

Martians Invaded Earth 13 000 Years Ago—Maybe

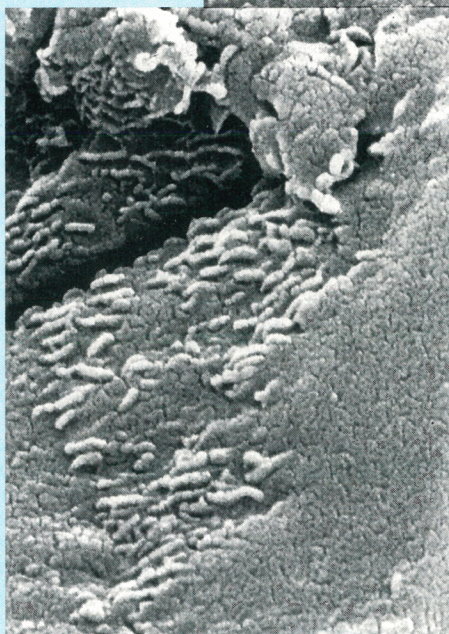
Okay, never mind that what may have been humankind's first encounter with extraterrestrial life¹ didn't have the drama of *The War of the Worlds*, *Independence Day* or even *My Favorite Martian*. Never mind that toy companies are now trying to figure out how to bid for the rights to and then market toys patterned after submicrometer-long extraterrestrial bacteria. What is important is for us to understand the chain of scientific reasoning that has led to the claim that the Allan Hills (ALH) 84001 meteorite may contain fossil evidence of life from Mars.

The least controversial link in the chain of evidence is the provenance of the 4.2-pound meteorite. Because of its composition, and especially because of the ratios of oxygen isotopes it contains, ALH 84001 is generally believed to have crystallized on Mars about 4.5 billion years ago. Subsequently, an impact riddled the rock with fractures, within which carbonate-rich fluids deposited nodules of carbonate minerals. Putative Martian microbes trapped within the nodules could have been preserved as microfossils. About sixteen million years ago, another impact launched the rock fragment on its celestial journey to Antarctica, where, after about 13 000 years, a National Science Foundation-sponsored collection team discovered it in 1984.

Controversy begins with the question of whether the carbonate was deposited at sufficiently low temperature² to preserve any Martian microbes present. Ralph Harvey (Case Western Reserve University) and Harry McSween (University of Tennessee at Knoxville) have suggested³ that the composition of the carbonate nodules and the absence of hydrous minerals within the nodules could be better explained if the nodules were deposited by carbonate-rich fluids heated to high temperatures by an impact. Such fluids would have destroyed any traces of Martian life. McSween, however, agrees that low-temperature deposition in conjunction with biological activity might explain not only the odd mix of carbonate species and associated minerals in the nodules, but also the etched surfaces within the nodules and the presence of many iron oxide and sulfide particles with compositions, sizes and forms reminiscent of particles produced by terrestrial microbes.

The mineralogical evidence for biological activity is more compelling when combined with the mass spectrum of polycyclic aromatic hydrocarbons (PAHs) associated with the nodules.

Such compounds can be produced by many processes, including—but not restricted to—the decay of the complex organic compounds associated with life. Simon Clemett, Xavier Chailier, Claude Maechling and Richard Zare, all of Stanford University, found that the PAHs in ALH 84001 are located



predominantly near the nodules, exhibit a mass spectrum consistent with the decay products of terrestrial biological compounds, show no evidence of resulting from sample contamination and seem to be of Martian origin.

Ironically, the most visually compelling evidence for Martian fossils—scanning electron micrographs of ovoid and segmented features (like those in the images above and at left) reminiscent of, but 100 times smaller than, terrestrial bacteria—may currently be the least scientifically convincing. At present, there is no information on the composition or internal structure of these features. According to William Schopf (University of California, Los Angeles), establishing the presence of cell membranes in several such features would strongly support the hypothesis that they are of biological origin. Transmission electron micrographs (TEMs) may provide such information some time next year. However, McSween cautions that, especially for features as small as these, the very

process of fossilization may have obliterated internal structure. Indeed, experience with terrestrial samples provides little guidance on what to expect from the TEMs because terrestrial samples are rarely subjected to such detailed scrutiny. "Meteorites reveal a lot of amazing phenomena in part because we examine them with expensive, high-tech machines," says McSween. "If we looked at terrestrial rocks in equal detail, we might find equally interesting features."

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References

1. D. S. McKay *et al.*, *Science* **273**, 924 (1996).
2. C. S. Romanek *et al.*, *Nature* **372**, 655 (1994).
3. R. P. Harvey, H. Y. McSween, *Nature* **382**, 49 (1996).

systematic effects in general than are absolute arrival times.

When the records from Antarctic seismographic stations of Soviet nuclear explosions proved suggestive

enough to warrant a more detailed study, the researchers expanded their study to look at seismic waves traversing three different paths through the inner core. They saw the following

results:

▷ Waves from earthquakes in the South Sandwich Islands (in the South Atlantic Ocean) arrived at College, Alaska (following a path making an