In Search of Life on Mars

What I’ll Talk About

- Some history
  - A view at the start of the 20th century
- Mariners to Mars
- Viking Mission
  - In search of life of Mars
- A meteorite
  - In search of life in a rock
- Some latest views from Mars
- Conclusions
  - Keeping it simple

The High Hopes

“...The planet Mars, on the other hand, exhibits in the clearest manner the traces of adaptation to the wants of living beings such as we are acquainted with. Processes are at work out yonder in space which appear utterly useless, a real waste of Nature’s energies, unless, like their correlatives on earth, they subserve the wants of organized beings.” [Richard Proctor, 1902]
From Schiaparelli...

- As seen by telescopes from Earth
  - An orange-red orb, with some darker patches and bright polar caps sometimes visible
- Giovanni Virginio Schiaparelli (1835-1910)
  - 1876 announced discovery of "canali" (channels) on Mars
  - Misreported as canals (artificial) by the press

To Percival Lowell

- Percival Lowell (1855-1916)
  - Appointed MIT astronomy professor in 1902
  - Published books
    - Mars (1895)
    - Mars and its Canals (1906)
    - Mars as the Abode of Life (1908)

Lowell's Observations and Explanation

- No canals
- Human brain tendencies:
  - Connect unrelated points together by lines
- Recent theory:
  - Lowell's telescope acted as an ophthalmoscope
    - Caused Lowell to see the reflection of the radial pattern of his own retinal blood vessels
More Historical Background

At the turn of the 20th century:
- Publication offered a reward for anyone coming forth with proof of life on another planet or anywhere in space EXCEPTING Mars
- Just about every major observatory had released hand paintings of Mars and some were even releasing photographs as astrophotography was in its infancy
- No two drawings could agree on the formations on the planet's surface
- They showed a Mars with a varied surface possessing darker and lighter areas, as well as the polar caps

Mariner 4, 6 and 7

- Mariner 4
- Mars flyby mission
- Closest approach came on July 15, 1965
- Pictures from this mission showed no canals and a surface that was disappointingly looking like that of the moon, quite LIFELESS
- In 1969 the United States launched Mariner 6 (February) and Mariner 7 (March)
- At closest approach (July for Mariner 6 and August for Mariner 7) both craft were at a distance of approximately 3400 kilometers

Mariner 4 Photographs
Mariners 6 and 7

-The Mariners (6 & 7) contained:
- narrow and wide angle cameras
- infra-red radiometer
- infra-red spectrometer
- ultra-violet spectrometer
- Temperature, pressure and atmospheric constituents were analyzed
- Pictures were still anything but spectacular

A Time to Fail and Succeed

-In 1969
- two unsuccessful attempts by the Russians

-In 1971
- both Americans and Russians had unsuccessful missions to Mars
- Russian Mars 2 and Mars 3
  - both equipped with lander modules but neither lander was successful
- Americans Mariner 9
  - reached Mars during a global dust storm
    - the storm did eventually subside and the mission was enough of a success so as to provide pictures for the choosing of a site for landing the upcoming Viking missions

Mariner’s Atmosphere

- First look provided by Mariner spacecraft
- Mariner 9 specifically
  - faced presence of a global dust storm
  - illustrated the progress of a feature that looked very much like a terrestrial cold front, visible as a bright band extending across many of the images
  - saw evidence of dust storm associated with strong winds
  - saw large crater rim produce wave clouds, believed to be composed of water ice (resembling “sonic boom shock wave”) produced by strong low level winds passing over the crater
  - saw day-to-day variations indicative of day-to-day weather changes and frontal systems
Mariner 9 Photographs

A Prelude to Viking
- First approved in December of 1968 for a 1973 launch
- Launch date postponed due to Congressional funding cutbacks
- Idea was to launch the craft in 1975 for a landing to take place on Independence Day in 1976
- Viking 1 was to be launched on August 11, 1975 but was postponed due to a malfunction
- While fashioning repairs for the spacecraft, the twin unit was substituted and so Viking 2 became Viking 1 and vice versa

Viking Liftoff
- Viking 1 launched August 20, 1975
- Viking 2 launched September 9, 1975
- Each Viking orbiter consisted of:
  - television camera system
  - an atmospheric water detector
  - an infra-red thermal mapper
**Viking Instruments**

- Each Viking lander contained:
  - television camera system
  - gas chromatograph mass spectrometer
  - x-ray fluorescence spectrometer
  - seismometer
  - biology lab
  - weather station
  - sampler arm

- Each aeroshell contained:
  - a retarding potential analyzer
  - upper-atmosphere mass spectrometer

**Arrival at Mars**

- Viking 1 arrived at Mars on June 19, 1976
  - took pictures to aid in the choice of a landing site for the lander
  - caused a delay in the landing beyond its Independence Day rendezvous

- Using the latest pictures, the western slopes of Chryse Planitia were selected for the landing of Viking Lander 1

**Another Giant Leap for Mankind**

- On July 20, 1976 (seven years after a man had taken his first steps on the moon)
  - Viking Lander 1 successfully descended upon the soil of Mars
  - immediately after successful touchdown, the lander had instructions for taking pictures with its camera (there was actually a concern that the lander might sink into the soil, and so at least a picture was desired before it conceivably had sunken)
The Viking Look

- The Viking cameras
  - not cameras in the conventional sense
  - each consisted of:
    - a nodding mirror
    - a rotating turret which caused the images to be reflected down to the photodiode, which built up a picture as a series of pixels from each scan of the mirror and rotation of the turret
  - criticized for its inability to detect any moving objects (some still felt it possible that there might be macroscopic creatures on the planet)

Viking Orbiter Photograph

The Face on Mars
The Face on Mars - Caption

The picture shows eroded mesa-like landforms. The huge rock formation in the center, which resembles a human head, is formed by shadows giving the illusion of eyes, nose and mouth. The feature is 1.5 kilometers (one mile) across, with the sun angle at approximately 20 degrees. The speckled appearance of the image is due to bit errors, emphasized by enlargement of the photo. The picture was taken on July 25 from a range of 1873 kilometers (1162 miles). Viking 2 will arrive in Mars orbit next Saturday (August 7) with a landing scheduled for early September.

The Changing Face

Viking Lander Photograph
Reach Out and Touch

On July 22, 1976 the sampler arm was to be deployed, however, there were difficulties overcome by ingenious engineers. The sampler arm was finally deployed on July 28.

First Results from Soil Sample

X-ray fluorescence spectrometer (to determine the inorganic composition of the soil sample)
- 15-30 percent silicon
- 12-16 percent iron
- 3-8 percent calcium
- 2-7 percent aluminum

A Mass Disappointment

Gas chromatograph mass spectrometer results
- indication of carbon dioxide
- little water
- NO organic compounds
The beginning of a controversy
- this negative result conflicted with results from the biology experiments
- indicative of the existence of microbial life
Looking for Life

- The biology laboratory
  - approximately a single cubic foot of volume
  - consisted of:
    - pyrolytic release experiment
    - labeled release experiment
    - gas exchange experiment

Pyrolytic Release Experiment

- PI was Norman Horowitz
- Basis of experiment
  - ability of an organism to metabolize carbon dioxide and produce some product (reverse process of Levin's experiment)
  - soil sample placed in test chamber for five days and incubated with/without light
  - if soil had fixed or metabolized the carbon dioxide (carbon-14 tagged) then pyrolysis of the sample would allow detection of labeled carbon in the chamber’s gas

Gas Exchange Experiment

- PI was Vance Oyama
- Basis of experiment
  - evidence of metabolism by noting changes in the gaseous environment of the sample
  - sample would be introduced into the chamber and the chamber's atmosphere analyzed
  - after a period of incubation, the gas would be re-examined and a comparison is made between this analysis and the initial analysis
Labeled Release Experiment

- PI was Gilbert Levin
- Basis for experiment
  - Property of microorganisms to metabolize organic compounds in a nutrient broth
  - Organics in broth tagged with carbon 14
  - If organisms in the sample were metabolizing the nutrient, the carbon-14 would appear in the chamber's gas by the appearance of tagged carbon monoxide or carbon dioxide

Biology Experiment Results

- All three biology experiments registered results which were indicative of some very active samples, and if these results were obtained on earth there would be no doubt that organisms were responsible
- Doubt of the biological results once the GCMS had failed to detect any organics within the soil sample

Explaining Biology Away

- Theories dealing with superoxides, peroxides and superperoxides to explain apparent positive results away the results of
- Only hold-out for the possibility that the biology experiments still might indicate the existence of life on Mars was Gilbert Levin (only science team member that still maintains belief that evidence of life was found)
Levin’s View Today

“After 25 years, the Mars LR data still excite attempts at a chemical explanation, three within the last year. This indicates that none of the 30 non-biological explanations offered to date has been completely convincing. New findings concerning the existence of liquid water on the surface of Mars, and extremophile microorganisms on Earth, are consistent with my conclusion that the LR detected living microorganisms in the soil of Mars (Levin 1997), which may explain the difficulties with the non-biological theories.”

Viking’s View of Atmosphere

Viking Lander meteorological instruments
- at end of boom that deployed after landing
  - contained thermocouple units to measure the atmospheric temperature and wind speed
  - an atmospheric pressure sensor which was not on the boom so as to be shielded from winds

First Mars Weather Report

Seymour Hess stated:
- “Light winds from the east in the late afternoon, changing to light winds from the southwest after midnight. Maximum winds were 15 miles per hour. Temperature ranged from minus 122 degrees Fahrenheit just after dawn to minus 22 degrees Fahrenheit. Pressure steady at 7.7 millibars.”
Viking Looks at Climate

- Long term data available
  - from Viking Lander 1 through November 5, 1982
  - from Viking Lander 2 through April 11, 1980

Viking Climate Conclusions

- discovered nature of surface pressure variations over the seasons and the cycling of the atmosphere between the polar caps
  - minimum in the pressure cycle occurs during the southern winter when the carbon dioxide mass condensing onto the south polar cap is a maximum
  - as the seasonal carbon dioxide sublimes out of the south polar cap, the pressure rises until the north polar cap starts to form
  - process reverses seasonally and carbon dioxide reforms at the south polar cap

More on Atmospheric Findings

- Other characteristics of Martian atmosphere
  - difference in pressures between the two landers
    - attributed to the difference in elevations between the two sites
    - there was also much noise on the pressure curves, which, in the end, was determined NOT to be noise, but associated with traveling cyclones of the kind that had been speculated upon based on images from Mariner of the dust storms
      - these cyclones occurred only during the winter
A Little Pressure

- Pressure variations detected
  - linked to optical depth computations and demonstrated the presence of what meteorologists call atmospheric tides
  - atmospheric tides should not be confused with gravitational tides
  - wind and pressure variations that are produced by the daily cycle of heating over the whole atmosphere
  - what results from the daily loading cycle, among other things, are traveling waves that follow the sun and have both diurnal and semidiurnal periods

Meridional Circulation

[Say What?]

- Landers helped produce charts of meridional circulation
  - on Earth we have the familiar pattern of rising motion in the tropics and a descending motion in the subtropics with a connecting meridional flow pattern
  - on Mars, there is a strong seasonally varying circulation rather than one centered about the equator
  - in summer the air rises near the subsolar point in the southern hemisphere subtropics and crosses the equator to a point where it can descend [more like a one-cell circulation with a strong descending motion in the winter hemisphere]

A Little Mars Geology

- Viking Orbiter images
  - largest volcano in solar system, Olympus Mons
  - large canyon, Valles Marineris
  - a global appearance roughly organized latitudinally
    - equatorial belt is somewhat darker than the mean albedo and very changeable over time
    - northern and southern mid-latitude regions are brighter, due probably to the deposits of very fine, bright material
  - a dark collar around the north polar region
  - polar regions with the very bright polar caps
More Beautiful Pictures

- High resolution images from Viking Orbiters
  - Contributed to better understanding the surface
  - Indication that the darker areas are where the silicates are somewhat more reduced and richer in ferrous rather than ferric silicates
  - Areas that were originally considered for landing were found to be too hilly
  - Surprised to find that the Lander was actually in a field strewn with rocks (e.g. Little Joe) large enough so that if the Lander had landed on one of them the mission would have failed

Summary of Mars Landing Sites

Pathfinder at Ares Vallis
Sojourner

- Sojourner weighed 10 kg and spent 3 months roaming on the surface.

Mars Global Surveyor

- Orbiting Mars from 1996 to the present
- Evidence of “recent” subsurface water
Recent Mission – Odyssey 2001

Recent Mission: Spirit Rover

Recent Mission: Opportunity Rover
A Pictorial Summary of Mars

Mars Interior

- Mars core
  - FeS (iron sulfide)
  - FeS has a lower density compared to the Earth’s Fe and Ni
  - diameter 40% of Mars
    - similar proportion to the Earth’s core/diameter

Mars Interior

- The core is solid, not liquid
  - do not expect a strong magnetic field
  - Magnetometers on MGS have discovered a weak magnetic field over certain regions of the planet
  - Mars once had a liquid core and magnetic dynamo in the past, and this has permanently magnetized some rocks.
  - These magnetic rocks are very old, suggesting the field was only ‘on’ for the first few hundred million years of Mars’ history.
- Mars is differentiated
  - Mantle and Crust
**Olympus Mons**

- Largest of the four great *Tharsis* volcanoes first seen by Mariner 9
- Largest volcano in the entire solar system
- About 27 km high and 700 km wide at the base

**Valles Marineris**

- A giant canyon system discovered by Mariner 9
- Named after the spacecraft
- Stretches more than 4000 km in length, 500 km wide, and up to 8 km deep

**Valles Marineris**

- Tectonic in origin
- Huge cracks in the crust widened and shaped by erosion
• Largest impact basin on Mars; rim of mountains showing much erosion
  • Approximately 2000 km across; 5 km below mean Martian surface level
  • Clouds sometimes found in interior region
  • Impact occurred during Late Heavy Bombardment stage of solar system formation, approximately 3.9 Gyr ago

**Hellas Basin**

**Terrain Comparison**

• Compare Olympus Mons with Everest (fold mountain) and Mauna Loa (shield volcano) on Earth.
  • Mountains on Earth and Venus can only rise 10-15 km before the rock begins to deform under its own weight

**The Tharsis Bulge**

A massive uplifted region

• 10 km above its surroundings
  • one of the least cratered terrains on Mars
  • Area equal to North America

Figure credits: (left) NASA/JPL (right) MGS/MOLA

Figure credits: University of North Dakota

Figure credit: NGDC/USGS
Canyon Widening Evidence

• Evidence of “mass wasting”

Impact Craters

• Ejecta patterns differ from the lunar impact craters
• Craters on Mars display a more fluid ejecta pattern
  • Consider what may have caused differences

Real Dunes

• This image is of ‘cemented’ sand dunes in the Herschel crater of the Terra Cimmeria taken by Mars Global Surveyor
• Image credit to MSSS/NASA/JPL
Channels – Runoff and ...

- Three major types
  1. Runoff channels
  2. Outflow channels
  3. Gullies
- Runoff channels
  - similar to terrestrial dry river beds
  - often seen on the steep sides of crater walls
  - as old as the cratered highlands
  - Evidence for a thicker, warmer atmosphere in the past

Outflow Channels

- Larger and less common than runoff channels
- Caused by flooding
- Evidenced by teardrop islands, terraced walls, and sandbars
- carved by flood waters rushing over original terrain

Meteorite from Mars

ALH84001
- possible evidence of fossil microbes from Mars
Statement from Daniel S. Goldin, NASA Administrator

"NASA has made a startling discovery that points to the possibility that a primitive form of microscopic life may have existed on Mars more than three billion years ago. The research is based on a sophisticated examination of an ancient Martian meteorite that landed on Earth some 13,000 years ago. "The evidence is exciting, even compelling, but not conclusive. It is a discovery that demands further scientific investigation. NASA is ready to assist the process of rigorous scientific investigation and lively scientific debate that will follow this discovery.

Goldin Statement (August 6, 1996)

"I want everyone to understand that we are not talking about 'little green men.' These are extremely small, single-cell structures that somewhat resemble bacteria on Earth. There is no evidence or suggestion that any higher life form ever existed on Mars. "The NASA scientists and researchers who made this discovery will be available at a news conference tomorrow to discuss their findings. They will outline the step-by-step 'detective story' that explains how the meteorite arrived here from Mars, and how they set about looking for evidence of long-ago life in this ancient rock. They will also release some fascinating images documenting their research." 

Science Paper by McKay et al.

"In examining the martian meteorite ALH84001 we have found that the following evidence is compatible with the existence of past life on Mars: (i) an igneous Mars rock (of unknown geologic context) that was penetrated by a fluid along fractures and pore spaces, which then became the sites of secondary mineral formation and possible biogenic activity; (ii) a formation age for the carbonate globules younger than the age of the igneous rock; (iii) SEM and TEM images of carbonate globules and features resembling terrestrial microorganisms, terrestrial biogenic carbonate structures, or microfossils; (iv) magnetite and Fe-sulfide particles that could have resulted from oxidation and reduction reactions known to be important in terrestrial microbial systems; and (v) the presence of PAHs associated with surfaces rich in carbonate globules. None of these observations is in itself conclusive for the existence of past life. Although there are alternative explanations for each of these phenomena taken individually, when they are considered collectively, particularly in view of their spatial association, we conclude that they are evidence for primitive life on early Mars."
Paper by Scott et al.

In an electrifying paper published in August, 1996 in the journal Science, David McKay (NASA Johnson Space Center) and his colleagues suggested there were fossils of martian organisms associated with carbonate minerals in martian meteorite ALH84001. How these carbonate minerals formed (biologic origin or not) and the temperature at which they formed (low or high) are hotly debated questions. We have proposed an entirely different origin: the carbonates in ALH84001 formed in seconds at high temperatures (>1000°C) from melts produced during a large impact on Mars 4.0 billion years ago (Scott and others, 1997). We infer that it is unlikely that the carbonates or any minerals in them contain mineralogical evidence for ancient martian life.

Paper by Scott and Barber

"Magnetic minerals in Martian meteorite ALH 84001 formed as a result of impact heating and decomposition of carbonate; they were never used as compasses by Martian microorganisms."

A Quick Review of Mars

Has been of interest for a century
- originally felt to show evidence of life
- has been targeted for study
- numerous missions - some fail, some succeed
- has been suggested as source of microbes
- will be studied in future
- Future life may well be human
Simplified Conclusions

- Did Viking find life on Mars?
  - Nope, but it was controversial
- Did Viking find ruins of an ancient civilization?
  - Nope
- Does ALH84001 contain microfossils?
  - Nope
- Do we know that there is no life on Mars?
  - Nope

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