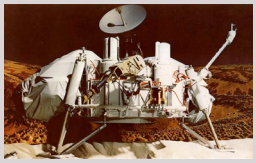
Mars astrobiology experiments

Only astrobiology experiments so far flew on the NASA *Viking* landers in the 1970s



Pair of identical orbiters and landers

Survived on the surface for 4-6 years

Carried cameras, chemical and biological experiments. Boom to scrape soil from the near-surface for analysis.

Basic principle of all 3 biology experiments was similar:

- expose soil to an environment favorable for life: (water, light, `nutrients')
- wait
- search for byproducts of life (CO_2, O_2, CH_4)

Discriminate between life and abiological chemical reactions using a control experiment - repeat the experiments using soil that had been heated to 160C to completely sterilize any living organisms.

On Earth, these experiments were shown to yield positive results for life in the standard case, and negative results for the control.

Labeled release experiment

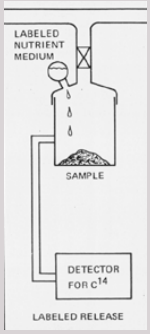
Added 1 ml of nutrient (water plus organic compounds) to 0.5 cm^3 of Martian soil

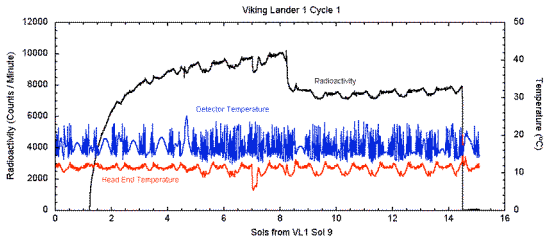
Organic compounds were `labeled' (marked) with radioactive carbon (^{14}C isotope)

Sample was incubated for 10 days

Gases were analyzed for ^{14}C

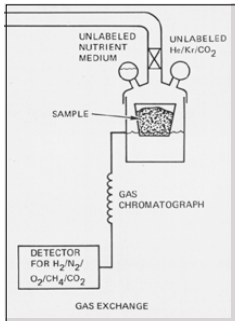
On Earth, microbes would give off CO_2, CO and CH_4 which would contain the radioactive isotope and could be detected





Result: radioactive gas was rapidly released when the nutrient was added. Second addition caused an initial *drop*, then a slow rise

Control sample gave no release of radioactive gas



Gas exchange experiment

1 cm^3 of soil was incubated in a nutrient `broth'. Any gases that were produced were analyzed by a gas chromatograph that was sensitive to CO_2, oxygen, methane, hydrogen and nitrogen

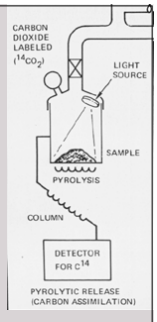
On Earth, oxygen or CO_2 would be detected

On Mars, oxygen was detected, not only in the standard experiment but also in the control run with sterilized soil

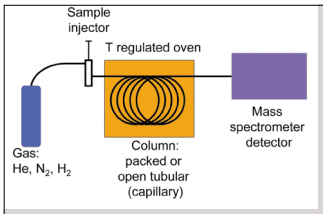
Pyrolytic release experiment

Simulated Martian atmosphere conditions:

- soil was exposed to a simulated Martian atmosphere containing CO_2 that was labeled with ^{14}C
- xenon lamp provided `sunlight'
- after 5 days, atmosphere was flushed
- sample was heated to 625C to break down organic compounds
- gas was analyzed for ^{14}C that had been taken up by life



Experiment yielded a positive result (^{14}C seen) both for the standard run and in the control run…



Also chemical analysis of the soil using a gas chromatograph - mass spectrometer instrument

Very sensitive to organic molecules - but **none** were detected in the Martian soil

Largely renders irrelevant the biological experiments - even the basic ingredients for life (very simple organic compounds) that are found even in space were not present in the Martian soil

Interpretation of the *Viking* experiments

Somewhat contradictory results were obtained. Most common interpretation:

- Solar UV flux on the surface of Mars destroys organic molecules close to the surface

No life was present in the Martian soil: apparently positive results from the biology experiments reflected inorganic reactions (probably an oxidant such as a peroxide present in the soil that was not anticipated in advance).

Illustrates the difficulty of trying to detect life in very unfamiliar environments…

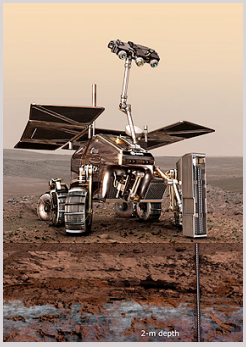
Counterarguments

Was the Viking GC-MS sensitive enough to detect organic molecules from a small number of microbes in the soil? e.g. would it work in Antarctic permafrost?

The specific soil conditions needed to provide the set of results seen in the biology experiments have proved hard to duplicate in the laboratory.

Nonetheless, consensus opinion is that Viking did not detect life on Mars…

ExoMars mission



NASA philosophy "Follow the water" - surviving life seems feasible only in (rare?) spots where there might be liquid water

Accumulated evidence suggests a wetter and warmer Mars in the past - can we search for life that died out billions of years ago?

Ultimate goal: sample return, but from where?

Signatures of ancient life:

- microfossils (but… confusion possible with very small mineral precipitates)
- isotopic carbon signatures (ratio ^{13}C to ^{12}C)
- survival of complex biomolecules (amino acids, chlorophyll, lipids)… these may survive better on Mars than on Earth because of the lack of plate tectonics. Amino acids can survive for billions of years at modest depths (1-2m)
- detection of chiral signature of life - but this is destroyed in wet environments

Where to look?

Locations where geological evidence points to standing bodies of water in the past

Heat destroys biosignatures - need to avoid volcanic areas or ancient lava flows

Existing life: need to locate warm spots where ice / water might exist at different times during the year… life might exist in the subsurface at modest depth there

ExoMars mission payload

2013 launch date

Rover with a drill to extract samples from 2m depth

Ground penetrating radar

Gas chromatograph - mass spectrometer - much more sensitive than Viking's version (~1000 times better)

Organic detector sensitive to amino acids, nucleobases

Life-marker chip - detects organic molecules with very high specificity