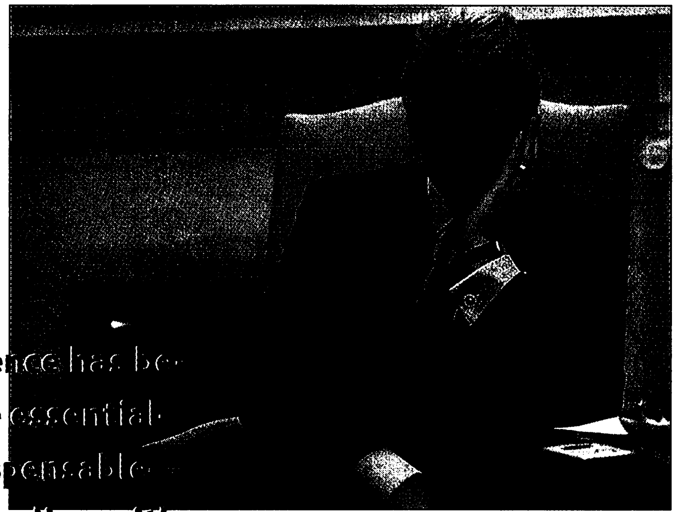
What do they do about genetically modified organisms? How do you balance political pressures with scientific reality? How do you define scientific reality? Does the European Union need the equivalent of the Food and Drug Administration?



**"Science has become essential indispensable to dealing with national security."**

*Science*: Let's pursue science literacy. I know you and Mrs. Clinton have been very interested in education. I don't know to what degree you're familiar with the state of science education and if you have some feelings about this. The latest report just came out about U.S. schoolchildren in math and science [*Science*, 8 December, p. 1866]. The 8th graders ranked in the middle of 38 countries in both subjects. So, I was wondering about your thoughts on the status of science education in particular.

**The President:** Well, I think there are basically two issues. One is, in a country as big and diverse as ours, how do you get more kids to take math and science courses at more advanced levels? And secondly, if you could do that, how would you have enough qualified teachers to do it?

I noticed that California passed a really sweeping initiative last year to try to give bonuses to people who will enroll as teachers. I think that, in the future, there will be more alternative certification mechanisms, and people will be paid more.

I also think that, at the advanced levels of science and math, a lot of high school systems are operating the way colleges do now—bringing people in to teach one course.

We are going to have a critical mass of people out there in America who know the things that all of our kids now need to know, but virtually 100% of them are making a lot more money than they can make teaching school.

A friend's daughter made $30 to $40 million in her late 20s or early 30s in a software enterprise. She's now just cashed out and spends all of her time teaching inner-city schools. But you're either going to have to find tons of people like that, or you're going to have to find ways to finance the education of young people to do this work for 4 or 5 years. Or you're going to have to have—in the junior and senior high schools—people who have this knowledge and yet who come in and teach a single course, just like someone who comes into a college classroom and teaches one course.

*Science*: In your speech last January at Caltech, you referred to releasing "your inner nerd." Do you think you'll do anything related to science after you leave office?

**The President:** Oh, I certainly hope so. I'm very interested in continuing to work in the climate-change area in particular, and doing what I can to convince the political systems of other countries that they have to participate in this and that there are economically beneficial ways to do the right thing for the global environment. And in order to do that, we have to continue basic research into alternative fuels and alternative technologies. There is no way to solve this over the long run unless we can get more growth out of fewer greenhouse gases.

The other thing that I'm particularly personally interested in is the breakdown of public health systems in so many countries, and how it disables them from dealing with things like the AIDS epidemic and other problems. So I expect those are two areas that I'll be involved in for a long time to come.

A fuller version of this interview is available online, at www.sciencemag.org/cgi/content/full/290/5500/2236.



MEETING GEOLOGICAL SOCIETY OF AMERICA

# Geologists Pursue Solar System's Oldest Relics

**RENO, NEVADA—Last month, the Geological Society of America held their annual meeting here. Offerings included claims for the oldest known examples in a class: the oldest scrap of ocean crust, the oldest sample of Earth, and the oldest trace of life—which happens to come from Mars.**

## Oldest Bit of Earth Hints at an Ocean

It's not much to look at, this quarter-of-a-millimeter speck of zirconium silicate. But according to extraordinarily sensitive microprobe analyses, it is the oldest bit of Earth known. The zircon's mere existence shows that the planet was separating out lighter continental crust at its surface 4.4 billion years ago, just 100 million years after Earth had formed—when it was barely a toddler, in human terms. More surprising, its isotopic composition implies that liquid water—perhaps an ocean of it—was around shortly after a planetary rime of rock had solidified and while huge rocks were pummeling Earth, regularly vaporizing both water and rock.

At the meeting, isotope geochemists William Peck, now at Colgate University, John Valley of the University of Wisconsin, Madison, and their colleagues presented their analyses of the new zircon they found among many younger ones in a sample from the Jack Hills of Western Australia. Others had discovered the previous record holder, a 4.2-billion-year-old zircon, in the same sample. "It's just a fantastic find," says geochemist Allan Treiman of the Lunar and Planetary Institute in Houston. "It pushes back the ages of continents and oceans on Earth. At least intermittently, Earth seems to have been a fairly familiar place that now and again gets hammered."

The find was made possible by the zircon's tenacity and by exquisite analytical sensitivity. Zircons form in abundance in silica-rich crustal rocks such as granite, and their durable structure lets them easily outlive granite's other minerals while preserving their original chemical and isotopic composition. The oldest granite known—much altered over the years—is just 4.0 billion years old. The zircons in the Jack Hills sample—a conglomeration of rocks baked and squeezed over the eons—actually eroded out of an older rock.

Peck and his colleagues dated the formation age of the zircon and that host rock by blasting out 20 cubic micrometers of zircon with the beam of an ion microprobe and measuring the isotopic composition of the zircon's lead, which had been produced by the steady decay of uranium. At 4.4 billion years, this zircon came just 100 million years after Earth reached its final size, likely as a planetwide "magma ocean." Even so, some solid rock must have formed and partially melted again. That second-generation magma then separated and solidified again to form granitic crust containing the zircon.

A second ion microprobe analysis turned up a surprising isotopic composition for the zircon's oxygen. It was distinctly richer in the heaviest stable isotope of oxygen, oxygen-18, than mantle rock was. The only way the magma that formed the zircon could have become so enriched, the group believes, was to first melt and incorporate rock that had interacted with water at low temperatures, such as soils, sediments, or ocean crusts. If the zircon had formed in magma that had interacted directly with water at high temperatures, the enriched signature of the water would not come through to be preserved.

The discovery of a "wet" 4.4-billion-year-old zircon has caught researchers' interest. "It's not a major surprise that there was continental crust around then," says geochemist Paul Mueller of the University of Florida, Gainesville. "It's more surprising [that] there may have been surface water." Apparently, there was enough time between the biggest impacts for Earth to cool and water to condense onto the surface. With water on the surface and continental rock all about, Treiman sees "no sign the tectonic processes then were any different [from] what's going on now." Perhaps an even older zircon will tell a different tale.

## Chinese Find Pushes Back Plate Tectonics

For 3 decades, geologists have been pushing the operation of plate tectonics farther and farther back into Earth's history. And the push continues.

At first, scientists proposed a few hundred million years ago as the earliest time when plates roamed, mid-ocean ridges churned out new crust, and old crust sank into the deep earth. But once they knew what to look for, they began finding older and older rocks that bear the marks of plate tectonics. Now, a new discovery, announced at the meeting, appears to push plate tectonics back another half-billion years or more to 2.7 billion years ago. That puts plate tectonics firmly in the Archean eon, when the planet had seemed to work differently than it does today.

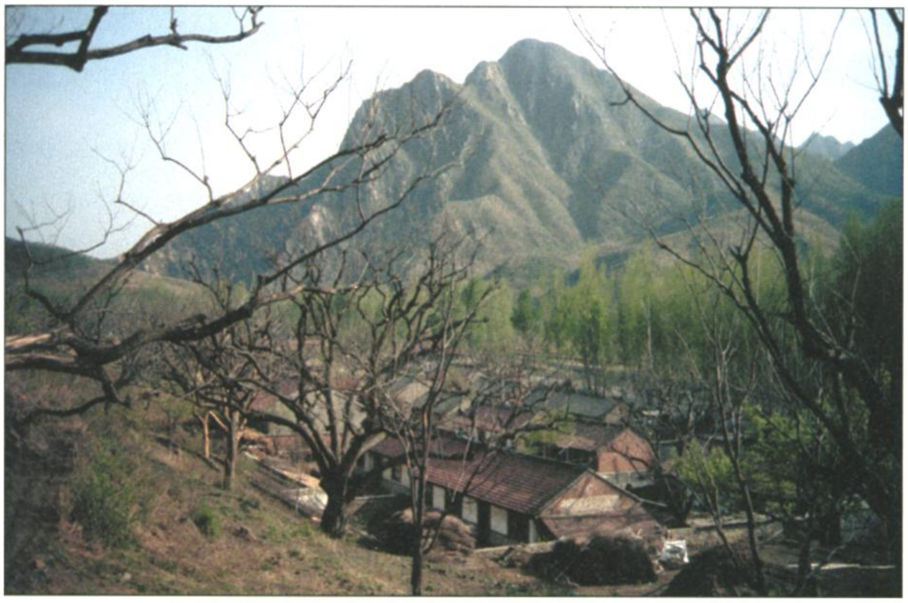
Reporting on last summer's fieldwork in the shadow of the Great Wall of China, geologists Timothy Kusky of St. Louis University in Missouri and Jiang-Hai Li of Peking University showed slides of a stretch of rock 20 kilometers long. They believe it's a scrap of the oldest known ocean crust bearing all the signs of generation at a mid-ocean ridge in the style of plate tectonics.

"The photos looked very impressive," says geologist Kevin Burke of the University of Houston. "It seems to be more grist for people who believe" some Archean rocks formed under plate tectonics. If the find is confirmed, researchers will have a window into just how plate tectonics, the ocean, and the mantle operated in Earth's younger, more energetic days.

Kusky and Li weren't looking for a further outpost for plate tectonics when they made their find. Kusky had come to Beijing for a series of invited lectures; afterward, Li took him on a tour of local geologic attractions. But at a stop on the third day, Kusky was astonished and delighted to see what appeared to be a hallmark of plate tectonics. Where their geologic map showed nondescript rock, he saw "sheeted dikes"—now-frozen, planar conduits that could have once fed magma from a chamber beneath a mid-ocean ridge to the sea floor.

On closer inspection, these dikes bore the distinctive signs of having risen, solidified, and been split apart by the next rising dike as the new crust spread to either side, just as it does today at midocean ridges. And above the sheeted dikes, they found ancient sea-floor sediments and "pillow lavas"—the distinctive billowy lavas that form only underwater. Below were the remains of a magma chamber, mantle rock, and a fault along which the whole assemblage could have been shoved up onto the continent.

That the whole sequence is an ophiolite—a complete section of ocean crust left perched on a continent by some ancient collision—"is pretty clear," says Kusky. "It has the whole stratigraphy." Radiometric dating places its formation—and presumably the operation of plate tectonics—at 2.7 billion years, 200 million years into the Archean.



**High and dry.** A scrap of 2.7-billion-year-old ocean crust—from sea-floor sediments to the remains of a mid-ocean ridge magma chamber—is exposed in the rugged terrain near the North China village of Dongwanzi.

CREDIT: T. KUSKY/ST. LOUIS UNIV.

Although they have nothing more than photographs to go on, geologists are receptive to Kusky's interpretation. "I'm intrigued by what he showed," says petrologist Robert Dymek of Washington University in St. Louis. "It's a good candidate" for an ophiolite. If it's upheld, the find would show that fewer than 2 billion years after Earth's formation, our planet—while still far hotter than now—was shedding its heat and shaping its surface the way it does today. Some geologists have argued that Earth's higher internal temperatures in the Archean would have favored some other means of carrying heat to the surface, such as a profusion of rising mantle plumes like the one thought to feed the volcanoes of Hawaii.

The Chinese cross section of ocean crust could also yield insights into Archean life that inhabited the ocean sediments, the ocean that deposited chemicals in the crust, and the mantle that sent gases into the Archean atmosphere. And Kusky is hopeful that this won't be the last ophiolite to push back the frontier of plate tectonics. This one is embedded in a zone of deformed rock called a greenstone belt that represents the bits and pieces caught between colliding plates. Similar greenstone belts, he notes, go back to 3.8 billion years ago, almost as far as the oldest rocks known.

## Tiny Magnets Point to Martian Life

The case for ancient life on Mars seemed only to weaken after the initial excitement 4 years ago over martian meteorite ALH84001. One by one, the proposed chemical and mineralogical signs of past life in the meteorite came to look unremarkable, like things that lifeless chemistry could just as well have made.

Now, the group that first startled the world with pictures of possible martian "worms" is playing what may be its last card. Nanometer-size bits of a magnetic mineral that riddle parts of the meteorite are indistinguishable from the tiny magnets made by some bacteria on Earth and unlike any such mineral known to form without life, the group reports. The putative "biomarker" is impressing researchers but not quite convincing them. Indeed, no evidence—short of a martian clamshell showing up—may ever be completely persuasive.

At the meeting and in a paper in the 1 December issue of *Geochimica et Cosmochimica Acta*, microscopist Kathie L. Thomas-Keprta of Lockheed Martin in Houston and eight colleagues (five of whom co-authored the original *Science* paper on ALH84001 with her) laid out their arguments for the meteorite's magnetic grains being shaped by biology, rather than just chemistry.

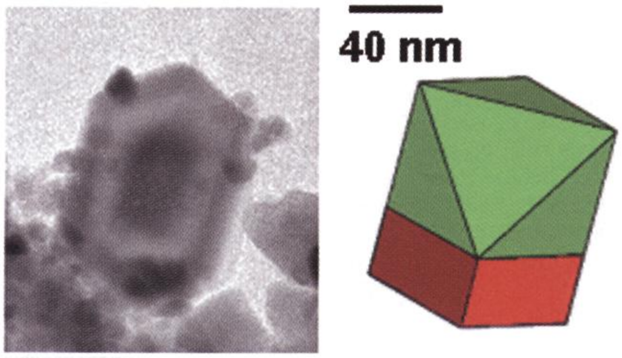
"They've done the job right," says Lindsay Keller of NASA's Johnson Space Center in Houston. "They've demonstrated that a fraction of the magnetite particles [in ALH84001] look exactly like the magnetite that certain strains of bacteria make. The next leap is the big one. If they'd come to this conclusion about magnetite from an Australian sediment, there'd be no controversy. Mars is where people can't make the leap."

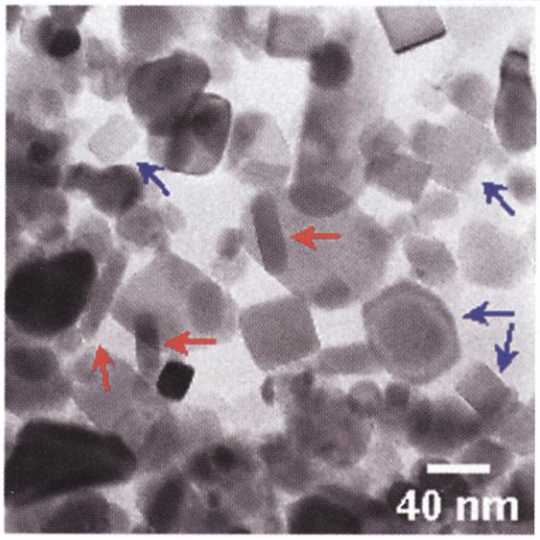
Thomas-Keprta and her co-authors are nudging their colleagues to take the plunge by documenting the similarity of some ALH84001 magnetite and the magnetite made by the MV-1 strain of marine bacteria. MV-1, like other such bacteria, extracts iron from its surroundings, synthesizes particles of iron oxide that act as tiny bar magnets, and strings the particles together to form one larger magnet. With it, MV-1 senses and orients itself along Earth's more or less vertical magnetic field lines that guide it into the low-oxygen bottom sediments that MV-1 prefers. In the case of MV-1, biological evolution seems to have honed its ability to align passively with the geomagnetic field, while expending the minimum amount of energy on creating magnets.

The magnetite in ALH84001, or at least a subset constituting about 27% of the total, appears to have been shaped by the same magnetically optimizing forces of biological evolution as MV-1 bacterial magnetite, argue Thomas-Keprta and her colleagues. Both sorts average about 40 nanometers in length; if they were much larger or smaller, they would maintain much weaker magnetic fields. Both are chemically pure, lacking significant chemical impurities (such as titanium and aluminum) that would reduce their magnetic strength; bacteria actively screen out such impurities. Both magnetites lack defects in their crystal structure that would weaken them magnetically. Both share an unusual crystal shape, termed hexa-octahedral, having 14 faces. And the hexa-octahedrons are elongated along the diagonal of their crystal structure, a shape that allows them to create the strongest field.

After an exhaustive search of the literature on magnetites formed in nature and in the laboratory, Thomas-Keprta could find nothing as similar to ALH84001 magnetite as that of the MV-1 bacteria. The hexa-octahedron magnetites of ALH84001 "are indistinguishable from biogenic magnetite particles produced by the strain of magnetotactic bacteria MV-1," the team writes, "suggesting similar mechanisms of formation."

Researchers who have read the *Geochimica* paper find it intriguing. "I have to admit these [ALH84001] particles look remarkably like particles produced by one particular species of bacteria on Earth," says magnetist Bruce Moskowitz of the University of Minnesota, Minneapolis. Moskowitz is particularly impressed with the exclusive crystal elongation on the diagonal, something purely chemical processes presumably wouldn't do, but "this is one of those extraordinary claims," he says. "I don't think the evidence is extraordinary yet."




**Bacterial body parts?** Among the assortment of magnetite grains in meteorite ALH84001, hexagonal prisms (blue arrows, left, and above) may have been made by bacteria.

Biophysicist Richard Frankel of California Polytechnic State University in San Luis Obispo agrees. The similarities are "remarkable," he says, but "before I say there were magnetotactic bacteria on Mars, I'm going to have to see a lot more evidence." Researchers are primarily concerned that some inorganic process—such as heat-induced decomposition of iron carbonates during one of the impacts suffered by ALH84001 on Mars—might have produced the magnetite.

Thomas-Keprta understands such responses. "I know it takes a bigger leap to make an interpretation," she says. "All we can do is interpret based on examples on Earth, [but] a biogenic explanation is a valid explanation." She recognizes that failing to disprove biogenicity of the ALH84001 magnetite is not the same as proving it. Still, she believes that research under way in other laboratories "will, in the long run, support this work." Attempts to synthesize hexa-octahedral magnetite by duplicating the geologic history of ALH84001 in the lab will fail, she predicts. That will have to suffice until that clamshell turns up.

–RICHARD A. KERR

CREDIT: THOMAS-KEPRTA *ET AL., GEOCHIMICA ET COSMOCHIMICA ACTA*