

Hot Idea Update  posted March 31, 1997

Life on Mars--The Debate Continues

Written by [G. Jeffrey Taylor](#)

Hawai'i Institute of Geophysics and Planetology

An exhilarating debate is taking place about whether a team of NASA and Stanford University scientists found evidence for life in a meteorite from Mars, as they claim, or whether their evidence can be attributed to completely nonbiologic processes or to contamination. **PSR Discoveries** [summarized](#) the original evidence for life in a martian meteorite in October, 1996.



Since then, many scientists have joined in the discussion and they have obtained new data for the martian meteorite at the center of the debate (ALH 84001, shown here) and other meteorites found in Antarctica. New data involve:

- additional [analysis of hydrocarbons](#) in meteorites, and
- electron microscope [examinations of tiny whisker-like, magnetite grains](#) (Fe₃O₄) in ALH 84001.

Most of the data tends to argue *against* some of the pieces of evidence that led to the bold interpretation that there were fossils in ALH 84001. Nevertheless, the great debate is far from over! Each piece of evidence will be tested in several ways.

Hydrocarbons: biological or contaminants?

One of the chief lines of evidence used by David McKay and his coworkers at the Johnson Space Center and Stanford University was the presence in ALH 84001 of a distinctive array of polycyclic aromatic hydrocarbons (PAHs). These are smelly, difficult-to-pronounce compounds composed of linked chains of benzene rings. Phenanthrene is shown here as an example (drawn by Brooks Bays, PSR Discoveries graphic artist). McKay and associates argued that the relative abundances of various types of PAHs in ALH 84001 were different from abundances produced by nonbiological processes, such as found in some types of meteorites and interplanetary dust. They concluded that the abundances of PAHs present in the martian meteorite most likely formed by the decomposition of biological compounds.



Phenanthrene
C₁₄H₁₂

Several investigators have pointed out that there are other ways of looking at the data. Edward Anders of the University of Chicago argues that all the PAHs observed in ALH 84001 can be made by nonbiological processes, depending on the proportions of carbon, hydrogen, and oxygen, and on the temperature and pressure at which the reactions took place. He also points out that a common type of carbon-bearing meteorite, CM chondrites, contain PAHs very much like those in ALH 84001, and there is no evidence for fossil life in those meteorites. Jeffrey Bell (a colleague of mine here at the University of Hawai'i) also noted the similarity of the PAHs in ALH 84001 and CM chondrites, and even [suggested a source](#) for

abundant CM material on the surface of Mars: chips from the disrupted precursors of Phobos and Deimos, the two satellites of Mars.

McKay's colleagues at Stanford, led by Simon Clement and Richard Zare, acknowledge these arguments, but argue that nonbiologic synthesis of PAHs at low temperatures (less than 150 °C) would not produce the distributions observed. On the other hand, if the temperatures did exceed 150 °C, Clement and Zare agree that nonbiologic processes, such as the [Fischer-Tropsch reaction](#), would produce PAH abundances like those measured in ALH 84001.



Thus, determining the **temperature** at which the carbonates formed is very important, and this is one of the most hotly contested points in the debate.

It may not matter whether the PAHs formed at high or low temperatures, if Luann Becker, Daniel Glavin, and Jeffrey Bada of Scripps Institute of Oceanography are right. (Dr. Becker is also with the Space Science Division at NASA Ames Research Center.) They argue that all the PAHs in ALH 84001 are contaminants. Dave McKay and his colleagues had conducted some rigorous tests for contamination, concluding there was none, but Becker and coworkers' work raises suspicions.

G. D. McDonald and J. Bada reported last year that they had found amino acids in another martian meteorite, designated EET 79001. This rock is a basaltic lava flow, and quite young, only 180 million years old. (ALH 84001 formed about 4.5 billion years ago.) Amino acids are complex organic compounds made and used by living organisms to make proteins. They are also found in carbonaceous chondrites. However, the amino acids in carbonaceous chondrites are a mixture of left- and right-handed molecules (a reference to the symmetry of the molecules). Organisms on Earth use L-amino acids, the left-handed variety. McDonald and Bada found only L-amino acids in EET 79001, which they interpreted as contaminants.



Why not conclude that the L-amino acids were produced on Mars by martian organisms? McDonald and Bada preferred the **contamination** interpretation because they also found similar amino acids in Antarctic ice.

Luann Becker's experiment was to measure the PAHs in EET 79001, and compare them to those in ALH 84001 and Antarctic ice. She found that the PAHs in carbonate minerals in EET 79001 were almost identical to those in ALH 84001. The PAHs measured in the ice were also similar to those in the meteorites, though not identical.

Comparison of PAHs

Data from Becker and Bada (Geochimica et Cosmochimica Acta, January, 1996)

Compound and atomic mass	ALH 84001	EET 79001	Ice
naphthalene (128)	not detected	not detected	present
fluorene (166)	not detected	not detected	not detected
phenanthrene or pyrene (178)	present	present	present
chrysene (228)	present	present	present
perylene (252)	present	present	present
anthanthrene (276)	not detected	present	not detected
anthanthracene (278)	present	present	present
coronene (300)	not detected	not detected	present

The PAHs in both meteorites are associated with carbonate mineral deposits. It is these carbonates in ALH 84001 that contain the evidence for fossil life, so why not simply conclude that Becker and Bada have discovered some evidence for life in a second martian meteorite? They argue that the small carbonate grains adsorb PAHs from any water in which they come in contact. To test that idea, Becker added carbonate to distilled water that contained a known amount of PAHs, let it interact overnight, and then extracted the carbonate for analysis. The results show that virtually all the PAH added to the water had concentrated into the carbonate grains, demonstrating how easily the carbonate soaks up PAHs, whatever the source.

From these measurements, Becker and coworkers concluded that the PAHs in both ALH 84001 and EET 79001 were contaminants, though they could not determine if the contamination occurred on Mars or in Antarctica. In either case, they believe that the source of the PAHs is probably material like the CM chondrites and interplanetary dust, which rains down on both Earth and Mars. Of course, water has not been flowing recently on Mars, so if the contamination took place there, it did so at a time when the climate on Mars was much different than it is now. The experiments support Bell's idea that the source of the CM-like PAHs were fragments of a disrupted ancient martian moon. The presence of terrestrial L-amino acids in EET 79001, though, argues that the contamination took place on Earth.



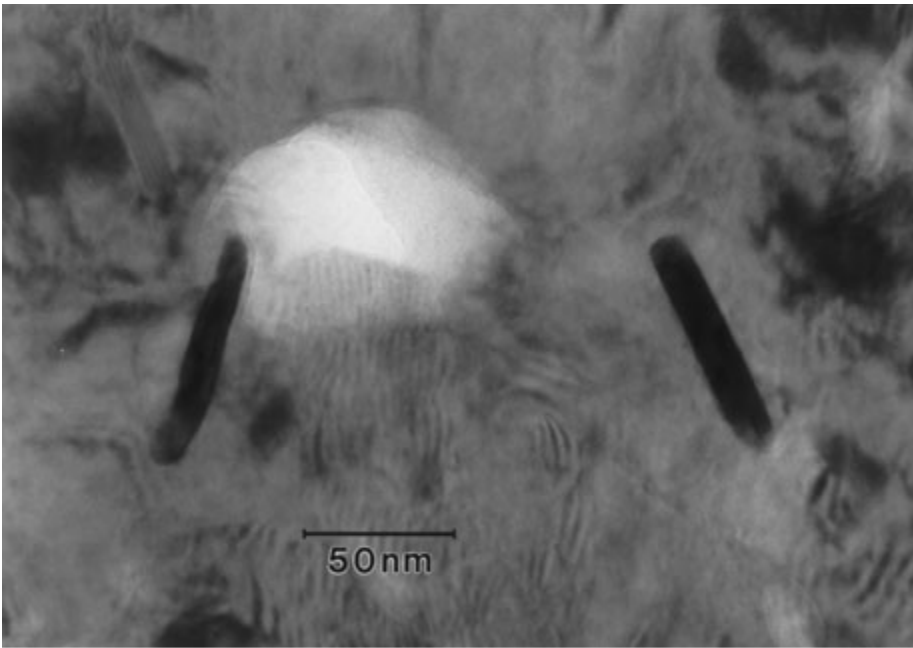
Of course, these arguments could be turned around. The similarity in the PAHs in the two meteorites and the Antarctic ice, and the presence of Earth-like amino acids in EET 79001 might indicate that life on Mars closely resembles life on Earth. And not explained as yet is the unusual isotopic composition of the carbon in ALH 84001, which Ian Wright, Monica Grady, and Colin Pillinger (Open University and Natural History Museum, England) suggest cannot be caused by contamination. The debate about the meaning of the organic analyses of the meteorites will continue, and more studies are planned, including measurements of other organic compounds and their isotopic compositions.

Whiskers of magnetite

Carbonate areas in ALH 84001 contain tiny grains of magnetite, Fe_3O_4 , which McKay and coworkers interpreted as having been manufactured by martian microorganisms. Some bacteria on Earth produce such tiny magnetite grains. However, a close look at the magnetites in ALH 84001 by John Bradley (MVA, Inc. and Georgia Institute of Technology), Ralph Harvey (Case Western Reserve University), and Harry Y. McSween (University of Tennessee) suggests that the magnetites formed by nonbiological processes at relatively high temperatures, 500 to 800 °C. Bradley and his colleagues used an analytical scanning transmission electron microscope to examine the magnetites. These high-tech devices allow scientists to study the shapes, crystal structures, and chemical compositions of grains smaller than 1 nanometer (one billionth of a meter).

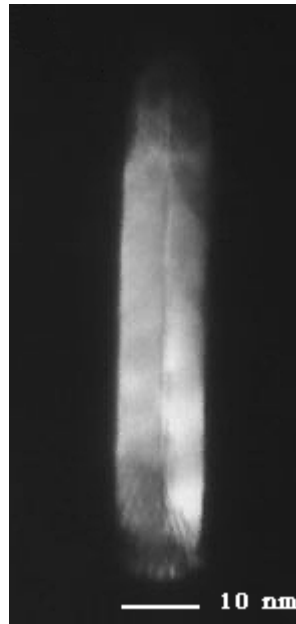
Most of the magnetites in the carbonate areas do not have distinctive diagnostic features that allow one to conclude whether they formed by biological or physical processes. However, Bradley found some grains shaped like whiskers or plates. These are only 50 to 150 nanometers long and have length to width ratios of 5 to 10 (so they are much longer than they are wide). According to Bradley and coworkers, these shapes are different from magnetites made by bacteria on Earth, which have length to width ratios of 3 or 4.

Electron microscope image below shows two prominent (dark) magnetite whiskers in ALH 84001. The grains are much longer than they are wide. They are similar in size and shape to the suspected nanofossils. One magnetite grain is associated with a cavity in the carbonate (the white area).



(from Bradley et al., 1996, "Magnetite whiskers and platelets in the ALH84001 martian meteorite: Evidence of vapor phase growth", *Geochimica et Cosmochimica Acta.*, vol. 60, no. 24, pp. 5149-5155.)

The whiskers have internal crystal structures that seem to differ from those of biologically-produced magnetite. Some have structures that resemble magnetites grown by a mechanism involving condensation of vapor to liquids, then to solid crystals. Others have distinctive lines along their lengths, as shown in the image on the right. This distinctive pattern is called a screw dislocation, and formed when the crystal grew. It is as if the crystal grew like a spiral staircase around a central post.



(from Bradley et al., 1996)

Magnetites formed by biological mechanisms have a high degree of crystal perfection. They do not contain screw dislocations or other structural defects. So, Bradley and his coworkers conclude that the magnetites in ALH 84001 were not made by martian microorganisms. Instead, the magnetites look like those formed at volcanic fumaroles, where they are deposited from a vapor.



(Cascades Volcano Observatory)

Example of a fumarole:
Oblique aerial view taken in 1980 of an active 300-foot-diameter fumarole near Spirit Lake, Washington.

This requires a high temperature, 500 to 800 °C, much higher than life could have survived. Harvey and McSween had already concluded, on the basis of chemical compositions, that the carbonates had formed at such high temperatures, though that interpretation is hotly contested.



Most of the magnetites in ALH84001 do not contain the distinctive structures, so perhaps some formed by vapor deposition at some time in the rock's history, but most did not. The relation of the magnetite whiskers to suspected fossils is unknown. In other words, there may be more than one source of magnetite. Furthermore, there has not been enough study of biologically-produced magnetite to rule out the presence of whiskers and screw dislocations in them.



A comprehensive study of **magnetite** in terrestrial microorganisms is needed before the magnetite case is closed.

As more data lead to additional interpretations, **PSR Discoveries** is committed to covering the continuing debate about evidence for life in a martian meteorite. See "[Not quite a Meeting of the Minds](#)" for an up-to-date summary of the scientific papers dealing with ALH 84001 presented at the 28th Lunar and Planetary Science Conference held in Houston, Texas on March 17-21, 1996.

Additional Resources

Becker, L., D. P. Glavin, and J. L. Bada, 1997, Polycyclic aromatic hydrocarbons (PAHs) in Antarctic Martian meteorites, carbonaceous chondrites, and polar Ice, *Geochimica et Cosmochimica Acta.*, v. 61, no. 3 pp.

Bradley J. P., R. P. Harvey, and H. Y. McSween Jr., 1996, Magnetite whiskers and platelets in the ALH84001 Martian meteorite: Evidence of vapor phase growth, *Geochimica et Cosmochimica Acta.*, v. 60, no. 24, pp. 5149-5155.

McDonald, G. D. and J. L. Bada, 1995, A search for endogenous amino acids in the Martian meteorite EETA79001, *Geochimica et Cosmochimica Acta.*, v. 59, pp. 1179-1184.

Wright, I. P., M. M. Grady, and C. T. Pillinger, 1997, An Investigation into the Association of Organic Compounds with Carbonates in ALH84001 (abstract), *Lunar and Planetary Science Conference XXVIII*, p. 1589-1590.



[[About PSRD](#) | [Archive](#) | [Search](#) | [Subscribe](#)]

[[Glossary](#) | [General Resources](#) | [Comments](#) | [Top of page](#)]

psrd@higp.hawaii.edu

main URL is <http://www.psr.d.hawaii.edu/>