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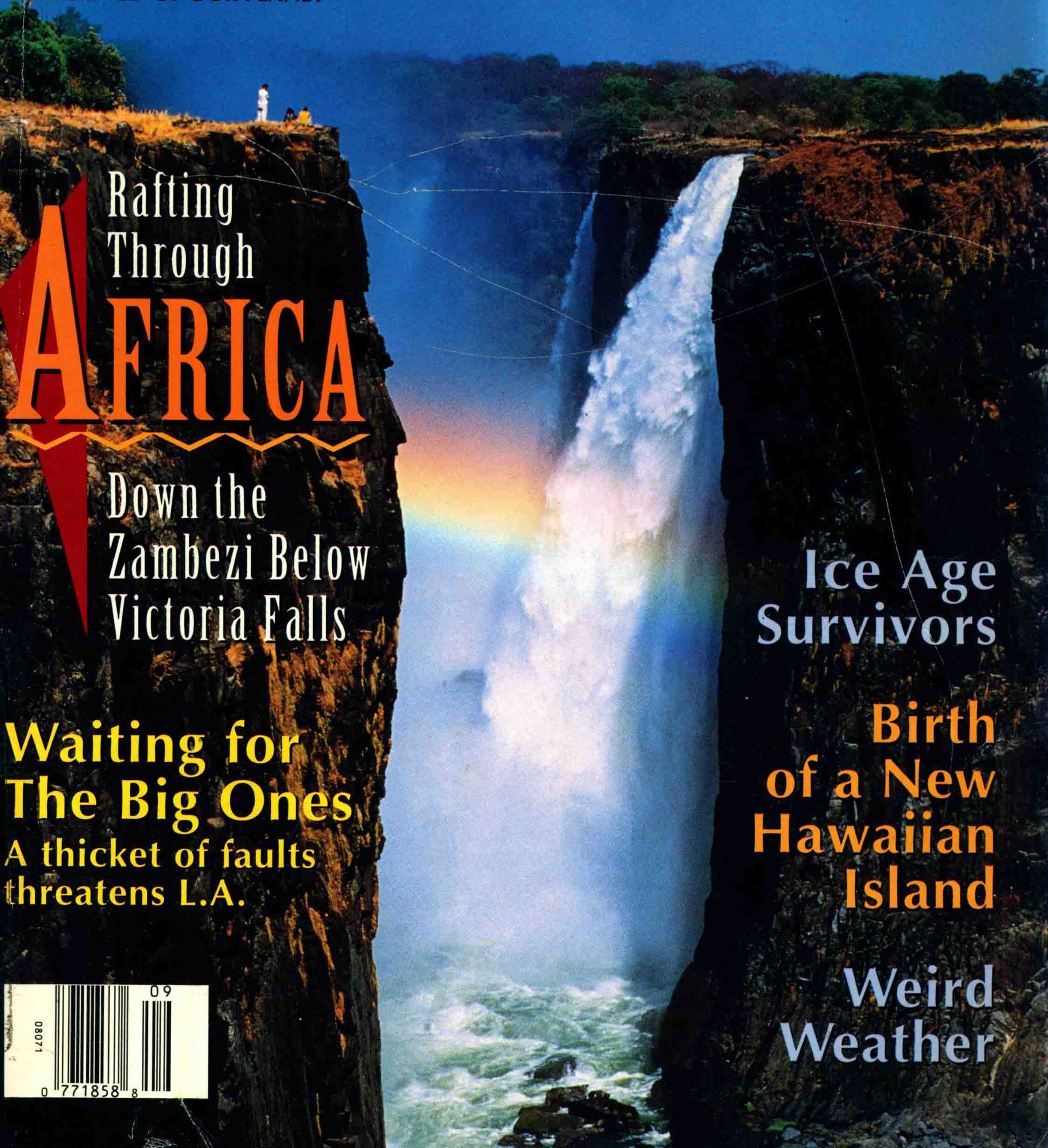

Rafting Through AFRICA

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Ice Age Survivors

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Rafting the wild rapids of the Zambezi River below Victoria Falls, p. 24

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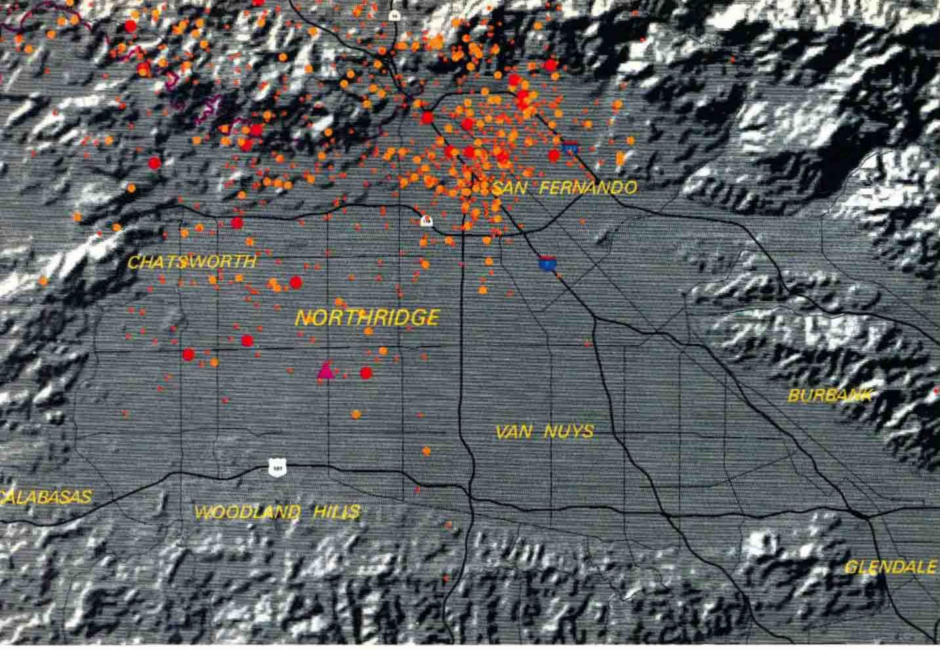

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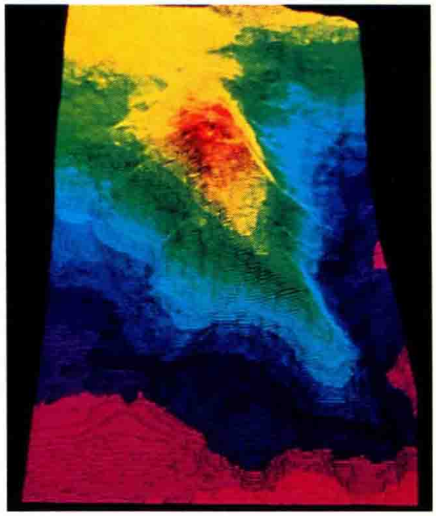
Aftershocks from last January's Northridge earthquake, p. 40



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Island on the rise: computer-generated view of Loihi, p. 56

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Courtesy NASA

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Exploring Loihi: The Next Hawaiian Island • 56

by Noreen Parks

Twenty-one miles off the Big Island, a young volcano is growing slowly upward — a Hawaiian island in the making. When it breaks the sea surface about 60,000 years from now, it may be simultaneously the youngest and the oldest land on Earth.

EARTH SHOTS

Hole-in-the-Rock Road • 78

by Djuna Bewley

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Endless Journey Travel Pack, Tagong Monastery, Tibet, Photo: Nancy Bushnell

Gerry Soifer is a veterinarian in Encinitas, California. *When he is not treating patients Gerry and his wife Nancy are visiting a remote monastery in Tibet, rafting the Zambezi River in Africa, or biking the backcountry in China. Gerry and Nancy's choice of travel gear is Eagle Creek.* ***Eagle Creek makes a complete range of travel gear for any type of travel;*** *from convertible travel packs to soft luggage and duffles, travel organizers, "Undercover" security items, as well as everyday briefcases and daypacks.*

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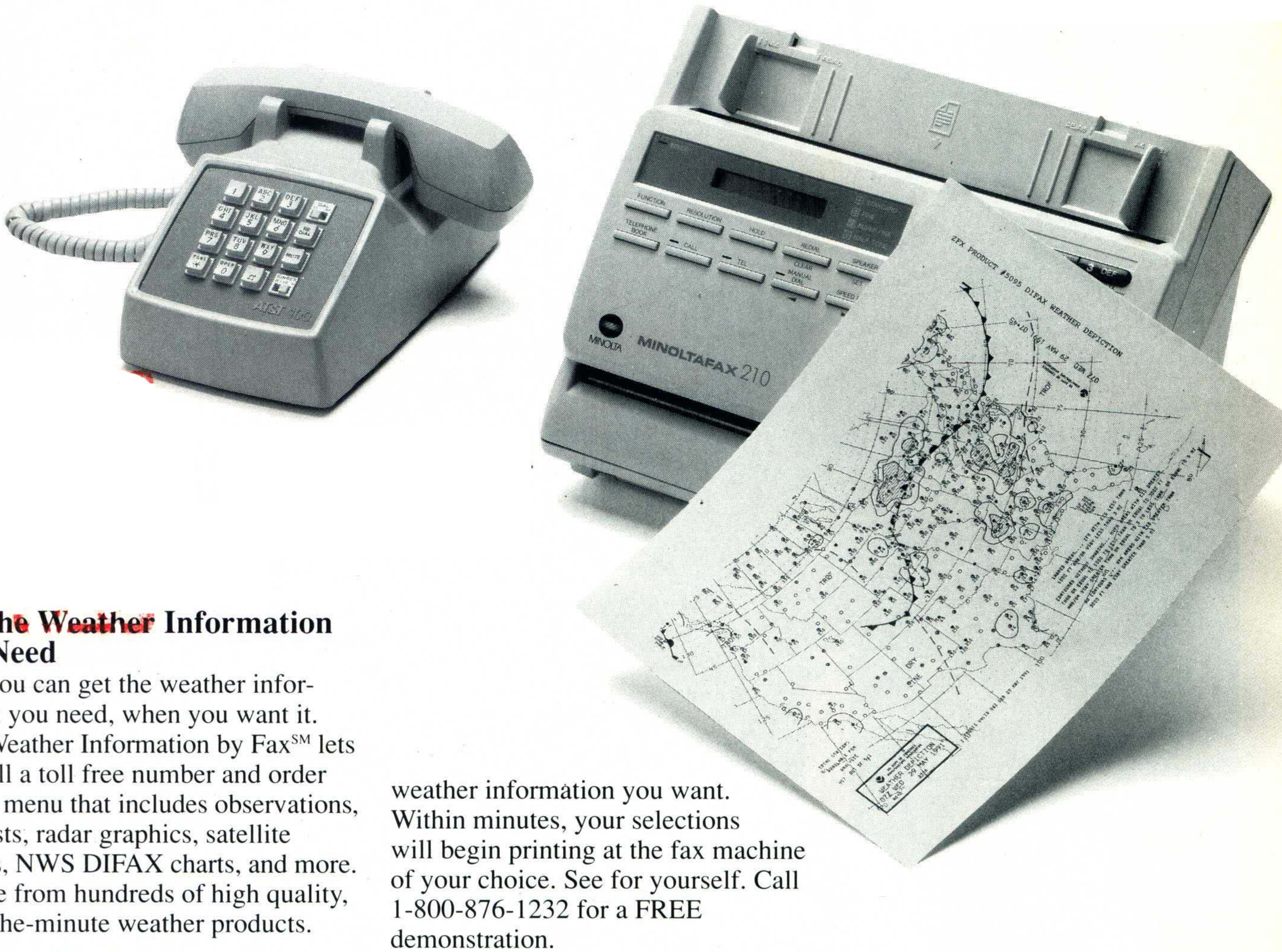
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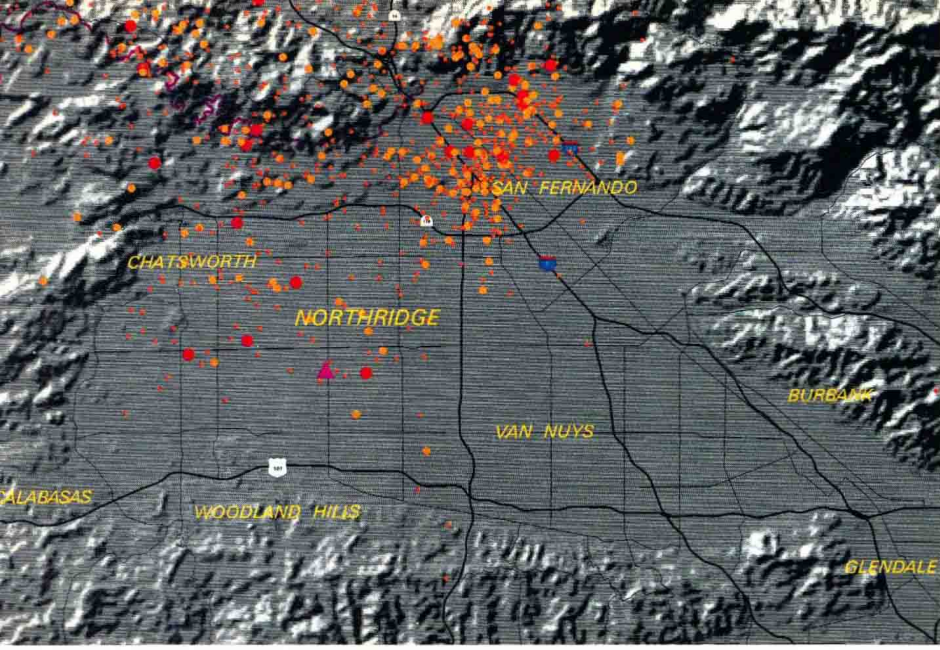
COVER: Victoria Falls, Zimbabwe. Ian Murphy/Tony Stone Worldwide.



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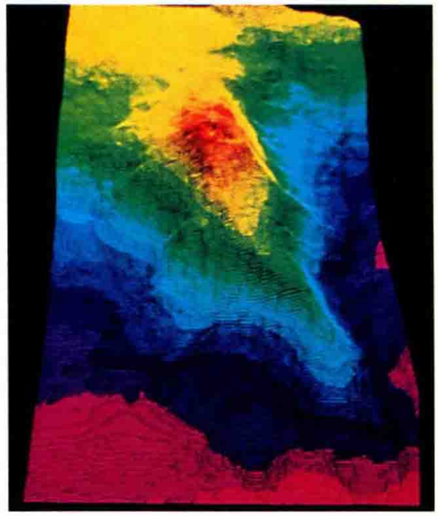

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L.A. Story

EARTH: Tom Yulsman

A building in Santa Monica shows evidence of violent shaking.

Santa Monica has a reputation as an urbane, environmentally friendly refuge within the Los Angeles suburbalopolis. When noxious smog is choking downtown L.A., for example, ocean breezes tend to clear the worst of the air pollution out of the mellow city by the sea.

But at 4:31 a.m. on January 17, Santa Monica was no refuge. At that moment, seismic waves from the magnitude 6.7 Northridge earthquake (see p. 40) were delivering hammer blows to the sleeping city. Considering that Santa Monica was 15 miles from the epicenter, seismologists were surprised at the extent of the damage there. All told, inspectors had to "red-tag" at least 140 buildings, declaring them unsafe for occupancy.

On a foggy morning walk through town in April, I saw three large apartment buildings with substantial chunks missing and many more that were boarded up, cordoned off or draped in so much scaffolding I couldn't tell exactly what had happened to them. But what really got to me was the more subtle but equally telling damage I saw in low-rise apartment buildings that had escaped the red tag. Everywhere I looked I saw cracked walls, bulging facades and other evidence of violent shaking. Much of this damage had occurred to stucco, wood-frame houses built atop slender pipes (to leave space for first floor garages). This kind of building, called a *dingbat*, is so common in Los Angeles that it's as much an emblem of the city as those ridiculous mansions cantilevered out from crumbling hillsides. Now, I guess, the jagged crack will join faux Spanish detailing as a characteristic element of the dingbat style.

Four days later, I attended a special session of the Seismological Society of America conference in Pasadena. It was convened so experts could discuss the damage that might ensue from a magnitude 7.0 quake under downtown Los Angeles — a plausible temblor three times more energetic than the Northridge quake. The bottom line: possible collapse of office towers, damage to local water lines requiring weeks to repair, more than $250 million worth of damage to the electrical power system, such severe strain on firefighting resources that "we're not going to be able to save buildings," said Robert Canfield, L.A.'s emergency management director. (He advised residents to learn to do their own firefighting.) Mind you, all this was from a quake 30 times less energetic than the magnitude 8.0 Big One expected within the next 30 years. By the end of the session, I shuddered to think what the next big quake might do to the residents of all those pre-damaged dingbats.

But I should have known that the one piece of good news to come out of the conference would involve the freeways. If a big quake occurs after 1995, when retrofitting of freeway bridges will be complete, "most of the damage will be [limited to] buckling of roadway approaches and settling," said James Brooks, chief engineer for the California Department of Transportation. "Repairs will take just a few hours or days."

Buildings will lie in ruin. Electricity and water will be cut off. But the freeways will stand triumphant. That's the L.A. story.

Tom Yulsman
Editor

Earth

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MAIL

Measuring Mt. McKinley

I want to thank you for publishing an excellent article on my mountain photography in your May issue. Rob French accurately untangled many facets of my life. I'm delighted that you selected three of my favorite pictures in your layout: Ansel Adams' beloved thunderstorm, "After the Storm on the Doldenhorn," and that dramatic and lucky closeup of the Aiguille de la République.

But with keen regret I must protest the thrust of the last two paragraphs. Those paragraphs say that I was unhappy about anyone's tampering with "my" altitude of Mt. McKinley, dating back about 40 years and calculated long before the use of lasers and Global Positioning Satellites. They also stated that I was sure of my original work and that it "perfectly matched" the new satellite data. Nothing could be further from the truth.

I was approached in 1989 by five young surveyors who were eager to calculate a new altitude for Mt. McKinley. They asked if I'd object to what they were doing. And they wanted to ask a few questions about how we nailed down the then new 1953-54 altitude. I replied that I was thrilled with what they planned to do, that it was clear that the GPS approach was sure to result in something new (higher or lower?) and that I'd gladly give them all of our raw field figures and tell them exactly what we'd done 40 years ago. The essence of science is change, and here was a wonderful example of just that. I also warned them that the U.S. Coast and Geodetic Survey (now the U.S. National Geodetic Survey) would want to review all of their field data before a newer latitude, longitude and altitude of Mt. McKinley could be officially announced.

In June 1989 the surveyors backpacked heavy GPS equipment to the top of 20,320-foot Mt. McKinley and operated it there at the same time that a number of similar receivers were operating at stations in the lowlands near the peak. The results were considered insufficient by Geodetic Survey scientists because they felt that several more lowland stations should be occupied and that gravity observations should be made at all of them.

The surveyors decided to oblige in June 1991 and invited my wife Barbara and me to join them. We coordinated our vacations and spent a wonderful week of work and camaraderie. I helped locate all of our old survey stations as well as the 1952-53 Geodetic Survey stations. I re-observed McKinley at all of my old stations with my trusty Wild T-3 theodolite, and the surveyors did GPS and gravity work.

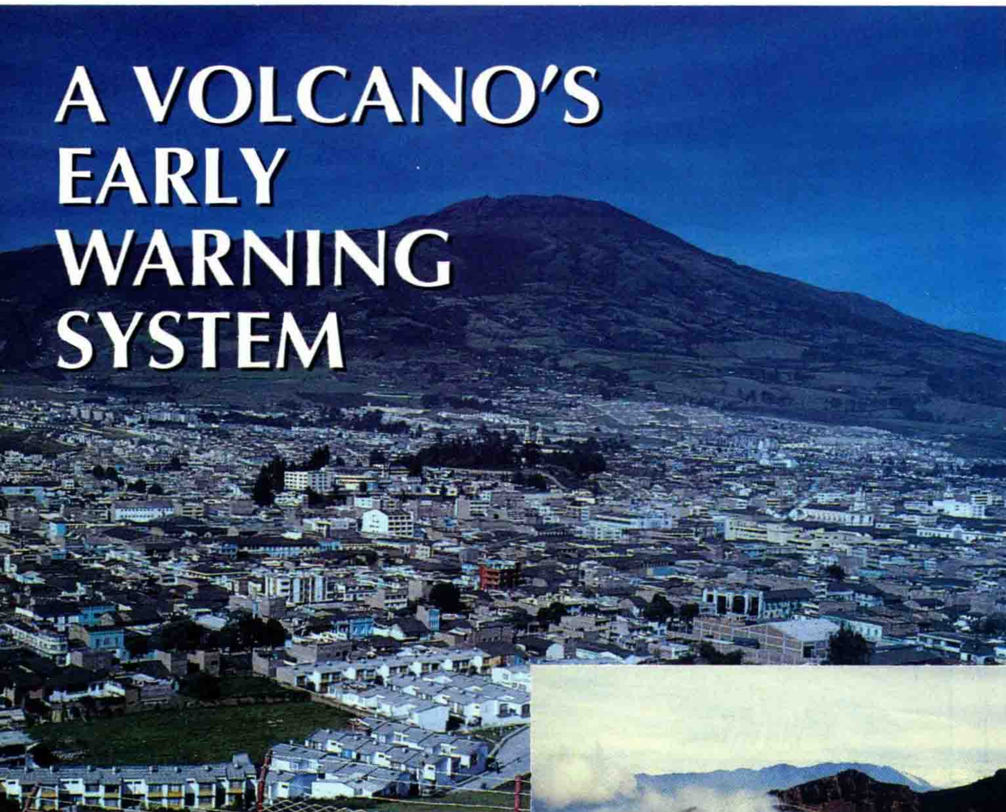
Once more the Geodetic Survey scientists rejected the data. They wanted still more gravity and GPS data. So here we are today, together, all still searching for new and convincing facts about North America's highest peak. "My" altitude will soon be set aside as obsolete. Its replacement will be the product of several years' worth of tenacity by these five competent and patient surveyors, delightful friends who clearly have not erred at all! I simply can't wait to learn the final results of their labors! — *Bradford Washburn, Boston Museum of Science, Boston, Massachusetts*

Yucca Mountain message

Dan Grossman and Seth Shulman did an adequate job of summarizing the Department of Energy's efforts to find a compelling reason not to bury nuclear wastes within Yucca Mountain (March 1994). Given the politics of what is at stake, no one should be surprised that the "problem" is relegated to one of earth science, engineering, and lots of litigation before the site is filled up. This is all stuff we feel pretty confident about in 1994. Yet I still haven't seen or heard of any DOE plan to assure that our descendents in 4020 or 8088 will know unambiguously what we buried in Yucca Mountain at the end of the second millenium. Can anyone design a messaging system that will be both resilient and intelligible, no matter what, 10,000 years into the future? — *Buzz Sellman, Dexter, Michigan* ⊕

Address your correspondence to Earth MAIL, P.O. Box 1612, Waukesha, WI 53187. Please include your full name, address and phone number. Letters may be edited for length and clarity.

A VOLCANO'S EARLY WARNING SYSTEM



Photos by Stanley Williams

The city of Pasto, Colombia, has a troublesome neighbor: the active volcano Galeras, which killed nine people in 1993. New research may point to a technique for forecasting Galeras' occasional explosive outbursts.

When Colombia's Galeras Volcano exploded on January 14, 1993, six volcanologists and three tourists lost their lives in a hail of ash, poisonous gases and glowing blocks of lava. Such surprise attacks have killed field volcanologists before and are considered a largely unavoidable occupational hazard.

Now, volcanologist Tobias Fischer of Arizona State University in Tempe has discovered a pre-eruption pattern of gas output and seismic rumbling at the very same volcano — a pattern that may someday help scientists to determine when explosive eruptions are imminent.

Fischer first noticed the pattern in the spring of 1993, as he scrutinized records of a March 23, 1993 eruption of Galeras, a larger (though nonfatal) outburst than the January incident. The pattern consisted of three distinct phases of activity. In the first phase, the amount of sulfur dioxide gas emanating from Galeras' crater rose gradually. At this time, low-frequency seismic rumbles originating from deep within Galeras' plumbing system were minimal. In the second phase, SO_2 decreased as the frequency, strength and duration of the rumbles increased. Finally, SO_2 flow reached a low point and the strength and duration of the low-frequency rumbling began to fall. Then Galeras erupted. Fischer and his U.S. and South American colleagues reported their findings in a recent issue of the journal *Nature*.

The researchers have also devised a possible explanation of what was going on in the volcano's guts. The low-frequency seismic waves, they say, are caused when steam, SO_2 and other gases rising from the volcano's magma reservoir break through obstructions in channels within the volcano. During phase one, these channels are mostly open, gas flows freely and low-frequency rumbling is minimal. But as rising gas and magma begin to seal off the channels, more and more pressure is required to break through obstructions, and the seismic events grow larger and longer. This explains why, during phase two, gas output falls as seismic activity ramps up.

In phase three, Fischer explains, gas begins to collect in quantity, just below the surface crater. As a result, the pressure difference between this higher region and the deeper system of magma-filled channels decreases. Then, when a pocket of gas breaks through an obstruction, the drop in pressure is smaller and the resulting seismic wave is shorter and weaker.

Finally, enough pressure builds up so that the plug of magma and debris in the crater can no longer hold it back, and the volcano releases its pent-up fury in a short, explosive eruption. This is what they suggest happened on January 14 and March 23.

Can this pattern be used to predict when a volcano is getting ready to blow? Not quite yet, says Fischer. "First we have to look at other volcanoes and see if we can observe something similar," he says. "This may turn out to be unique to Galeras." Or maybe not: A similar pattern has been observed at other volcanoes, including Karkar in New Guinea and Pinatubo in the Philippines.

"The thing behind this research is to understand volcanoes," Fischer says, "but it would be nice to find a way to forecast eruptions a bit better than we can now." — *Daniel Pendick*

The Crystal at the Center of the Earth

About 3,200 miles beneath your feet is a mass of solid metal 800 miles in diameter that some scientists believe is very much like a single, inclined crystal of iron.

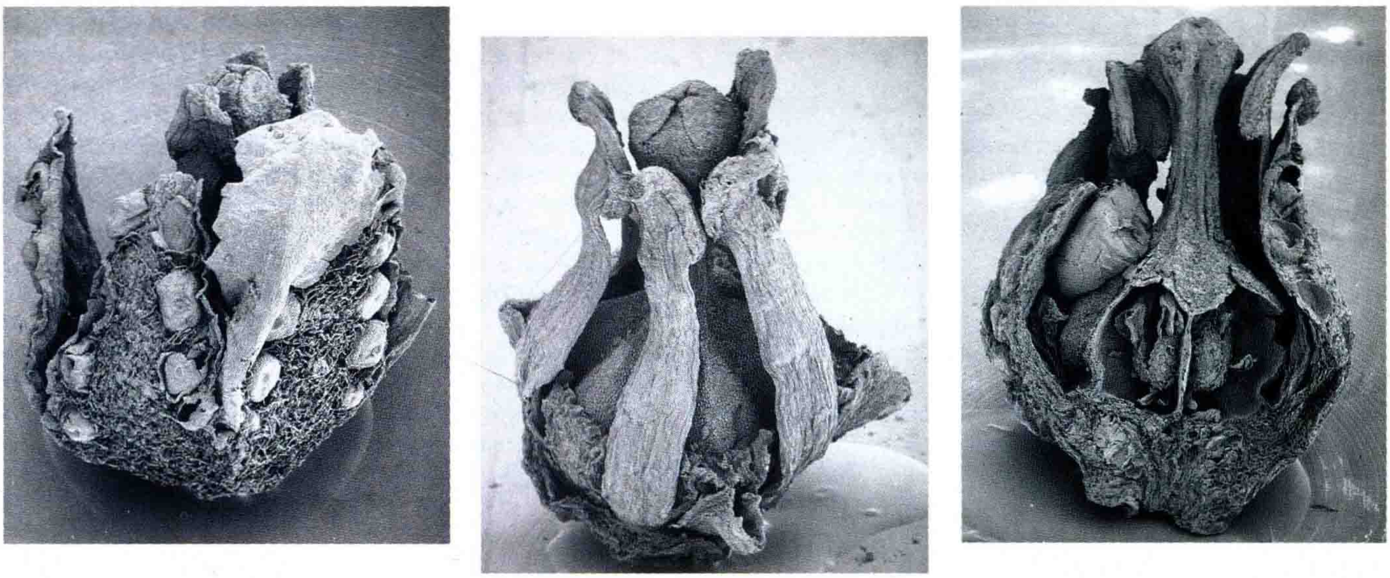
The idea that a gigantic iron "crystal" comprises the planet's inner core was first proposed in 1986 by two Harvard scientists who had analyzed the speed of earthquake shock waves passing through the center of the Earth. Now a second team of Harvard scientists has analyzed shock waves from 15,722 earthquakes to obtain the first clear three-dimensional details of the inner core's crystallographic properties.

Geophysicists Adam Dziewonski and Wei-Jia Su found that seismic waves passing through the inner core in a pole-to-pole direction traveled faster than those passing through parallel to the equator. The same property, called *anisotropy*, affects *light* waves travelling through many crystals. Waves passing through such crystals in one direction (parallel to the crystal's axis of symmetry) move faster than those passing through in other directions. The precise pattern of anisotropy the Harvard scientists found matched that of *epsilon iron*, a form of iron whose crystals grow in hexagonal columns. Epsilon iron is not naturally found up here on Earth's surface because it will grow only under enormous pressure.

These findings corroborate what previous researchers have found. But for the first time, Dziewonski and Su have also calculated the orientation of the inner core's axis of symmetry. Like Earth's magnetic field, it appears to be tilted 12.5 degrees away from the planet's axis of rotation, the researchers announced at a recent meeting of the Seismological Society of America. According to Dziewonski, this suggests that the magnetic field may have played a key role in orienting the axis as the core grew.

Dziewonski sketches out this speculative picture of the evolution of the inner core:

About 1.5 billion years ago, Earth lacked a solid core. In its place was an ocean of molten metal. As the heat left over from Earth's birth slowly dissipated, iron crystals began "freezing out" of the metallic ocean. These were no ordinary crystals. Under the unimaginable pressure of 3 million kilograms per square centimeter that exists 3,200 miles (5,100 km) down, hexagonal columns of epsilon iron began crystallizing with axes of symmetry aligned with Earth's magnetic field. Over the eons, countless crystals of epsilon iron have grown together into the inner core — a solid mass with some of the properties of a single crystal. New epsilon iron crystals are constantly growing around this mass in a "mushy zone" separating the inner and outer cores. In other words, the crystal at the center of the Earth is growing even as you read these words. — *Tom Yulsman*



Courtesy William Crepet and Kevin Nixon

These three fossil flowers grew on a plant related to the blueberry 90 million years ago on North America's Atlantic coastal plain. Their morphology suggests that they were pollinated by insects, possibly bees, according to paleobotanists William Crepet and Kevin Nixon of Cornell University in Ithaca, New York. The fossil on the left has well-preserved petals and hairy sepals. The sepals have glands embedded around their edges. Crepet and Nixon removed the sepals and petals from the flower in the center, the better to reveal the blade-shaped stamens (male parts) and the jug-shaped pistil (female part). They also cut the fossil on the right to reveal the the ovules (unfertilized seeds) within the pistil. In doing so, they found a bonus: a structure that appears to be the cocoon of an unknown insect.

Coral Reefs: Why So Rich?

Fred Bavendam/Allstock

Coral reefs are famous for the abundance and richness of their life, yet they are able to live in a nutrient-poor environment. New research may answer why.

Scientists call it the paradox of the coral reef: Reefs support a wide spectrum and huge abundance of life, yet they lie in the warm but nutrient-poor tropical oceans. How do these underwater rain forests maintain their high levels of biological activity in the middle of what is essentially a marine desert?

For about a decade, ecologists have suspected that reefs make the most of scarce supplies of dissolved nutrients and gases through an efficient program of biological recycling. But two California researchers are questioning this explanation. Robert Carpenter of California State University in Northridge and Susan Williams of San Diego State University suspect that the feeding habits of the long-spined black sea urchin may have a greater effect on reef production than nutrient recycling.

According to preliminary research on a Caribbean reef at St. Croix in the U.S. Virgin Islands, intensive feeding on Caribbean reef algae by the urchins seems to increase the speed of water flowing over the reef surface. This may in turn increase the flow of nutrients to the algae, maintaining their rapid growth rates. "It's speculative at this point," says Carpenter. "What we're doing is proposing some other avenues that need to be explored."

The primary producers of the reef are not the corals themselves but colonies of photosynthesizing algae known as *turfs*. "The real powerhouse of organic production is the inconspicuous scuz living on the dead coral substratum," Williams says.

The heavily grazed algal communities are typically a few millimeters thick, but still manage to generate as much organic matter per unit area as a cornfield. This producer base supports the corals, fish and other animals higher in the reef food chain.

The urchins keep the algal turfs trimmed to a height of one to four millimeters. Measurements and laboratory experiments suggest that such closely mowed turfs speed the flow of water over the reef. With faster water, more dissolved gases and nutrients reach the algae, maintaining their high rates of photosynthesis and nitrogen fixation. So the underlying mechanism of reef production may be physical (water flow) rather than biological (recycling).

That could have some important implications for understanding reef ecosystems. Physical processes external to the reef — wind, wave and ocean currents — may directly affect the rate of biological production of coral reefs after all. And this, Williams says, may mean the reefs are more vulnerable to global climate changes than the traditional recycling explanation would suggest. — *Daniel Pendick*

WHAT BIODIVERSITY IS GOOD FOR

Conservationists have long argued that biological diversity helps keeps ecosystems stable and healthy. Now, for the first time, they have convincing evidence to prove it.

The evidence comes from the Minnesota prairie, or more precisely, from a 12-year study of 207 prairie plots. In 1982, David Tilman and his colleagues at the University of Minnesota began fertilizing some of the plots with nitrogen — a procedure that increases overall plant growth but decreases the number of species. The result was an array of ecosystems that varied widely in their diversity, some containing only one type of grass, others as many as 26 different species of grass and broadleaf plants.

At first the researchers didn't know whether the study would teach them anything about how biodiversity affects the health of ecosystems. To address that issue, they'd need some help from nature — a drought or outbreak of pests, for instance, that would destabilize the ecosystems. If biodiversity were all it was cracked up to be, species-rich plots would survive and recover better than species-poor plots.

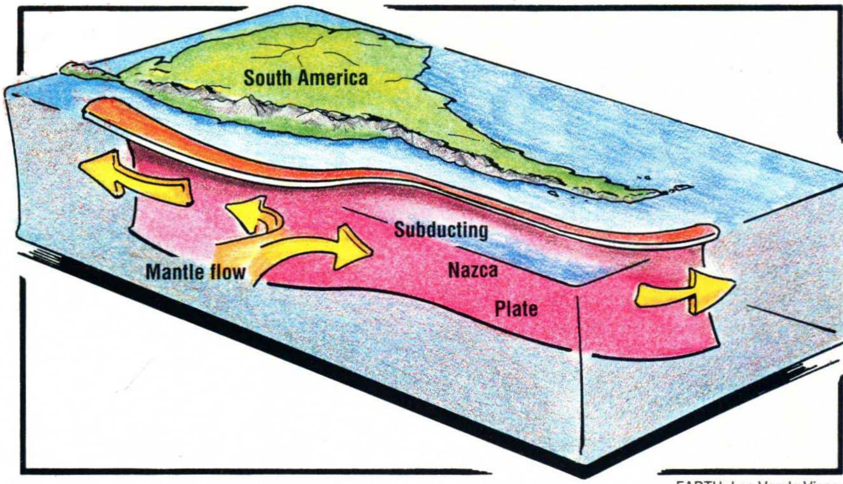
In 1987-88, nature obliged with the state's worst drought in 50 years. For the next several years, Tilman and his team measured how the drought affected the plots — how much plant cover they lost and how long it took them to regain it. The results, recently published in *Nature*, were unequivocal: The fewer species a plot contained, the more cover it lost and the more slowly it recovered. In the least diverse ecosystems, productivity plummeted with each additional species removed. "I was amazed at how clear and strong the effect was," Tilman says.

Tilman's co-author, John Downing of the University of Montreal, explains the effects of biodiversity as nature's hedge against disaster: Diverse ecosystems are more likely to contain at least a few species evolved to cope with any particular calamity. "Canada is hockey country, so I like to use the analogy of a hockey team," he says. "You can send out a team that's missing some players. But each player has a different ability of some kind. Each may save the game under certain conditions."

Strong as the overall results of the study were, they did leave some intriguing questions unanswered. For example, the researchers noticed that the benefits of biodiversity seemed to taper off in the most diverse plots. In these plots, the more species an ecosystem contained, the less benefit each additional species offered. Does this mean that the benefits of diversity eventually taper off completely? No one knows for sure.

Nor do scientists know whether biodiversity has the same stabilizing effect on other ecosystems as it did on the Minnesota prairie. As Downing says, "The same concept should work in other ecosystems, but we need to do strong science that allows us to say it with impunity." — *Ruth Flanagan*

Against the Grain



EARTH: Lee Vande Visse

The plunging Nazca Plate appears to deflect the flow of mantle off South America's west coast, defying the conventional wisdom on subducting plates.

Earth's tectonic plates are like rafts floating on a highly viscous pond. In the pond — the mantle, that is — currents churn not only across the surface but up and down as well. And when the pondwater churns downward, it sometimes drags a raft down with it. In other words, the plate subducts into the mantle.

That is the conventional picture of the relation between plate tectonics and mantle flow. But a recent analysis of mantle flow along the South American coast tells a different story.

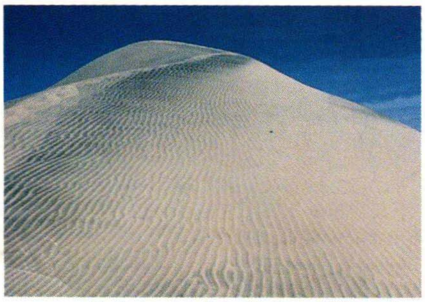
Raymond Russo and other geologists at the Carnegie Institute in Washington, D.C., measured the movement of mantle where the Nazca Plate slips under South America's west coast. They did this by taking advantage of the interaction between seismic waves from earthquakes and the crystal structure of the mineral olivine, which makes up most of the upper layer of the mantle.

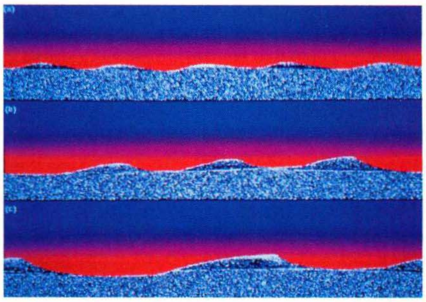
Under the pressure of the Earth's interior, olivine forms a clothlike matrix of long, unbroken crystal chains that line up with the direction of the mantle's flow. When a seismic wave of one type (known as a shear wave) passes through the olivine matrix, it splits into two waves, one slow and one fast. By comparing the waves, the scientists are able to determine the orientation of the olivine chains and thus chart the motion of the mantle.

When Russo and his colleagues analyzed waves from 350 earthquakes that occurred between 1982 and 1993 — using seismometers at 19 sites scattered through Africa, North America and South America — they found that the mantle didn't follow the same path as the rock slab. As the plate moves into the trench that borders South America and then under the continent itself, Russo says, the mantle seems "to be flowing around South America as opposed to straight down under it."

It's almost as though the slab is acting like a paddle in water, Russo says, pushing water (or mantle) back and to the sides. If that is really what is happening, he says, it contradicts the usual thought that the mantle's convective flow is the engine that powers the motion of continental plates. This seemingly unusual flow pattern may explain a number of geologic oddities in the area, including eastward motion of the Caribbean Sea plates and the high elevation and unusual topography of the central Andes.

Whether mantle flows like this near other subducting slabs, however, is unclear. But preliminary data do seem to contradict rather than support the traditional model. "It looks like the situation in the Western Pacific is even more complicated than what's going on under South America," Russo says. — *Scott Fields*





Photos courtesy Robert Anderson/UC Santa Cruz

Wind-formed ripples are a familiar feature of sand dunes (left), but researchers have only recently produced the first convincing ones in computer simulations (right). Previous digital ripples had two problems: They were too symmetrical and they did not show the real-world pattern of coarse sand grains on the tops of ripples and fine ones in the troughs between them. Geologist Robert Anderson and mathematician Kirby Bunas of the University of California at Santa Cruz overcame those problems with a program that made simulated sand grains of two sizes bounce off each other as they blew in a simulated wind. Small ripples appeared after 5 million collisions and began marching from left to right across the screen. After 10 million collisions, the ripples were larger, but it took 20 million collisions to produce asymmetric, properly sorted ripples.