Interplanetary Odyssey

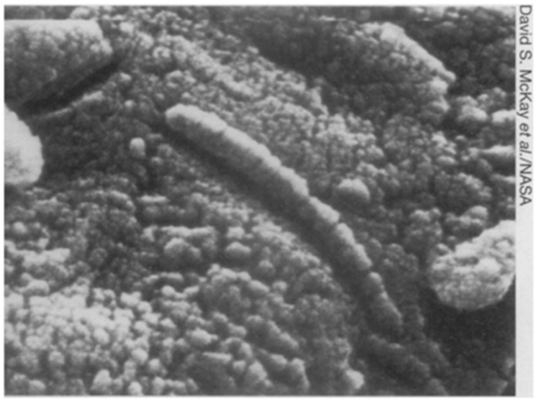
Can a rock journeying from Mars to Earth carry life?

By RON COWEN

Take two planets, smack one with an asteroid, and what do you get? A convoluted game of interplanetary pinball worthy of a Rube Goldberg contraption.

Sixteen million years ago, an asteroid slammed into the oldest terrain on Mars, blasting loose a 2-kilogram chunk of the Red Planet. The rock hurtled into space, zigzagging through the inner solar system until it happened to collide with Earth about 13,000 years ago, landing in a barren Antarctic ice field.

In 1984, a meteorite specialist drove up in a snowmobile and found the rock. A decade later, a geologist realized that it hails from Mars, and other scientists discovered evidence suggestive of ancient life. The news quickly ricocheted around the world (SN: 8/10/96, p. 84).



David S. McKay et al./NASA

This electron micrograph shows a bizarre, tubelike structure found in the meteorite ALH84001, a rock believed to have come from Mars. Less than one-hundredth of the width of a human hair, the structure might be a fossil of primitive life on the Red Planet.

The series of events that culminated in front-page headlines may sound far-fetched. However, recent computer simulations suggest that bits and pieces of all the inner planets—Mercury, Venus, Earth, and Mars—are occasionally flung into space. Most of the rocks ultimately dive into the sun, are kicked out of the solar system, or get pulverized in the asteroid belt.

The same computer simulations indicate that a few of all the rocks gouged from Mars find their way to Earth. While most chunks take millions of years to get here, a few may make the trip in just 16,000 years.

In the rare instance where the orbits of the two planets are properly aligned, a Martian rock could come our way in "less than a year, as fast as a spacecraft from Mars," asserts Joseph A. Burns of Cornell University. He and his collaborators, including Brett J. Gladman, now at Nice Observatory in France, reported their findings in the March 8 SCIENCE.

"We know that the planets are interchanging matter. Therefore, how do we know that life hasn't gone from one place to another?" asks Richard N. Zare, a chemist at Stanford University and a member of the team that found what may be relics of ancient life in the Martian meteorite. "Assuming [our] work is confirmed, it's a huge question."

Burns, Gladman, and their colleagues began their study by examining a rocky migration closer to home. Moon rocks have also been found in Antarctica, and the researchers wanted to find out how likely it is that material blasted off the moon by an asteroid or comet would fall to Earth and how quickly the journey could be made. Scientists had considered these questions before, but faster computers enabled the team to track the simulated journey of individual rocks for millions of years. In the December 1995 ICARUS, they reported that about 40 percent of all the lunar fragments reach Earth. Half the fragments make the trip in no more than 50,000 years.

With its lunar analysis completed, the team turned its attention to a broader issue—the transfer of rock from one planet to another. They determined that the vast majority of fragments blasted from Mercury and Venus wouldn't reach Earth; the few that do typically require 100 million years to get here.

Mars was considered a more intriguing planet to investigate: Twelve meteorites at hand are thought to hail from the Red Planet. All of these meteorites contain the same ratio of oxygen isotopes, indicating that they come from the same parent body. The ratio is distinct from that of meteorites from the moon, most rocks on Earth, or asteroids. In addition, pockets of gas trapped in the youngest of the 12 meteorites are the same as those found in the present Martian atmosphere, as measured by the Viking landers in 1976.

Unlike a chunk of the moon, a fragment of Mars typically takes an indirect path to Earth. First, though, it must both survive the collision that lifted it off the surface and move fast enough to escape the planet's gravitational grasp.

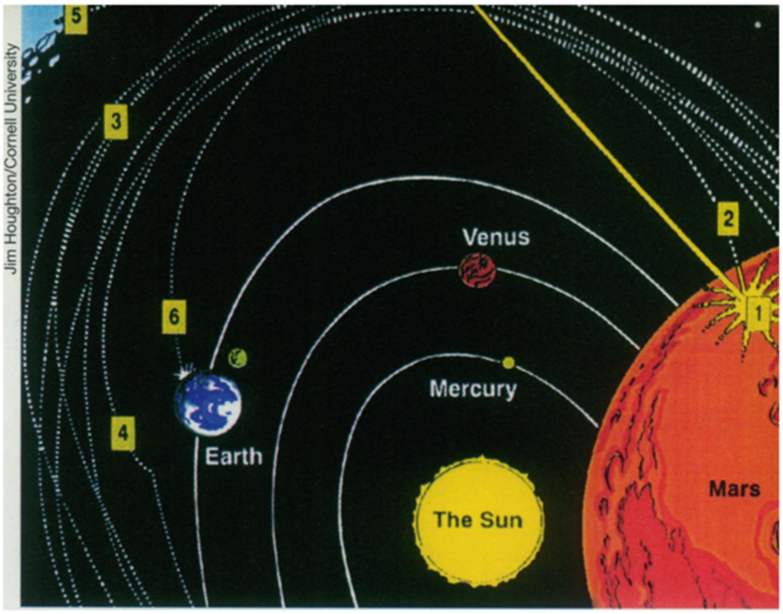
In a model proposed by several researchers, including H.J. Melosh of the University of Arizona in Tucson and his colleagues, a body slamming into a planet produces a crater and generates a shock wave that pulverizes any debris in its path. However, nearby surface material that is shielded from the brunt of the impact can be launched from the planet. If such a rock has a velocity of more than 5 kilometers per second, it will leave Mars for good.

After departing from the Red Planet, the rock faces other hurdles. Because it starts out with an orbit similar to that of Mars, it hasn't a prayer of reaching Earth unless its path changes dramatically. To cross Earth's path, the orbit of this Martian refugee must be elongated.

The change in orbit can occur in several ways. If the rock makes many close passes by Mars, the Red Planet may stretch out the rock's path. More important, the chunk may have an orbit whose angle of inclination vibrates in sync with that of Jupiter or Saturn. Under this special condition, known as a resonance, the path of the rock may become highly elongated and tilted so that it crosses Earth's path relatively quickly.

From older computer simulations, which did not account for resonances, researchers had reported that a rock from Mars would take an average of 100 million years to reach Earth. Burns and his colleagues have now reduced that travel time to 10 million years.

That's good news, says Christopher P.



A tortuous path from Mars to Earth: An asteroid or comet slams into Mars, blasting loose fragments of the planet (1). Some of the pieces have enough speed to escape the planet (2). The gravitational tug of distant planets gradually modifies the orbits of the ejected material (3). Sometimes, close encounters with the other terrestrial planets—Mercury, Venus, and Earth—can abruptly change the material's path (4). Some of the fragments are kicked out of the solar system (5), while others burn up in the sun or suffer fatal collisions with asteroids. Millions of years after leaving Mars, a few of the fragments reach Earth (6).

McKay of NASA's Ames Research Center in Mountain View, Calif., because other studies suggest that if dormant or frozen organisms encased in a Martian rock had ever traveled to Earth, they might survive the rugged journey for no more than 10 million years.

During the trip, bombardment by the sun's harmful ultraviolet radiation would not present a problem, he notes, "because even the thinnest layer of dirt would shield the material," let alone a layer of rock. Cosmic rays—energetic charged particles that pervade space—are more penetrating and could damage the DNA of organisms near the rock's surface. However, a few meters of rock could protect them from cosmic ray damage.

Ironically, radiation from the rock itself would pose the biggest threat to survival, McKay says. Over a span of 10 million years, radioactive nuclei such as potassium, uranium, and thorium, which are likely to be present in the rock, could generate the equivalent of miniature bullet holes in an organism's DNA. Frozen or dormant organisms would be unable to repair the damage.

The question of long-term survival might turn out to be a moot point, says McKay. "Seeding a planet [with life] would only take one rock that happened to make a rapid transit."

Such musings, of course, have taken on new life since the discovery that an ancient Martian meteorite known as ALH84001 contains organic compounds as well as possible fossils of primitive bacteria.

"Obviously, our work has a lot more relevance now," notes Burns. "It's interesting getting a chunk of Mars to Earth. Getting a chunk containing evidence of primitive life is even more interesting."

In light of the meteorite discovery, another finding from Burns' team appears especially provocative. He and his colleagues report that it's about 30 times easier for a wayfarer from Mars to reach Earth than for a rock from Earth to fly to Mars. Earth's stronger gravity and thick atmosphere prevent most dislodged rocks from escaping.

"If you want to believe that life [in the solar system] originated on just one planet and transferred elsewhere, the transfer would have to be from Mars to Earth," says Burns. "If life ever existed on Mars, [some relic of it] probably came here."

But did life ever exist on Mars? The Mars of today—at least its surface—is a frigid desert apparently devoid of organic compounds and other chemicals that can sustain life. Planetary scientists, however, have several reasons for believing that in the past, the Red Planet was wetter and warmer.

The best evidence, says McKay, remains the images taken by the Viking craft. Viking spied channels that could have been produced by a sudden rush of water, possibly from the melting of subsurface deposits of ice. Viking also discovered another water-derived feature, valley networks, that seems to have been sculpted by a steady source of running water, either rain or melting snow. These ancient, meandering scars occur mostly in the heavily cratered southern highlands, Mars' oldest terrain, which dates back 3.5 to 4.0 billion years ago.

Steadily running water would require a thick, carbon-dioxide-rich atmosphere to generate precipitation and keep the planet from freezing.

Scientists haven't figured out how Mars could retain such an atmosphere. Liquid water snares carbon dioxide, creating carbonic acid, which then reacts with surface rock to produce solid carbonates. This process depletes the atmosphere of carbon dioxide, and Mars would have rapidly become the frozen desert seen today.

On Earth, in contrast, carbon dioxide in the atmosphere doesn't disappear. Because of tectonic plate activity—the shift of the continental plates—some of Earth's surface continually sinks and is replaced by fresher material. In the process, carbonate-rich rock descends to great depths, where it decomposes to create carbon dioxide. Volcanic activity returns the carbon dioxide to the surface, replenishing the atmosphere, McKay notes.

Mars shows no evidence of ever having had tectonic plate activity. Although this may have limited the planet's ability to sustain life, it could have been a great advantage to life's evolution for the first billion years or so, McKay says. The reduced level of geologic activity may have allowed life on Mars to build up an oxygen-rich atmosphere quickly. By accumulating such an atmosphere, the Red Planet may early on have offered a haven to organisms, allowing life to gain a foothold.

Perhaps just as the Martian atmosphere eroded, a chance collision with an asteroid or comet propelled the living material to Earth.

Evidence of ancient life on Earth dates to 3.5 billion years ago, with some hint of biological activity about 300 million years earlier. McKay argues that the earliest terrestrial fossils represent bacteria that appear to be arranged in a community.

Indeed, notes McKay, the main reason that some scientists seriously consider an extraterrestrial origin for life is that relatively sophisticated organisms seem to have appeared on Earth just as soon as conditions became hospitable.

"Either life on Earth began whole, like the goddess Athena springing whole from the head of Zeus, or it began somewhere else," says McKay.

For now, such musings remain in the realm of speculation. Other scientists, including James F. Kasting of Pennsylvania State University in State College, argue that there's no reason to think Earth was any less hospitable than early Mars to the birth of life.

Kenneth H. Nealson of the University of Wisconsin-Milwaukee notes that biological activity may not have originated only on Mars, but it's the one place in the solar system—thanks to its stable, ancient surface—that may have preserved the very earliest records of such activity.

Whether or not the Red Planet serves as the solar system's earliest burial ground, the chunks that have fallen to Earth have become precious commodities. In August, scientists returned to the Antarctic ice fields, hoping to find more of these jewels from long ago. □