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Not Quite a Meeting of the Minds

-- Report from the Lunar and Planetary Science Conference

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The annual Lunar and Planetary Science Conference was held at the Johnson Space Center in Houston from March 17 to March 21, 1997. The LPSC (as we all call it) is the largest conference devoted exclusively to planetary science, and certainly the most diverse in its coverage. The screens in one lecture room might be showing pictures of the amazingly intricate surface of Ganymede. Another might be displaying photographs of the result of an experiment designed to reproduce conditions in the cloud of dust and gas from which the planets formed. Still another could be showing images of lava flows on Venus.

This was the 28th LPSC. For the first eight years of its existence, the conference was called the "Lunar Science Conference" and focused on results of studies of the data and lunar samples returned by the Apollo program. As the years went by, however, other planetary studies began to be reported at the conference, so in 1979 conference organizers added "planetary" to the name. They might need to add "biology" next as many researchers focus on martian meteorite ALH 84001 and its purported fossils. This was the year nanobacteria and biomarkers came to the LPSC.

In a break with our policy of reporting only on published research, **PSR Discoveries** has prepared this summary of the status of the scientific debate about life in martian meteorite ALH 84001. (See related October, 1996 article, "Life on Mars".) Rather than discuss the results of each of the talks given at the conference, I highlight the problem areas that need to be addressed before any consensus develops about the evidence for fossils in ALH 84001. If you'd like to see the range of topics discussed, take a look at the conference program.

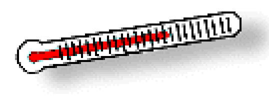
A wildly complicated rock

As more people look closely at ALH 84001, it is obvious that it is incredibly complicated. This is especially true of the carbonate occurrences in the rock. Scientists are focusing attention on the carbonates because that's where most of the evidence for life is found. They are complexly zoned in chemical and mineral compositions, and show intricate relationships among the all the minerals associated with the carbonates. There are somewhat large magnetite and sulfide mineral grains, and very tiny ones, and magnetite may occur in more than one location in the carbonate globules. The carbonate minerals occur in a variety of ways, including as round globules, flattened pancakes, vein fillings, and between fragmented pyroxene crystals (pyroxene is the main mineral in the rock).

With all this complexity, it is no wonder no one agrees! It seemed clear to me when listening to the discussions at the conference that some of the disagreement stems from different investigators looking at different portions of the rock. It is as if they are climbing all over a huge elephant, each seeing a different part. One scientist sees a large eye and claims that the sample can see, but concludes that it cannot eat or smell as he found no mouth or nose. Another examines the tip of the trunk and suspects that the creature can smell, but appears to have no eyes. Another examines the surface of the trunk, concluding that the creature has a flexible leg that rarely touches the ground. None of them agrees with the other, and none of them has the entire picture.

Another interesting problem arises because of differences in analytical approach. Some scientists emphasize the chemical compositions of the minerals, others the abundances of different isotopes of carbon, oxygen, or sulfur, while still others study the shapes of minerals and how they are intergrown. These different approaches tend to lead to different viewpoints. Only when all the observations are tied together will we begin to understand this wildly complicated rock from Mars.

Did the carbonates form hot or cold?



A very important issue is the temperature of formation of the carbonate minerals. Because the suspected fossils are associated with the carbonates, the carbonates must have formed at a suitably low temperature (less than 150 C) for life to have existed. If it could be proven that the carbonates formed at a high temperature, say above 250 C (some folks have suggested the carbonates formed at 500 to 700 C), then life could not have existed at the time of carbonate formation. Of course, proving a low-temperature origin does not prove that life existed in the rock, only that conditions were suitable for life.

Geologists have devised several ways to determine the temperature at which a rock formed. In fact, we can also determine the pressure. However, most of the techniques we use to do this require two or more minerals to be in chemical equilibrium, which means they reached an agreement with each other about how much of each element or isotope they would contain. This level of agreement can be measured in the laboratory. Unfortunately, it appears that the minerals in ALH 84001 did not have time to reach an amicable agreement--they are not in equilibrium. This makes it very difficult to estimate the temperature of formation, and has led to the impressive disagreement in the estimated temperatures. The general compositions and isotopic abundances in the carbonates are like those in many carbonates on Earth, however, suggesting they formed at a relatively low temperature. On the other hand, few experiments have been done on rapidly crystallized carbonates at high temperature.

The solution will come from more complicated ways of determining temperatures. These involve understanding the rates at which minerals form and the speed with which elements can move through minerals. This general type of problem is called kinetics, and is very important in all geologic studies. It is also an area where we lack sufficient data. So, for now, the temperature of formation of the carbonates is not known.

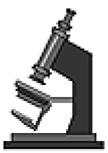
Contamination and related problems

The original paper by Dave McKay and his associates had carefully considered the problem of contamination of the sample with organic material while it was sitting on the ice in Antarctica. Nevertheless, some investigators, such as Luann Becker and Jeff Bader, have showed that contamination may be a serious problem (see their arguments summarized in Life on Mars--The Debate Continues). The meteorites found in Antarctica are preserved once they are buried in the ice, but when they emerge again at places like the Allan

Hills, they may sit in puddles of water off and on for many years, allowing lots of time for organic chemicals and perhaps even bacteria to enter the rock. The problem may be quite serious, though more tests need to be done to determine the extent of contamination. The central problem is that the Earth is teeming with life and it seems to find places to live practically everywhere, even underground (see Life Underground, Dec. 96 article).

Besides the opportunity for contamination in Antarctica, there is a chance for contamination in the curatorial facility at the Johnson Space Center, in spite of the careful procedures followed. In fact, since the discovery of possible life in ALH 84001, the curatorial laboratory has tightened its procedures to ensure that no contamination by organic chemicals will take place.

A form of contamination may take place when samples are being prepared for analysis in a scanning electron microscope. The samples need to be coated with an electrical conductor to carry off the electrical charge added by the beam of electrons that is sprayed onto the sample. To coat the sample, gold, copper, or other metals are deposited onto the sample from a vapor. This process can produce unusual features on the rock surface, commonly called "sample preparation artifacts." The concern is that some of these artifacts might resemble the minute fossil-like objects in ALH 84001. To get around this, electron microscopes that do not require coatings are available, but have not yet been used extensively to study ALH 84001. Another way to get around the problem is to search for features similar to the ALH 84001 microfossils in other meteorites that do not contain fossils and that fell recently.

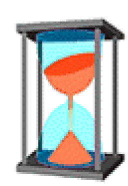


Do nanofossils exist on Earth?

The original paper by Dave McKay and coworkers compared the small fossil-like objects in ALH 84001 to very small microfossils found in some rocks on Earth. The problem is that these small features, called "nanobacteria" to emphasize that they are smaller than "microfossils," have not been proven to everyone's satisfaction to be fossils. The guidelines for determining that small features in ancient terrestial rocks are fossils have not been applied to the study of nanofossils as yet. (See Rules for Identifying Ancient Life, Oct. 96 article.) For example, no documented cases of cell division have been described.

This lack of documentation means that the terrestrial nanobacteria used for comparison may not have been bacteria at all. On the other hand, they might be small bacteria, or the shrunken remains of bacteria, or parts of bacteria. Whatever the answer, detailed studies of both live bacteria that live in rocks and fossilized bacteria on Earth must be done before we can use them for comparison to the fossil-like features in ALH 84001.

When did the carbonates form?



One piece of evidence used to infer that ALH 84001 houses fossil life is the age of the carbonate globules in the rock. It was thought to be 3.6 billion years old. This is about the time when Mars was wettest, hence more likely to promote the development of life. However, another study concluded the age was only 1.3 billion years, much younger than the wettest period on Mars. This huge descrepancy will not be easy to understand because it is very difficult to date the carbonates. The minerals contain only small amounts of the elements used for dating by the usual methods, such as potassium-argon and rubidium-strontium, making the measurements extremely difficult on the small quantities available. In addition, some methods, such as rubidium-strontium, require that the minerals be separated from one another, a very difficult task in the complicated carbonate globules.

At present, the only ages that seem to be well known is the original crystallization age, about 4.5 billion years, and an impact-heating age sometime between 3.8 and 4.05 billion years. If the carbonates were redistributed and heated by the impact event, then the carbonate age is the same as the impact age. But until the origin of the carbonate is worked out, this is not known.

Searching for Answers

Debate at the conference--during sessions, out in the hallways, over dinner--was vigorous, but far from vicious. Most of the proponents for one view or another (for example, high temperature versus low temperature origin for the carbonates), are quite sure they are right, which does arouse some passion! But all involved asked each other difficult questions that must be answered before we can say we know what happened to make ALH 84001 the way it is today.

Some investigators will turn out to be right, others wrong, but there will be no losers. Everyone will have contributed to a better understanding of the geological history of Mars. Studies will help us understand carbonate formation, life in Antarctica, analytical techniques, nanofossils on Earth, climate on Mars, how to search for life on Mars, and how life evolved. And, the rock is interesting in its own right, independent of whether tiny organisms crawled around in it, and even independent of the origin of carbonates. ALH 84001 is a piece of the ancient crust of Mars, so it contains important information about the formation of the crust of that fascinating planet.

Additional Resources

McKay, David S., and others, 1996, Search for Past Life on Mars: Possible Relic Biogenic Activity in Martian Meteorite ALH84001, *Science*, vol. 273, p. 924-930.

Thousands of meteorites are collected in Antarctica through a program managed jointly by the National Science Foundation, Smithsonian Institution, and the National Aeronautics and Space Administration. Find out more from the Johnson Space Center and the Antarctic Search for Meteorites program.

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