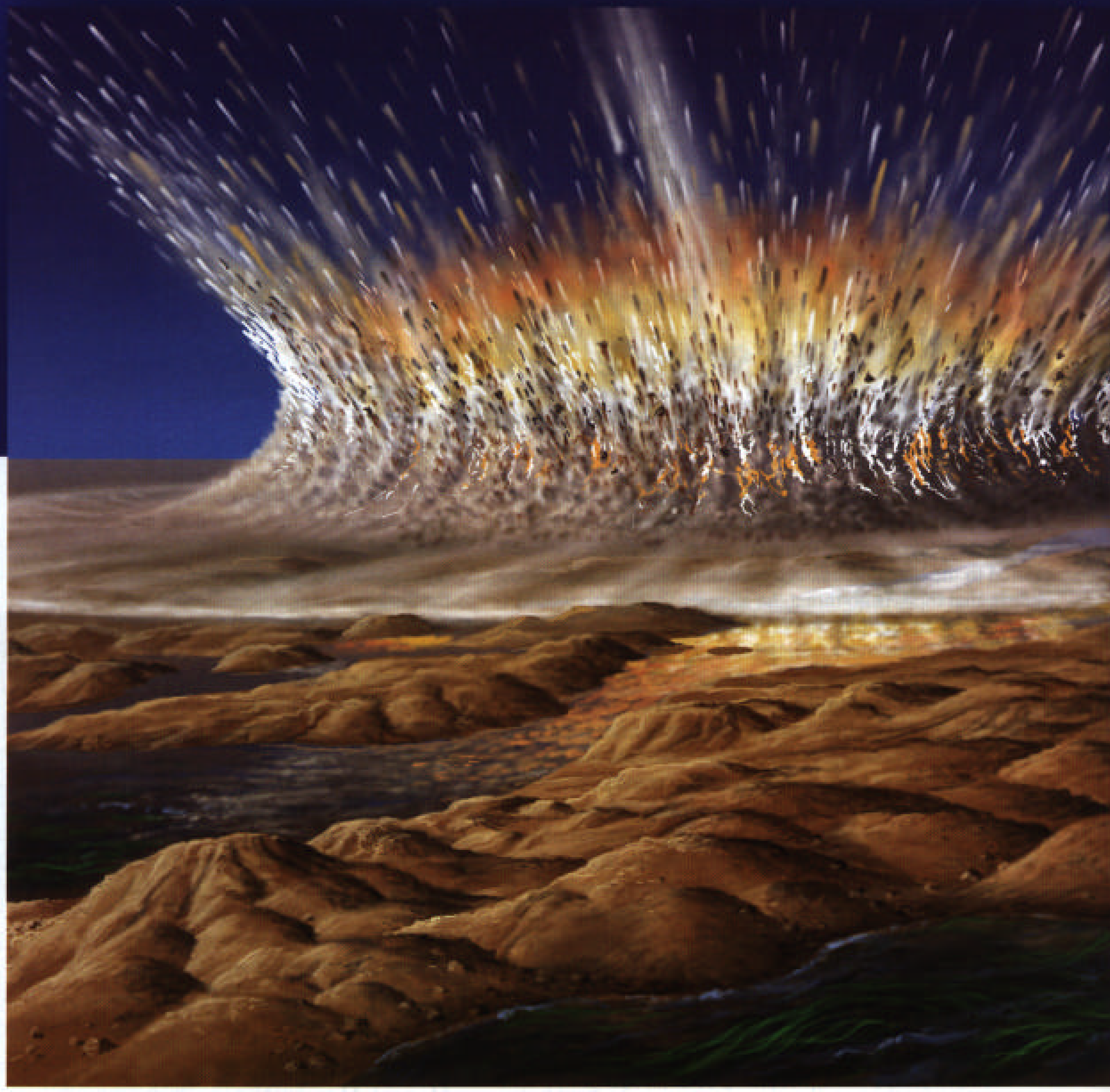
Life From

Testing Panspermia With M



Can it be that some of the earliest life on Earth was "imported" from somewhere else? That concept, known as panspermia, is illustrated here. This panel depicts a meteorite from Mars crashing to Earth some 3.8 billion years ago. The meteorite was itself blasted Earthward by a larger impact event on Mars sometime earlier. The green masses drifting in the stream are the only visible living things on the scene.

by Benjamin P. Weiss and Joseph L. Kirschvink

The origin of life is a tricky problem. The probability not only of getting all the right ingredients together in one place, with the right amount of energy, but also of organizing those ingredients into a complex organism capable of replicating itself seems extremely small. Plus, this all had to happen very quickly—possibly within a few hundred million years.

For more than a half-billion years after it accreted into a solid planet, Earth was repeatedly sterilized by a rain of protoplanetary objects, effectively making it impossible to harbor life. Then, about 3.9 billion years ago, the rain turned into a drizzle of occasional impacts, and life could have gotten a toehold. But the window between the end of the bombardment and the era for which we have concrete evidence of life is short in geologic terms—there are hints of biological activity in 3.8-billion-year-old rocks found in

Space?

artian Meteorite ALH84001

This panel shows the aftermath of the impact, not only in the half-kilometer-wide crater in the distance but also in the new life-forms springing up along the water near the secondary impact pits. These life-forms developed from spores that hitched a ride on the meteorite, a process that might have occurred on both planets numerous times over geologic time.

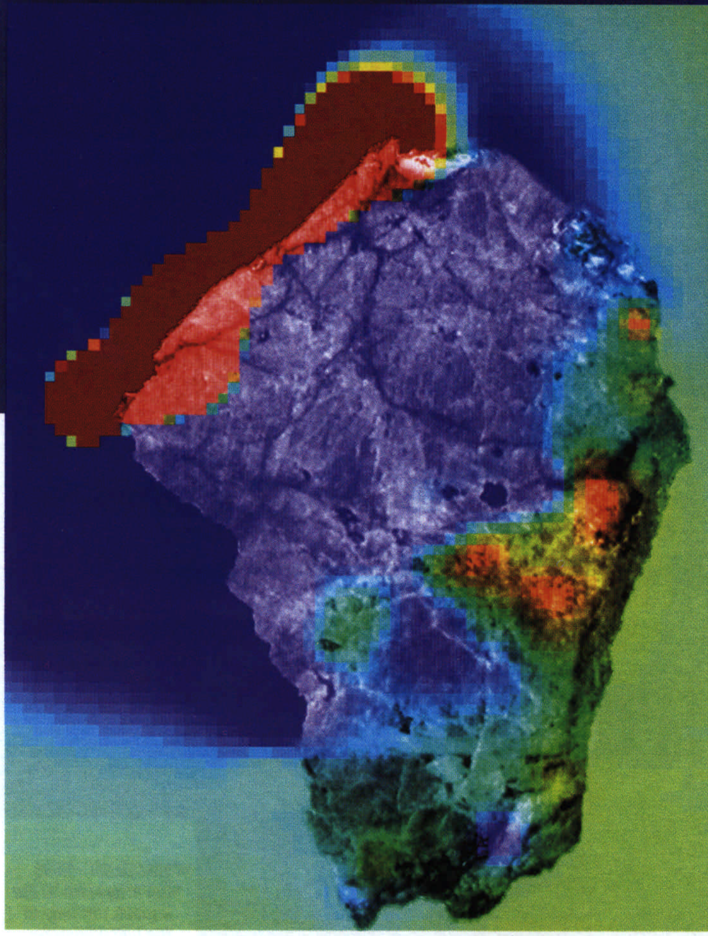
Paintings: Don Davis

Greenland and possible fossil bacteria in 3.5-billion-year-old rocks found in Australia.

One way around the problem is to posit that life did not begin here at all but rather came to Earth from somewhere else. This hypothesis, that life may have originated elsewhere than on Earth and spread from planet to planet throughout the cosmos, is called panspermia. A bit of cheating is involved, since panspermia begs the question as to how life started on whatever world it did. On the other hand, panspermia could have extended the time that life had to evolve after the period of bombardment, since life ejected into space could reseed the sterilized planet of its origin.

An Ancient Idea

Panspermia is an ancient idea and, despite its science fiction-like feel, one that has received serious scrutiny by many



Left: Magnetic microscope imaging of a 1-mm slice of Martian meteorite ALH84001, taken from near the outside of the meteorite. The fusion crust on the upper left side of the sample has been remagnetized in Earth's field, while the interior of the meteorite retains the weaker, heterogeneous magnetism it acquired on Mars.
Image: Francis MacDonald and Franz Baudenbacher

Right: Magnetic microscope images of a 1-mm slice of ALH84001, taken from the interior of the meteorite. (A) Magnetization of the sample at room temperature before heating. (B) Magnetization of the sample after being heated to 40 degrees Celsius (104 degrees Fahrenheit). Arrows point to some features that weakened following the heating. The scale bars represent 2 millimeters. *Images: © Science 2000*

famous scientists. Its essential elements can be traced back to at least 500 B.C., when the Greek philosopher Anaxagoras imagined that life infused and spread itself throughout the cosmos. Much later, in 1821, the Frenchman Sales-Guyon de Montlivault imagined seeds from the Moon inoculating the first life on Earth. Then, in the mid-1800s, German physicist H. E. Richter, recognizing that some meteorites contain abundant carbon, suggested that life could have traveled to Earth via meteorites. Lord Kelvin concurred: "We must regard it as probable in the highest degree that there are countless seed-bearing meteoric stones moving about through space."

But writing in his 1908 classic, *Worlds in the Making*, the Nobel prize-winning chemist Svante Arrhenius rejected this possibility:

> Fantastic is the idea that organisms . . . caught . . . in meteorites . . . are carried out into universal space and deposited on other celestial bodies. The surface of meteorites becomes incandescent in their flight through the atmosphere, and so any germs which they might possibly have caught would be destroyed.

If Arrhenius had ever actually picked up a newly fallen meteorite, he'd probably have had fewer reservations: the rock would have been freezing cold. The frictional heat from atmospheric passage can only diffuse several millimeters into a rock during the few minutes it spends falling through the air; the ablating away of molten drops removes most of the heat. This leaves behind a thin, melted "fusion crust," but the inside remains unaffected.

By the early 1970s the idea of panspermia was well accepted. Another Nobel laureate, Francis Crick, proposed with Leslie Orgel that terrestrial life may have originated from "directed panspermia"—that is, intelligent extraterrestrials dispatching primitive organisms as proxy colonists.

Put to a Test

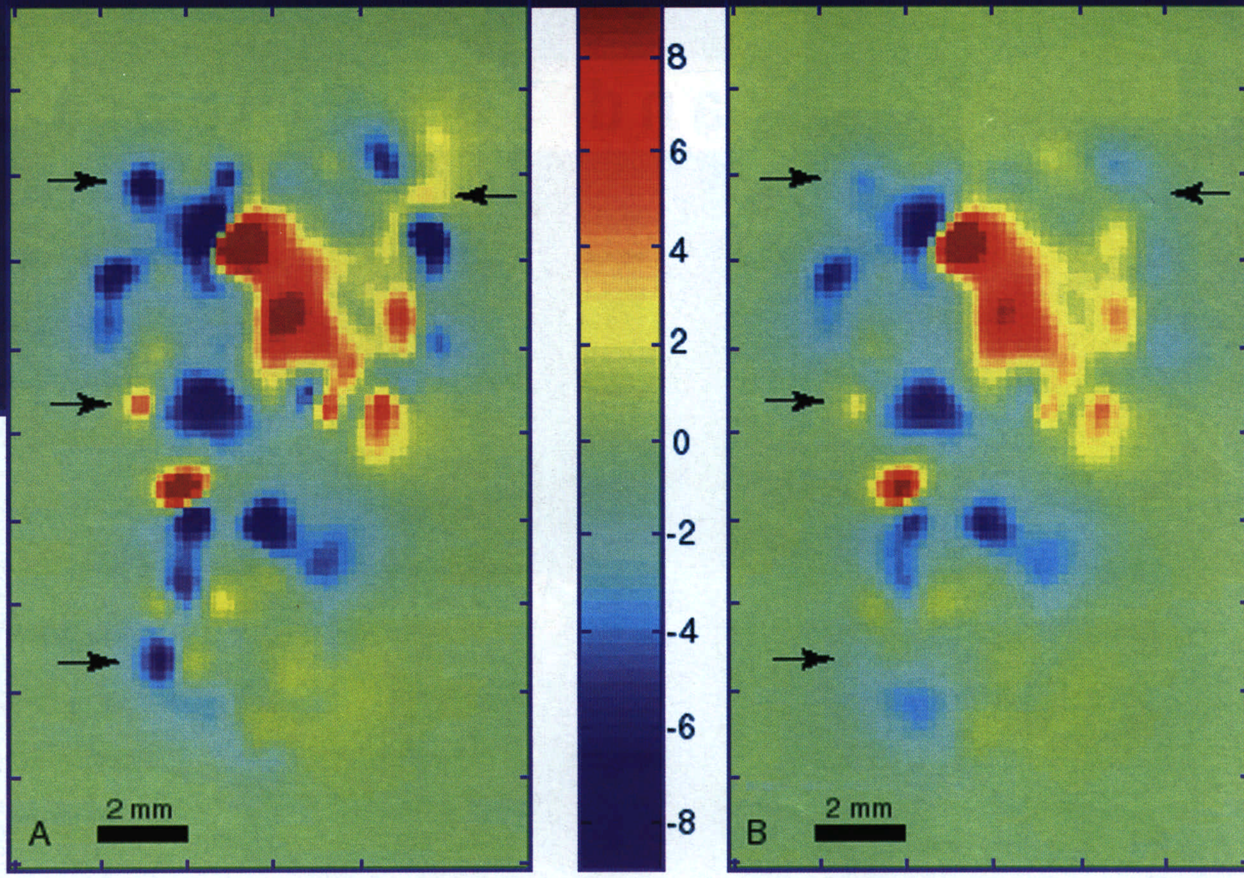
Clearly, Earth's atmosphere will not sterilize the interior of pebble-size meteorites; yet it's not known whether rocks can be ejected from the surface of a planet without a severe cooking. After all, the only natural process capable of ejecting a rock from the Martian surface is the impact of a comet or asteroid, a violent event indeed. (See "Swapping Rocks" in the July/August 1994 issue of *The Planetary Report*.)

For this reason Eugene Shoemaker, one of the fathers of modern planetary geology, 30 years ago declared that any impact ejecta managing to escape Mars' gravity would be vaporized or completely melted. In the 1980s the discovery of unmelted, largely intact (though highly shocked) meteorites from Mars discounted this idea. Consequently, Jay Melosh of the University of Arizona theorized that some rocks could be blasted off Mars by an impact without being shocked (and, by extension, heated) at all! We decided to test this theory by studying the magnetic properties of a Martian rock: the famous ALH84001.

ALH84001 is a strange rock for many reasons: it is a meteorite, it is from Mars, and it is the oldest known rock from any planet (more than a half-billion years older than any Earth rock). Plus it contains carbonate globules rimmed with tiny iron-oxide particles that have been interpreted as 4-billion-year-old fossils of ancient Martian magnetotactic bacteria.

ALH84001 came to our laboratory at Caltech through luck and happenstance: it was blasted off Mars by an asteroid or comet 15 million years ago and, after wandering through space, landed 11,000 years ago in Antarctica, where a team of NASA and National Science Foundation scientists found it in 1984. We convinced NASA to lend us a chunk so that we could study its magnetic properties, which can be changed by heat, and thus determine the rock's level of heat during its ejection from Mars.

For our study we used Vanderbilt University's SQUID (Superconducting Quantum Interference Device) Microscope. Designed by a physicist named Franz Baudenbacher, the SQUID Microscope is one of the world's most sensitive instruments for producing high-resolution images of the magnetic fields of rocks. The first slice of ALH84001 we



examined showed a piece of the outer fusion crust stuck to one edge, resulting in an enormously strong magnetic field (image on page 10).

But just a few millimeters in, the rock appeared to contain a weak, spatially heterogeneous magnetization pattern acquired on Mars. This is exactly what we expected and demonstrates that the interior of the meteorite could not have been heated more than several hundred degrees (and probably much less) during its passage through the Earth's atmosphere.

Using the same technique, we made two magnetic images of another slice of ALH84001, extracted from the interior of the meteorite. In the first image, taken without heating the rock, we observed the same heterogeneous pattern of magnetization as in the interior portion of the previous slice (image A, above).

We then heated the slice to 40 degrees Celsius (104 degrees Fahrenheit), cooled it in zero magnetic field, and reimaged it. Many of the magnetic features decreased or disappeared entirely (image B, above); they did not reappear when the sample was heated and cooled to the same temperature but in a weak applied magnetic field.

Confirming Evidence

These results demonstrate that ALH84001 had not been heated to even 40 degrees Celsius (104 degrees Fahrenheit) since before leaving the Martian surface, confirming Melosh's theory that rocks could be ejected off the surface of Mars without being heat sterilized.

At such temperatures, prokaryotes (simple, one-celled organisms without well-defined nuclei) and even simple eukaryotes (organisms with well-defined nuclei) like fungi or plant seeds might survive the launch. Unfortunately, we cannot constrain the formation temperature of the carbonate globules—although we think the observed magnetization originated on Mars, we don't yet know exactly when that took place. (Constraining the temperature at which the carbonate globules in ALH84001 formed would help settle the debate over possible life traces in the meteorite. A high formation temperature could rule out life as we know it in the rock; a low temperature would be conducive to life.)

Although it's unlikely that ALH84001 itself brought Martians to Earth (it spent nearly 15 million years wandering through cold, airless space), it is not unreasonable to assume that if there were life on Mars, other rocks have already transferred it here. Computer-dynamic simulations suggest that about a billion tons of Martian rock have landed on Earth since the solar system formed, and every million years or so about a dozen fist-size rocks are transferred from Mars to Earth in just a couple of years. In fact, one in ten million of the arriving Martian rocks could have been transferred in less than a year!

Finally, consider that researchers have brought back living bacterial spores from an orbiting satellite where the bacteria spent more than five years bathed in strong ultraviolet light in a deep vacuum. Consider, too, that such bacteria can survive the high pressures and shock they might encounter during ejection. Evidently it is likely that if Martian microorganisms exist, they have been transported to Earth throughout most of our planet's history. Maybe, then, we don't need to go all the way to Mars to find Martians.

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