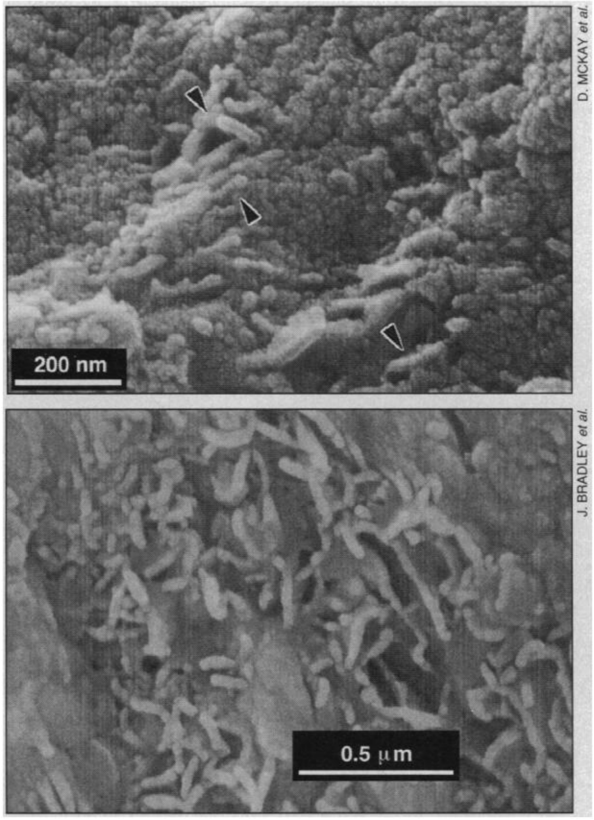
Putative Martian Microbes Called Microscopy Artifacts

Ever since they made their public debut 15 months ago, the squiggly little objects that might—or might not—be microscopic fossils in a meteorite from Mars have been at the center of a heated debate. Most scientists have focused on arcane arguments about mineral isotopic compositions and formation temperatures (*Science*, 4 April, p. 30), but for many, the proposed microfossils provoked a more visceral reaction—they simply look lifelike. Looks can be deceptive, however, and a group of three meteoriticists now argues that there's nothing lifelike about the martian "bugs." Rather, they're simply a trick of the eye abetted by the peculiarities of the powerful microscopes used to image them.

In a short paper in this week's *Nature*, John Bradley of MVA Inc. in Norcross, Georgia, Ralph Harvey of Case Western Reserve University in Cleveland, and Harry McSween of the University of Tennessee, Knoxville, present their own nanometer-scale images of martian meteorite ALH84001. They argue that most of the putative microfossils are nothing more than narrow ledges of mineral protruding from the underlying rock, that under certain viewing conditions can masquerade as fossil bacteria. "There are regions that are absolutely teeming with these emergent [mineral] structures, whose shapes appear to be indistinguishable from some of the proposed nanofossils," says Bradley.

The originators of the nanofossils from Mars idea, led by David McKay of NASA's Johnson Space Center in Houston, defend themselves in a response accompanying the Bradley paper. "You have to be very careful," says team member Kathie Thomas-Keprta of Lockheed Martin in Houston. "We know that the [mineral structures] are there, but that's not what we're calling the martian 'bugs.'" The exchange leaves other researchers wondering what kind of evidence might end the debate. "Few if any rocks have been studied as intensively as 84001, [yet] there is room for multiple interpretations," says microscopist Peter Buseck of Arizona State University in Tempe. The problem, says interplanetary dust specialist Donald Brownlee of the University of Washington, Seattle, is that a structure's shape is very weak evidence for past life. "I don't know how you can ever resolve this" with microscopy alone, he says.

To make their original claims last year, the McKay group used a field-emission scanning electron microscope (FE-SEM) to image swarms of possible microfossils as well as "The Worm," the lone, segmented structure that seems a dead ringer for a worm (see photo next page). In an FE-SEM, the beam of electrons that scans back and forth across the sample is so narrow that it creates an image with nanometer-scale resolution—far better than a standard SEM can achieve. Bradley and colleagues now use that same advanced technology to arrive at an interpretation of ALH84001's structures as being lifeless. Given the new level of detail seen by an FE-SEM, "a lot of things we see on surfaces are new to us," says Bradley, and they may not be what they appear. On the surfaces of fractures inside ALH84001, he and his colleagues found what they are calling "emergent lamellae," crystalline "lips or ledges" where the natural layering of the minerals pyroxene and carbonate has been accentuated the way individual sheets stand out on the edge of a loose sheaf of papers.



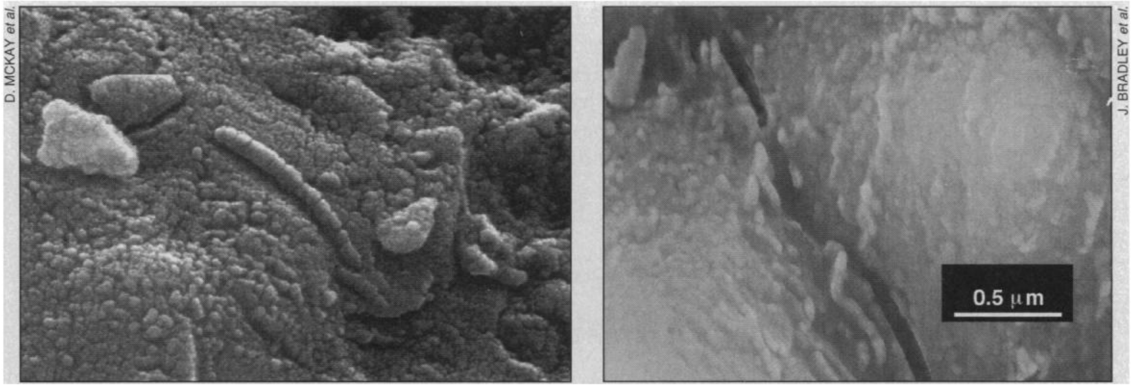
Animal or mineral? Proposed martian microfossils *(top)* resemble mineral edges in same meteorite *(bottom)*.

Viewing those mineral edges under an FE-SEM can give the impression of tiny, elongated bacteria, says Bradley, for two reasons. SEM generally requires that the sample be coated with a thin film of metal so that the SEM's electrons do not charge the sample and fuzz up the view. But coating samples with such metals, including the gold-palladium mixture usually used by the McKay group, can change texture, round off shapes, and even create segmentation like the worm's, says Bradley. In addition, the perceived "wormness" of the layers depends on the viewing angle, he says, so that ledges obviously rooted in the underlying mineral in one perspective can, with a dollop of metal and a twist of the viewing angle, transform into a "bug" or even a worm. And when these layers appear highly aligned, they are reminiscent of the "herds" of proposed microfossils in roughly parallel poses presented at the 1996 press conference announcing the McKay group's findings,* says Bradley. "What we are reporting is a whole population of elongated forms that bear an uncanny resemblance to the proposed nanofossils. I can't see the difference," he says.

McKay and company say they can. "You really cannot mistake [mineral layers] for the features that we are calling possible microfossils," says Thomas-Keprta, "because [layers] are so well aligned and they range over a huge area." Possible microfossils, on the other hand, are not so orderly. They can overlap each other or stand in relative isolation; some even have an S shape. What's more, the Houston researchers have tried to account for the subtle effects of metal coatings by imaging a variety of surfaces, both coated and uncoated—and they say that the effects don't produce structures like the microfossils.

In addition, says Thomas-Keprta, the emergent lamellae are in general too small to be mistaken for microfossils. The McKay group is not abandoning its claim that structures as small as 0.02 micrometer could be microfossils, despite complaints from biologists that no living thing could be so small, but "we are concentrating on some of the larger features in part because they are less controversial," says Thomas-Keprta. And some of the largest "microfossils" are 0.75 micrometer long, while most of Bradley's layers in his *Nature* images are 0.1 micrometer and

* NASA images of possible microfossils in meteorite ALH84001 can be viewed on the World Wide Web at http://rsd.gsfc.nasa.gov/marslife



D. MCKAY *et al.* / J. BRADLEY *et al.*

Battle of the bugs. A wormlike form *(left)* is a prime example of a possible microfossil from Mars, but some argue that a mineral structure from the same meteorite *(right, lower center)* might also pass for a microfossil.

smaller, she says.

Finally, just because Bradley failed to find any structures resembling microfossils doesn't mean they are not there, says Thomas-Keprta. The McKay group has seen layers in some parts of the meteorite all along, but hadn't discussed them because they weren't sure what they were; they suspect that lamellae are clays starting to weather out of the pyroxene. But to maximize the chances of finding possible microfossils, they look most closely on the rims of the so-called carbonate rosettes, Thomas-Keprta says, and there they find no layers.

Bradley has a counter-rebuttal for each of these defenses. He says that some lamellae do indeed mimic the putative microfossils, appearing jumbled in lifelike poses, ranging up to a micrometer in length, and even exhibiting a distinct, wormlike S-shape (see images). And he and his colleagues say they find layers on both pyroxene and carbonate. In the rims of rosettes, Bradley agrees that there are no lamellae. But there, he argues that the impostors may be nonbiological magnetite "whiskers" or grains, as he and his colleagues have suggested before. So in the view of Bradley and his colleagues, "although some of the elongated forms of ALH84001 could conceivably be martian nanofossils, the majority appear to be either emergent substrate lamellae or magnetite [grains]."

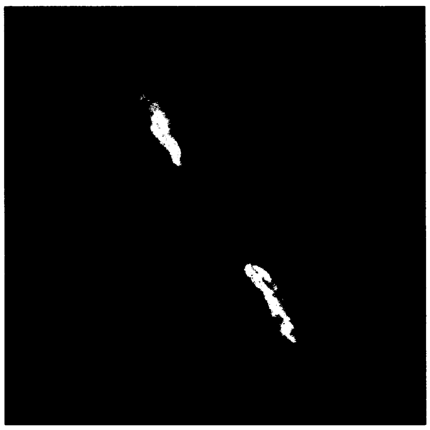
How can all this be resolved? Bradley's results show that "there are definitely nonbiological processes that can produce these 'buglike' morphologies," says Brownlee. But Bradley can't prove whether the particular structures imaged by the McKay group are microfossils or artifacts. "Who knows?" says Washington's Brownlee. "I'm not nearly as hopeful as when I first saw the McKay paper." If the shapes of structures can't settle the issue, perhaps the McKay group's planned dissection of a microfossil will help. But the claim of life on Mars may have to stand or fall on other evidence. "It may not be possible to prove they are microfossils from Mars," says Brownlee.

–Richard A. Kerr

ASTRONOMY

Dust Disks May Point Way to Exoplanets

UTRECHT, THE NETHERLANDS—Dust is not always a sign of failure, says Carsten Dominik of Leiden Observatory in the Netherlands. Astronomers have traditionally believed that the formation of planets would leave little or no dust around a star because all the dust would end up in planets; a disk of dust, they thought, was a sign that no planets had formed in that particular system. But Dominik and his colleagues have now found a dust disk around 55 Cancri, a dim, sunlike star in the constellation Cancer that is thought to be accompanied by one or possibly two massive planets (*Science*, 26 July 1996, p. 429). Apparently, dust disks and planets are not mutually exclusive after all.



A. M. LAGRANGE *et al.*/LABORATOIRE D'ASTROPHYSIQUE DE GRENOBLE

Dusty surroundings. Dust disks like this one around Beta Pictoris can coexist with planets.

Observing the star using the German ISOPHOT camera on board Europe's Infrared Space Observatory (ISO), Dominik's team found that it is "too bright" in the infrared. In a report soon to be published in *Astronomy & Astrophysics Letters*, they conclude that the excess radiation can only be explained by a disk of cool dust particles. More than a decade ago, IRAS, a U.S.–Dutch infrared satellite, observed such disks around other stars, but until now they have never been seen around stars suspected of hosting planets. The new discovery leads Dominik to suggest that a sunlike star surrounded by a dust disk might be a promising place to hunt for exoplanets.

The team found the bulk of the infrared excess around the wavelength of 60 micrometers, implying that most of the dust particles have temperatures between 40 and 100 kelvins. This puts the dust some 9 billion kilometers from the star, roughly the same distance as from our own sun to the Kuiper belt, a region beyond the orbit of Neptune that contains dust and numerous "ice dwarfs"—cometlike bodies tens of kilometers across. "This disk is comparable to the Kuiper belt in our own solar system," says Dominik, "although it contains a lot more dust. We wouldn't be able to see the Kuiper Belt from afar [with ISO]." Dominik adds that the disk around 55 Cancri is not the protoplanetary disk from which planets are believed to form; the star is much too old to show the remains of this primordial disk.

Supporting the Kuiper belt analogy is the second putative planet around 55 Cancri, which orbits at a large distance from the star. In our own solar system, the inner edge of the Kuiper belt is swept out by the gravity of Neptune, the outermost massive planet. In the same way, the second planet of 55 Cancri might define the inner edge of the dust disk, says Dominik. Just how the disk persists is something of a puzzle for astronomers, however. Microscopic dust particles should spiral down into the central star within 20 million years, so Dominik's team believes the disk must be continuously replenished in some way, presumably by erosion of larger objects, such as a large number of ice dwarfs similar to those in the Kuiper belt.

No one yet knows whether the ISO discovery implies that other "dusty" stars are promising places to look for exoplanets. Ac-