-4 m layers and leaving them undisturbed for 0.6-0.8 Ga, as established by neutron capture effects

Tools at the Start of Apollo

- Age dating by ^{87}Rb-^{87}Sr and ^{40}Ar-^{39}Ar, only
- Dating by U-Pb only of soils, during the missions
- No U-Th-Pb ages on rocks for several years due to high U/Pb and Th/Pb, very low ^{204}Pb, and high Pb analytical blanks
- No ^{147,146}Sm-^{143,142}Nd, ^{187}Re-^{187}Os, ^{182}Hf-^{182}W
- Platinum Group Elements by INAA and RNAA, with very low sensitivity (no Re, almost no Os measurements) -- no NTIMS, MC-ICP-MS, MC-TIMS
- Apollo funding resulted in key developments of instruments and analytical techniques and science

Apollo Chronology

- ^{87}Rb-^{87}Sr: at the starting gate, only one laboratory with sufficiently precise and sensitive mass spectrometry (and chemistry) to measure internal isochrons on Apollo 11 low-K and high-K basalts
  - Rb-Sr internal isochrons depended on unpredicted minor phases with low Rb, Sr (Rb/Sr~0/0, higher than in major phases, e. g., in ilmenite, cristobalite, quintessence)
- ^{40}Ar-^{39}Ar: stepwise heating technique developed to perfection (G. Turner, CIT, Phys. Inst., Berne);
  - Most reliable ages on plagioclase mineral separates
  - Less reliable results on highland samples (due to redistribution of ^{39}Ar from recoil from fine grained interstitial phases); reverting to judicious K-Ar ages
- Learning how to date Mars rocks will not be trivial

Neutron Capture Effects

- Taking advantage of high thermal and epithermal neutron capture cross sections for Gd and Sm
- Funded by Apollo, early development of REE chemical separations (Tera) and Gd mass spectrometry (Wasserburg, Burnett, Eugster), with high efficiency of ionization for Gd as GdO^+, followed closely by development of Sm (SmO^+) (Burnett, Russ, Wasserburg)
- Production rates, as a function of depth, confirmed in situ by the Lunar Neutron Probe, flown on Apollo 17 (Burnett, Woolum, Weiss, Bauman)
- Regolith gardening rates determined
- Effects can also help address irradiation effects for humans
- Extension of techniques to NdO^+ led directly to the development of Sm-Nd dating (Lugmair)
  - N. B. Ionization efficiencies: $NdO^+ >> SmO^+ > GdO^+$!

Post Apollo Missions

- Development of U-Th-Pb
  - Measurement of highland breccias
  - Recognition of volatile, parentless radiogenic Pb, produced between 4.5-4.0 Ga and mobilized on a grand scale at 4.0 Ga
  - Recognition and proposal for a Terminal Lunar Cataclysm (Tera, Wasserburg, Papanastassiou, 1974)
- Development of Sm-Nd
  - First on meteorites (Juvinas, G. Lugmair, 1975)
  - Used on lunar samples (first, DePaolo, Papanastassiou, Wasserburg, 1978)
  - Recognition of long-standing crustal and mantle reservoirs on the Moon
  - Extensive Sm-Nd dating of lunar samples since then

The Apollo Effect

- Apollo funding permitted the shift of physicists, chemists, and geologists to interdisciplinary planetary sciences and the development of advanced analytical techniques and instrumentation (which was later applied to and revolutionized terrestrial work)

The Ares Effect?

- When will Mars Sample Return funding permit the equivalent flourishing of planetary sample science and life-detection?

What Makes MSR Different?

- Extensive prior orbital and in situ work
- Small expected sample size and, hence, small number of samples and limited diversity
- Extensive planetary evolution to present
- Water and other volatiles as prerequisites for biologic activity
- The probability for biological activity, extinct or extant
- Extent of sample alteration

Sample Size and Diversity

- Moon
  - 6 landing sites
  - 58 to 741 samples per site (2196 samples, total)
  - 22 to 111 kg per site (382 kg total)
  - Rocks, soil, cores
- Mars
  - 1 or 2 landing sites
  - Tens of samples per site
  - ~ 500 g per site (**but needs to be updated)**
  - Rocks, soils, (cores), atmosphere

Life on Mars?

- Moon
  - No evidence of present or past life in any sample
- Mars
  - Conceivable that some locations may be capable of supporting life (both past and present), having capabilities of terrestrial extremophiles
  - Are extremophiles considered hardy organisms?
  - Characteristics and hazard of Mars life (if it exists) are unknown
  - Abundance of Mars life (if it exists) is probably extremely low in samples (organic molecules in the soil < 1 ppb)
  - This level of uncertainty will persist until the first sample return mission and probably after it

Terrestrial-Type Assumptions

- Follow
  - The water
  - The brines
  - The acid or oxidizing brines
  - The hydrated components
- Timescale of water evolution?
  - For Earth: climate change chronologies based on U-Th disequilibrium dating of corals – not applicable on Mars if timescale for evaporites is greater than 0.5 Ma and if U/Th fractionation is not mediated by organisms

Conclusions

- Prior to sample return, we interpret wonderful orbital and in situ observations of other planets in terms of our very detailed terrestrial experience
- For the Moon, Apollo samples demonstrated that our interpretations and theories were inaccurate
- The same will be reasonably true about Mars
- Hence, applying our terrestrial interpretations to Mars and requiring earth-centric, detailed sample collection processes may over-constrain MSR
- It is important to identify which scientific questions and which part of Mars' evolution, should actually be addressed by the first MSR and get on with it

SAMPLE HANDLING

Since This is a CAPTEM-Sponsored Meeting

Key Concepts

- Sample handling and preservation and hazard assessment are important functions
- Preliminary examination of samples is necessary for sample hazard assessment and for sample allocations
- Clean facilities and clean sample handling are required
- Conflicts, cross contamination issues will be present and need to be resolved, to maximize science return
- Extensive experience is available for extraterrestrial samples and must be sought and applied
- Extensive experience is available in studies of pathogens and life detection and must be sought and applied as required by law and as scientifically necessary
- An Advisory and Oversight Committee must be in place, combining the extensive experience in diverse sciences
- Apollo experience and committee structure (LSAPT, CAPTEM) offer a key perspective to emulate

Sample Handling

- Starts with flight mission design, material choices and documentation, contamination removal and characterization, sample collection, sample storage, container sealing, prior to return
- Design Mars Sample Receiving and Sample Curation facilities
- Devise a unified advisory committee to oversee activities from the mission design start and into the distant future, as indicated by LSAPT/CAPTEM experience
- Invest in technology, in R&A, and in people, and take advantage of multidisciplinary experience. The Apollo generation is on its way out. Any advice we provide is based on experience and is not for our personal scientific gain

Back-up slides

Sample Temperatures

- Moon
  - Surface at the equator (mean) -19 ± 140 ^{o}C
  - 100 cm depth ~ -19 ^{o}C (isothermal)
- Mars
  - Surface average -57 ^{o}C ± 80 ^{o}C
  - 100 cm depth ~ -53 ^{o}C (isothermal)
  - A first sample return need not be maintained cold, any more than lunar samples should have been maintained under vacuum
  - The decision will be a combination of science, technology, and cost, for MSR to remain a reality

Water and Other Volatiles

- Moon
  - No evidence of water in any Apollo sample
  - Solar wind implanted H, He, C <200 ppm
  - No atmosphere

Mars

  - Water ice
  - Hydrated minerals
  - Adsorbed atmospheric gas
  - Atmosphere (95% CO_2; 6 mb)