

Meteorites from Mars

- Easy way to get pieces of Mars to study
- Asteroid impact on Mars knocks off pieces. Some land on Earth
- Evidence for Life?

Martian Meteorites

Antarctic ice fields are a good place to look for meteorites in general
e.g. Allan Hills Region (AH)

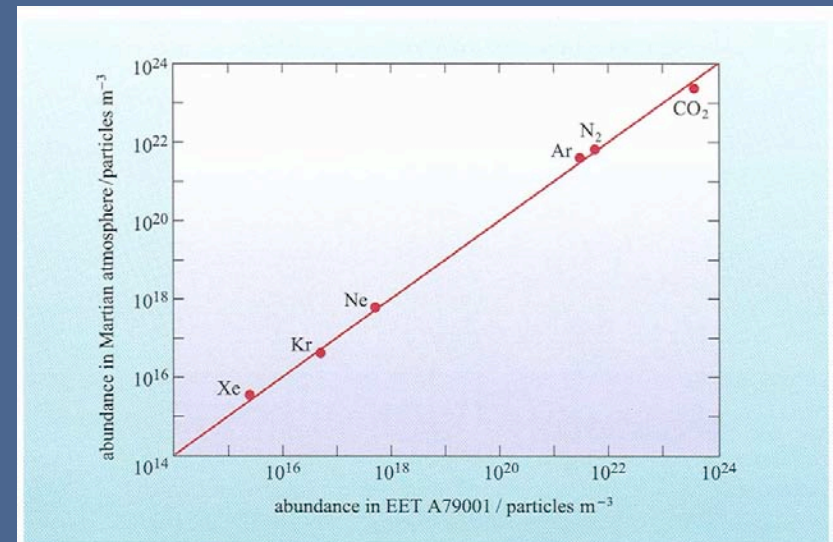
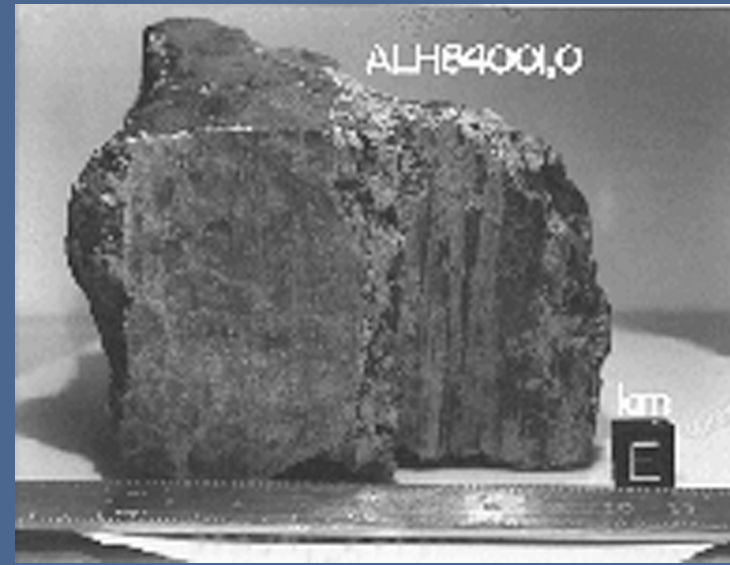
ALH 84001--oldest of 12 rocks thought
To have come from Mars.
Weighs 4 pounds (softball-sized)
found in 1984

Why is it believed to be from Mars?

Abundance ratios of oxygen isotopes
same in 12, different from known
meteorites from moon, most Earth rocks,
or asteroids.

Pockets of gas in some of the 12 have
Same composition as present Martian
atmosphere.

Evidence is *very* convincing.



Likely history of the Mars meteorites

1. Rock solidified on Mars **4.5 billion years ago**.
2. Pieces of Mars blasted loose by impact of asteroid or comet about **16 Myr ago** (date from radiation damage).
3. A small fraction escape Mars' gravity.
4. These particles would orbit the sun in relatively stable orbits for most of their lives, except for gradual orbit alterations by tug of distant planets.
5. Occasionally, a close encounter with inner planets abruptly changes the path.
6. Many of the objects eventually fall into the sun, collide with asteroids, or escape the solar system.
7. A small fraction of the fragments hits the Earth, 13,000 years ago, in Antarctica.

Over 10 to 100 million years, as much as about 7 percent of the original material could find its way to Earth this way. And it goes both ways: some life-bearing rocks from Earth have probably found their way to Mars (and elsewhere).

Signs of Life?

McKay et al., *Science*, **273**, 924 (Aug. 16, 1996)

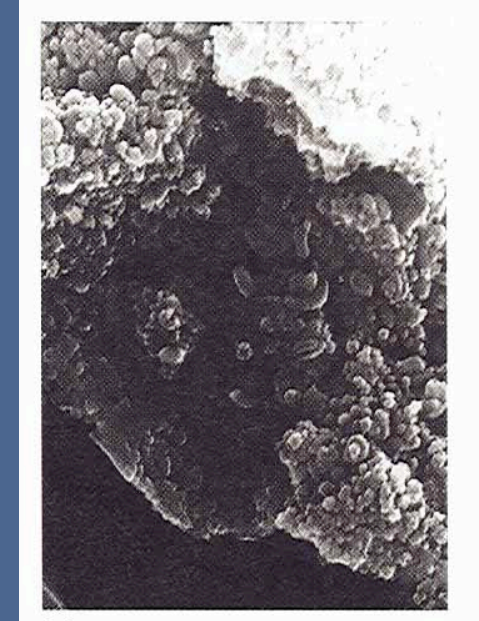
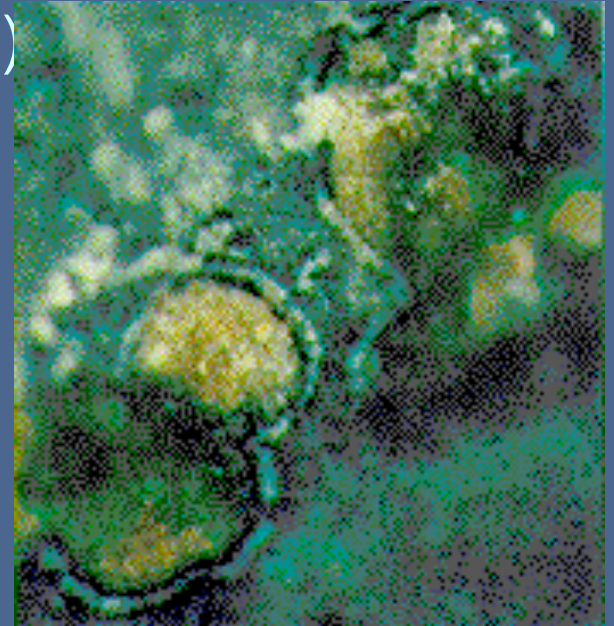
1. PAH molecules --these are fairly complex organics, and can be produced by breakdown of biological tissues. But are found on the Earth (terrestrial contamination?), in meteorites, and also identified in interstellar dust grains, so this doesn't require biology.

2. Carbonate Globules (100 μm across)

Cores of manganese & rings of iron carbonate and iron sulfide similar to globules associated with bacterial action in liquid on Earth.

But can form *without* bacteria on Earth

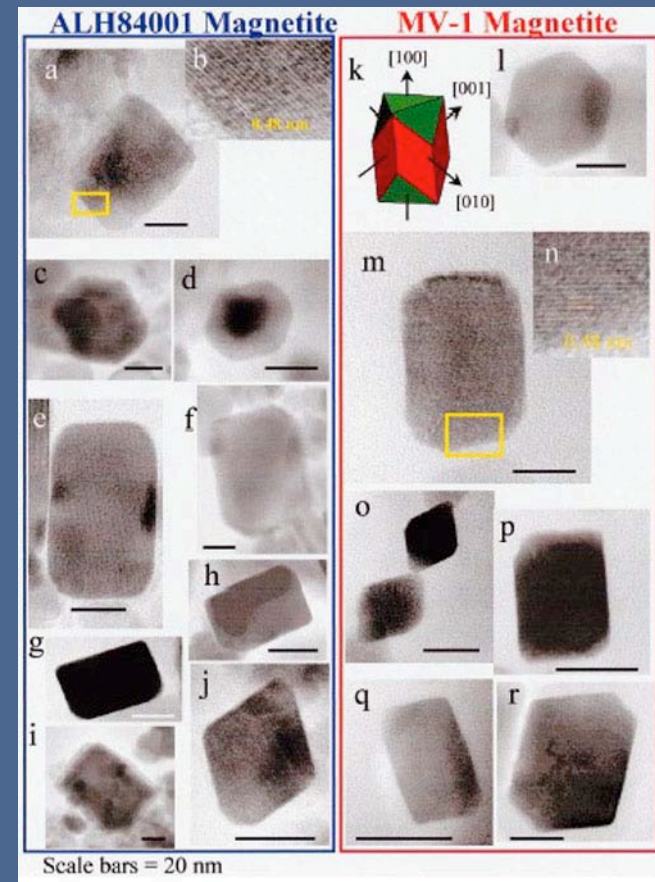
Dispute about temperature at which globules formed



3. Magnetite Grains 100 nanometers (nm) ($100 \times 10^{-9} \text{ m} = 0.1 \mu\text{m} = 10^{-5} \text{ cm}$)

Shapes similar to crystals produced by bacteria on Earth.

Magnetite is especially interesting because it is used by some Earth bacteria to “navigate” through Earth’s magnetic field. When bacteria decompose, they leave “magnetofossils” shaped like cubes or teardrops, like some those found in ALH84001.



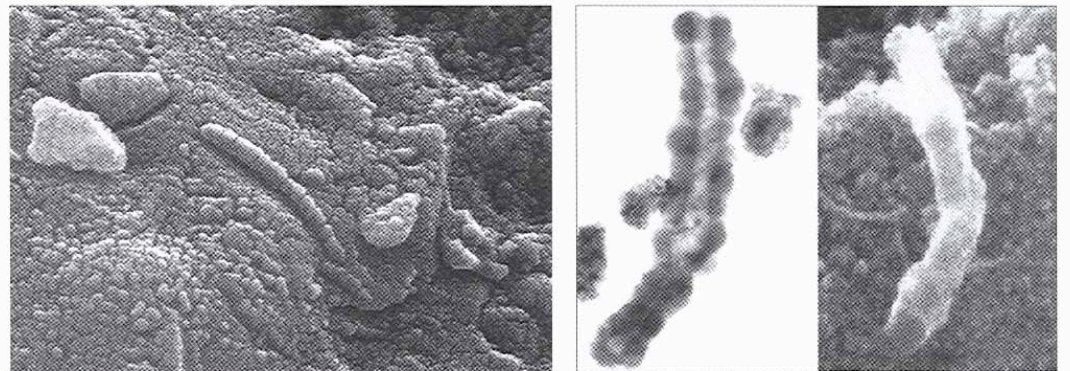
4. Fossilized Bacteria?

With scanning electron microscope, see tubular and egg-shaped structures (20 - 100nm long) that resemble fossils of oldest single cell Bacteria found on Earth.

(Note: Schopf evidence no longer viable for Earth.)

Problem: $\sim 10 - 100 \times$ smaller than normal bacteria.

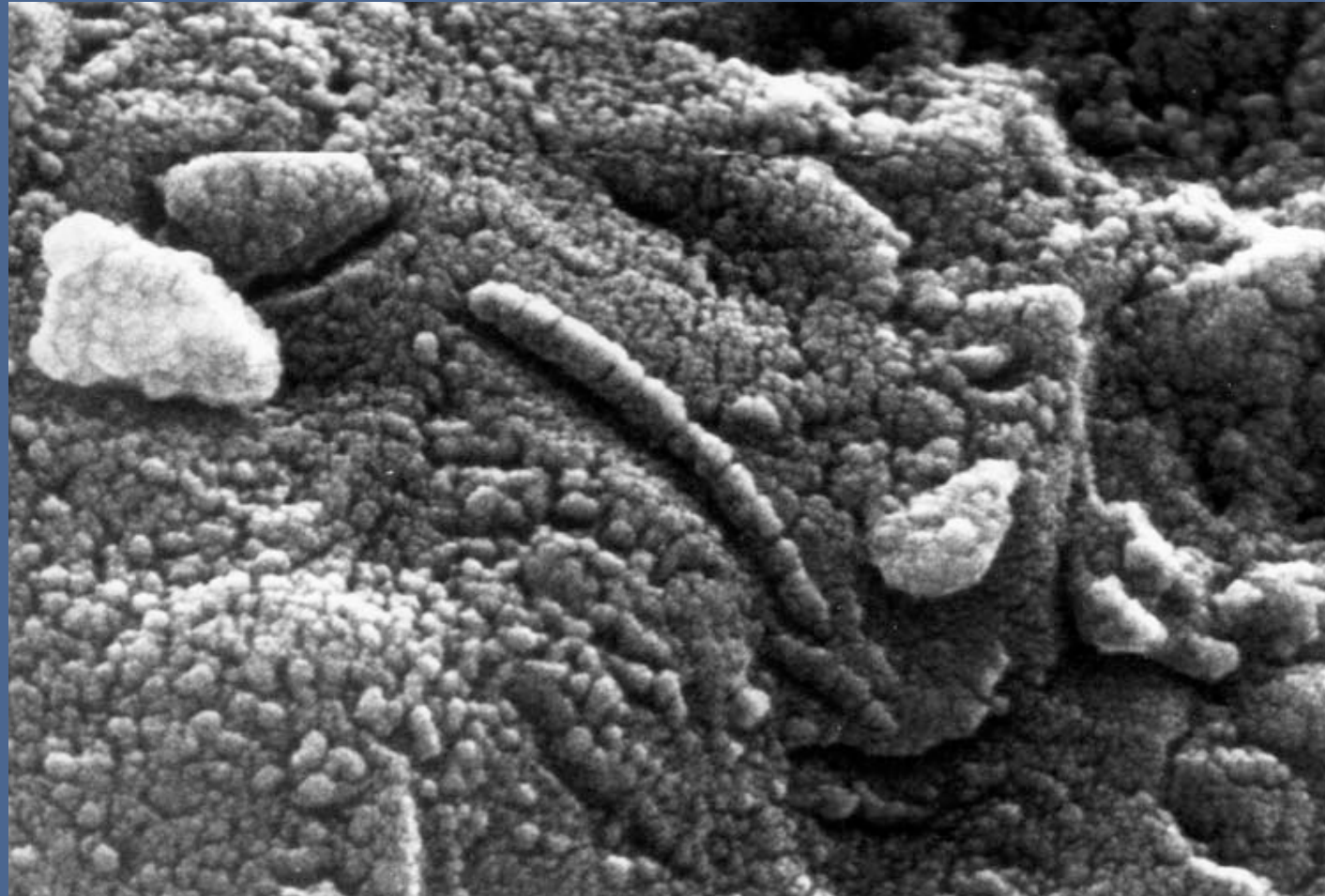
Where would you fit a genome?



(a)

(b)

(a) The segmented object (380 nm long) was found in the Martian meteorite ALH 84001 and has been interpreted as a fossil microbe. It is claimed to resemble fossilized bacteria found on Earth. For example, the near-vertical objects in (b), which are of the same length as the object in (a), were found at a depth of 400 m below the terrestrial surface.



Later Developments

1. Several studies support lower temperature for carbonate globule formation - consistent with life
2. Folk finds similar shapes in Allende meteorite (not from Mars)
3. Bada et al., 1998, Science **279**, 362 Found amino acids, suggestive of terrestrial contamination
4. Many more meteorites from Mars being found.

Los Angeles Martian Meteorite



Martian meteorite found in LA county in 1999

245 gm

Criticisms

(see your text for additional discussion of pros and cons):

1. Possibility of contamination in the last 13,000 years. But life from Mars proponents point out that the PAH concentration increases from surface to interior, opposite from what's expected from contamination.

Dec. 1996--Becker et al (UCSD; paper published in *Geochimica et Cosmochimica Acta*) claim the PAHs are probably contaminants from Antarctic ice. All the PAHs found in the Martian meteorite were found in the ice samples, and also in other Antarctic meteorites, including several that didn't come from Mars. They claim that the PAHs are found deep within fissures because they collect on surfaces of carbonate grains.

2. Carbonates and PAH's could have formed in absence of water. One proposal suggests asteroid smashing into Mars' surface, liquifying the carbon dioxide frost.

3. Two geochemists at U.Colo. claim that the temperature at which the carbonates formed was higher than NASA scientists suggest, possibly hotter than any microorganism could survive. This is crucial because the carbonates are central to the lines of evidence. They derived a temperature of over 600 °C! But another group, using a different technique, found a formation temperature for the carbonates of only 80 °C! So still very uncertain.

4. Evidence that the magnetite particles are non-biological.

Dec.1996 paper in Geo.Cosmo.Acta by 3 US geoscientists find that the magnetite particles grew “like a tightly wound spiral staircase” (axial screw dislocation). This form is totally absent in any known magnetite produced by living organisms. They *are* formed at fumaroles (volcanic vents that release hot gases which then condense; need T around 500-800 C for this, agreeing with earlier analysis that carbonate globules must have formed at > 450 C.

5. There should be a large, round crater on Mars from the impact, but none this big have been found.

But it could have been a low-angle impact of a much smaller object, creating an elliptical crater. In 1996 Barlow claimed 2 craters (out of 42,283 Mars craters inspected) as possible sites.

6. Part of the support for biological interpretation was high enrichment in C¹² over C¹³. But Oxford geologist Martin Brasier claims repeated freezing and thawing could produce a similar result. (Recall that Martin Brasier is the same person who brought to light the questionable nature of the 3.5 billion year old “fossil” evidence for life on Earth.)

7. The sizes of the purported fossil forms are *tiny*, much smaller than even the smallest prokaryotic cell on Earth. There is severe doubt whether such small objects could contain enough genetic material for even the most primitive of organisms.