Searching for Life in a Martian Meteorite

A seesaw of results

By RON COWEN

At a crowded press conference in Washington, D.C., last August, onlookers had to strain to catch a glimpse of the celebrity in their midst. Jostling each other for a better view, paparazzi fired flash after flash.

The tiny object inside the airtight container wasn't wearing spandex or sporting an electric guitar. But this rock was certainly a star.

Scientists at the NASA conference reported that the potato-shaped meteorite, identified as originating from Mars, may contain fossils of ancient, primitive bacteria from the Red Planet (SN: 8/10/96, p. 84).

Five months later, the controversy surrounding that claim has only escalated. With new evidence on both sides of the issue appearing in peer-reviewed journals, hyped in press releases, and presented at subsequent meetings, information about the Martian meteorite ALH84001 is proving confusing. Some suggest that the debate over whether the meteorite contains fossils from Mars won't be settled anytime soon.

If only this rock could talk.

NASA

Nanofossils or just high-temperature deposits of magnetite? Researchers disagree on the origin of these worm-shaped features, which are several hundred nanometers in length.

Although scientists argue over many properties of meteorite ALH84001, discovered in an Antarctic ice field a decade ago, they concur on several basic facts. Like the other 11 rocks classified as Martian, ALH84001 contains oxygen whose distinctive isotopic composition points to an origin on Mars. This meteorite stands out from the others, however, because it's by far the oldest. Radioactive dating of certain isotopes in the rock indicates that it formed beneath the Martian crust some 4.5 billion years ago. Its advanced age has attracted keen interest because ancient Mars is thought to have been considerably warmer, wetter, and more hospitable to life than the modern planet's tundralike landscape.

When the scientists who first studied the meteorite reported their findings in the Aug. 16 SCIENCE, they cited four lines of evidence that, together, suggest ALH84001 may contain fossil life. Microscopic globules of carbonates in the meteorite may have formed when a carbon-rich liquid, such as carbon dioxide dissolved in water, percolated through cracks, leaving behind the solid precipitate. The presence of water is generally thought to be a prerequisite for life.

The black-and-white rims of the golden globules contain deposits of iron sulfide and a type of iron oxide called magnetite. Although a nonbiological process can form these minerals, primitive terrestrial bacteria also produce them.

The rock contains a variety of polycyclic aromatic hydrocarbons (PAHs). Although these substances can form through chemical processes that do not involve life, they often arise on Earth as by-products of biological decomposition. It's intriguing that the PAHs lie near the carbonates, the team argues, because that's where these hydrocarbons would be expected to reside if they had a biological origin.

Finally, electron microscopy revealed that the meteorite contains tiny worm-shaped and ovoid features, typically only a few hundred nanometers in diameter. Although they are only one-hundredth the size, these shapes are similar to fossils left by primitive bacteria on Earth.

Other researchers have attacked each of these arguments. "Since August, everything I've seen—other people's work and my own—has weakened their proposal," says planetary scientist John F. Kerridge of the University of California, San Diego. "Now I think they don't have a shred of evidence to back it up."

In a dramatic report to be published next week, a group of researchers refutes the very notion that the features in ALH84001 are microscopic fossils. Harry Y. McSween Jr. of the University of Tennessee in Knoxville and his colleagues used transmission electron microscopy (TEM) to examine the area of the rock containing the carbonate globules. TEM probes the composition and structure, as well as the shape, of microscopic objects.

The researchers say that the TEM confirmed the presence of the wormlike and ovoid features and revealed that they are composed of magnetite. That finding appeared to give a major boost to the proponents of life on Mars, because some terrestrial microfossils contain magnetite. However, closer inspection of the internal structure of the magnetite in ALH84001 revealed that it could not have been formed by a living organism, the team says.

On Earth, primitive bacteria leave a residue of magnetite in one particular form—a chain of crystals. In contrast, much of the magnetite in the Martian rock consists of single, elongated crystals.

Even more revealing, some of the elongated crystals—the whisker-shaped ones, which appear to correspond to the wormlike microscopic fossils—contain a spiral defect. Such a defect is a dead give-away that these crystals formed as a result of high-temperature volcanic activity, the team argues. The other elongated crystals in ALH84001, the platelets, which appear to correspond to the ovoid microscopic fossils, don't have this defect but are often associated with the whiskers.

"There's nothing else that looks like nanofossils [in the rock sample], and the things that look like nanofossils aren't," McSween asserts.

One of McSween's collaborators, John P. Bradley of the Georgia Institute of Technology in Atlanta, found a report noting that magnetite takes on a whiskery appearance in volcanic vents at temperatures of about 800°C. Water-based life could not have survived at this high temperature, the team notes.

Bradley, Ralph P. Harvey of Case Western Reserve University in Cleveland, and McSween will report their findings in GEOCHIMICA ET COSMOCHIMICA ACTA.

Coauthors of the initial meteorite study, including David S. McKay of NASA's Johnson Space Center (JSC) in Houston, discount the significance of the new report. "We're very puzzled by their findings, and we don't think they're looking in the same place," he says.

Although McKay's team hasn't used TEM to analyze the composition or internal structure of the features they call microfossils, they have applied the technique to the magnetite crystals at the rim of the carbonate globules. "We're seeing hundreds and hundreds of cubic or equidimensional magnetite crystals," many with no defects, rather than elongated crystals with a spiral defect, McKay says. Most significantly, TEM images recently made by his team reveal that magnetite crystals at the rim form small

Continued on p. 383

Continued from p. 380

chains, a finding that supports a biogenic origin for the mineral.

Using different radioactive dating techniques, two independent research groups disagree on when ALH84001 acquired its carbonates. One team suggests that the carbonates were deposited some 3.6 billion years ago, when researchers believe Mars had an abundant supply of water. Another estimates that they were inserted about 1.4 billion years ago, by which time Mars' water supply might have dwindled.

The time of carbonate deposition remains an open question, but McSween notes that the more recent age is consistent with his team's experiments, reported in the July 4 NATURE, indicating that the material derived from a hot vapor rather than liquid water. That scenario severely weakens the case for a biological origin of the carbonates, he notes.

Not necessarily, contends Kathie L. Thomas-Keprta of Lockheed Martin in Houston, a coauthor of the initial meteorite study. She says the composition of the carbonates varies throughout the tiny samples of ALH84001 the team examined, with bands of calcium-rich carbonates adjacent to calcium-poor ones, for example. That distribution argues for low-temperature deposition, she contends. A high-temperature process would be more likely to generate a uniform globule.

The temperature at which the carbonates formed does not dictate whether the rocks ever housed life, says Craig S. Schwandt of JSC. However they formed, he argues, the carbonates in the rock may have created a haven for primitive bacteria that arrived later. Carbonates regulate pH and could act as a buffer zone inside a rock that might otherwise be inhospitable to life. Schwandt proposes that the carbonates formed first, laying down a niche for mineral-producing bacteria that later colonized the margins of the globules.

Jeffrey L. Bada of the Scripps Institution of Oceanography in La Jolla, Calif., says he's all but convinced that cell walls and other biological artifacts, if found, come from meltwater that passed through the meteorite during its 13,000-year sojourn in the Antarctic. The meltwater, he notes, contains PAHs whose molecular weights are the same as those found in the Martian rock.

Bada and his colleagues melted blocks of Antarctic ice and inserted solid carbonates into the solution. The next day, they found the carbonates heavily contaminated by PAHs from the water. It's long been known that carbonates scavenge PAHs, he explains, and the experiment demonstrates that the PAHs found in the Martian rock could have come from Antarctica. "This rock has been on Earth for too darn long" for contamination not to be a major problem, he concludes.

Simon J. Clemett of Stanford University and his colleague are less worried about contamination. They examined a large supply of micrometeorites from the same Antarctic ice field as ALH84001. Because these tiny rocks have a much larger surface-to-volume area, they would seem to be more susceptible to contamination, yet all of the rocks had different distributions of PAHs. Had contamination been significant, the rocks should all have had the same PAH distribution, the researchers say.

Whatever the outcome of the debate over ALH84001, the potato-shaped rock from Mars may become an icon for the ages, says astrophysicist Richard Berendzen of American University in Washington, D.C. In exploring the possibility of life on the Red Planet, he says, "We'll find our destiny. We'll find our future. We'll find ourselves." □

Materials Science

Corinna Wu reports from Boston at the Materials Research Society meeting

Biological glue for cartilage . . .

To help damaged cartilage heal, scientists are developing implants on which cartilage cells can grow. These cellular scaffolds, however, must be held firmly in place at the site of the injury. Julia J. Hwang of the University of Illinois at Urbana-Champaign and her colleagues are synthesizing a biodegradable glue that may do the job.

The glue consists of long, hybrid molecules that stick to cartilage on one end and the implant on the other. "They contain units of lactic acid, which preferentially absorb onto the [implant] surfaces," Hwang says.

The molecules also link with each other, enhancing the glue's strength. The cartilage scaffolding must be precisely cut before it is implanted because "the shape has to be a very good fit to get tight adhesion," says Anna Gutowska of the Pacific Northwest National Laboratory in Richland, Wash.

. . . and for corneas

Fibrin glue, made from a blood-clotting substance, can seal tissues together, eliminating the need to suture a wound. The glue is commonly used after surgery on the cornea, says Russell T. Kronengold of the Robert Wood Johnson Medical School in Piscataway, N.J., "because suturing can lead to astigmatism." Although it is biologically compatible, fibrin glue is not very strong, he notes. Kronengold and his colleagues have improved its strength 26 percent by mixing gelatin with the glue, making it nearly as strong as stitches.

In cataract surgery, ophthalmologists usually leave the cuts in the cornea to seal themselves. However, in automated lamellar keratoplasty, a procedure that corrects near-sightedness, the loose flaps of the cornea sometimes shift around, leading to complications. Scanning electron micrographs show that the modified fibrin glue can seal those wounds effectively.

Aerogel films as electronic insulators

As computer chips get smaller, the need for high-quality component materials grows larger. One of the latest prospects is nanoporous silica, a whisper-light gel that's an exceptionally good electrical insulator. Douglas M. Smith, president of NanoPore in Albuquerque, N.M., reports a simplified method that deposits thin films of this material and enables researchers to control both the thickness and the porosity of the films.

For years, nanoporous silica has been used as bulk thermal insulation in refrigerators and for other industrial applications in a form called an aerogel. Because it contains an abundance of air-filled pores, many only 20 or 30 nanometers in diameter, the gel effectively blocks the transfer of heat.

The pores also make the gel almost as good an electrical insulator as air. The gel could shield chip components from each other to prevent cross talk—interference that becomes increasingly troublesome as the components of electronic devices are crammed closer together. Use of nanoporous silica could also allow chips to run faster, says Changming Jin of Texas Instruments in Dallas. Jin presented his group's research on characterizing the deposited films and making them water repellent.

Unlike silica gels used for thermal insulation, gels for computer chips must be able to dissipate heat rapidly. "As you shrink the device size, the metal mass gets smaller and smaller," Jin says, "but it's going to pass the same current." The increased current density generates more heat, which can damage the electronic components.

To improve heat conduction, Jin and his colleagues are testing denser gels, which have about 75 percent of the gel volume filled with air. Silica gels used for thermal insulation typically have porosities of 95 to 99 percent, he says.