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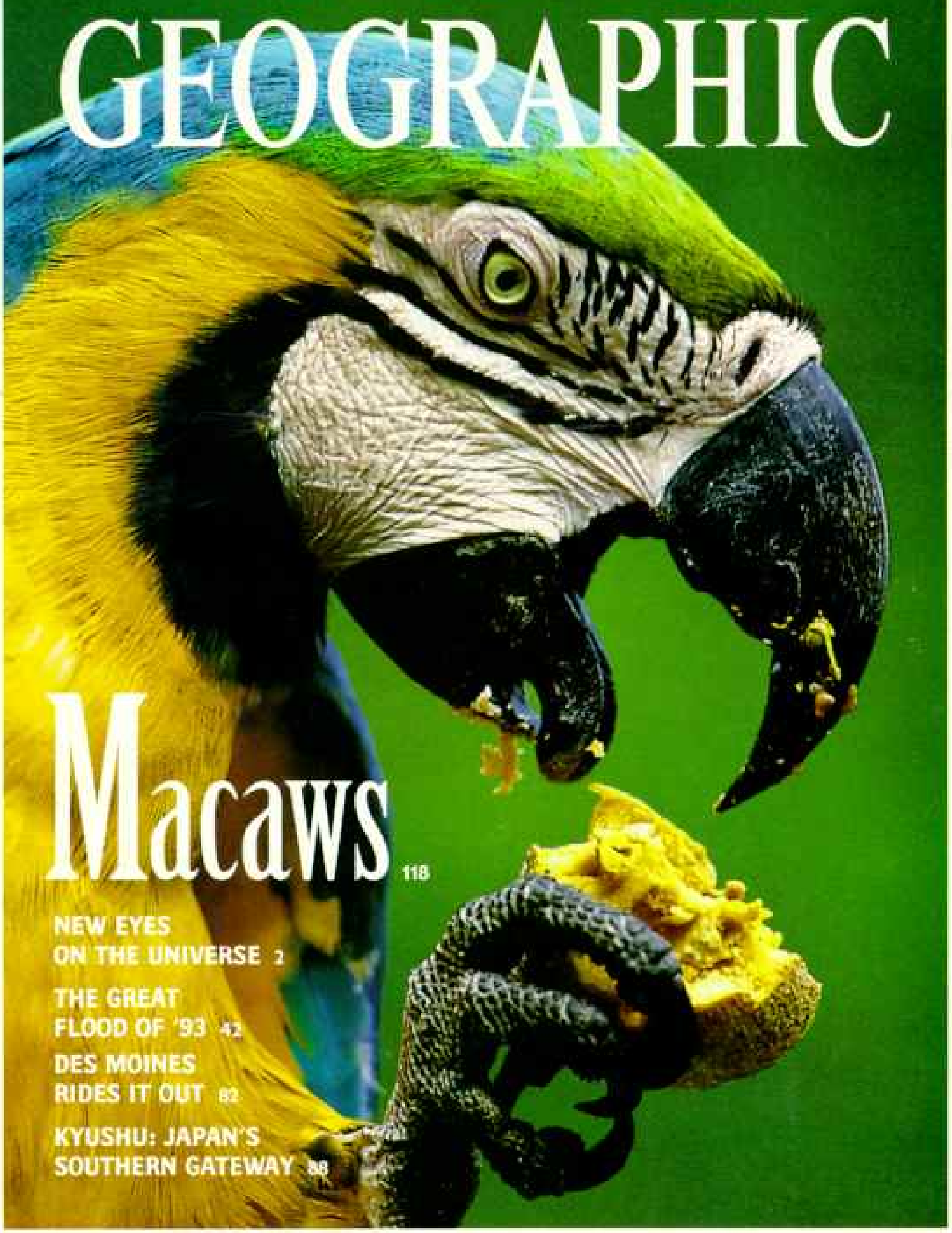

Macaws 118

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NATIONAL GEOGRAPHIC

JANUARY 1994

COVER: With perhaps the strongest bite of any bird, a blue-and-yellow macaw in the Peruvian Amazon tears away fruit pulp to crack and eat the seed. Photograph by Frans Lanting.

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New eyes on the

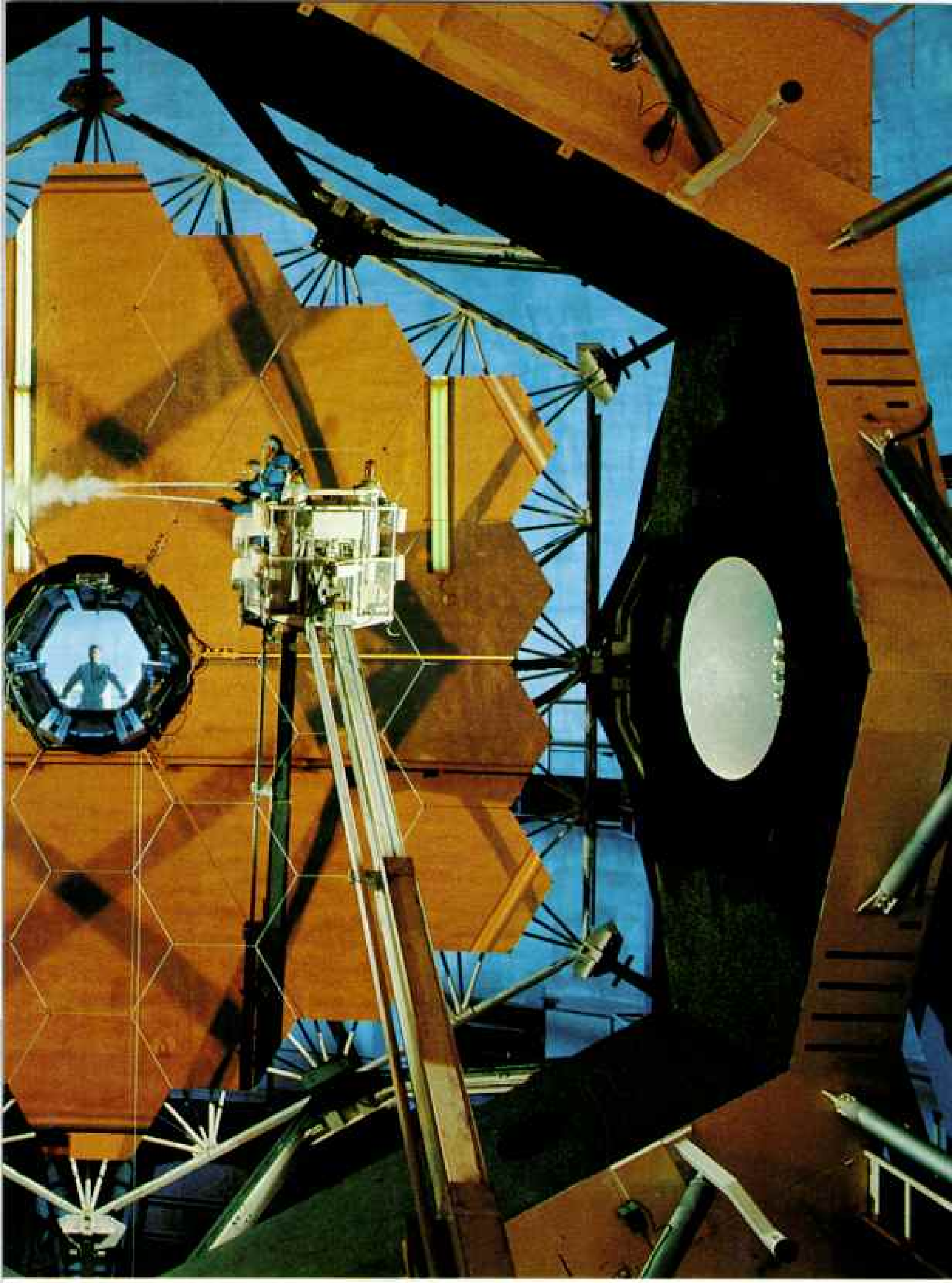
UNIVERSE

Vast and ancient on a nearly incomprehensible scale, the cosmos is having its measure taken as humankind probes its most remote reaches. At the Starfire Optical Range in New Mexico, a green copper-vapor laser and an orange sodium-wavelength laser are aimed skyward through telescopes. The beams are reflected by gases at specific layers of the atmosphere—creating artificial stars. Using points of laser light to measure the distorting atmospheric effects that cause real stars to twinkle, computers can adjust telescope optics to form images of unprecedented clarity. Such technological advances enable new and newly upgraded ground-based telescopes to strip away many of the limitations imposed by earth's atmosphere.

By BRADFORD A. SMITH

Photographs by
ROGER H. RESSMEYER

MIRROR ON THE SKY, Hawaii's Keck Telescope gets a cleaning with carbon dioxide snow from facility manager Ron Laub. The ten-meter-wide mirror surface—the world's largest—is made up of 36 hexagonal segments, individually aimed by computer. Here it reflects an orange-lit inner wall of its dome. The center opening holds observing instruments.



ILLUMINATED BY A SHOCK WAVE from an exploded star, a gas cloud glows as it is compressed and heated. The wave, racing at about a hundred miles a second from the lower right, reveals oxygen (blue), sulfur (red), and hydrogen (green) in the cloud. The halos around several of the stars result from the imaging process.

J. J. HESTER, ARIZONA STATE UNIVERSITY, AND NASA

THE UNIVERSE

IN THE FADING TWILIGHT on the summit of Mauna Kea, I can just make out the stark volcanic landscape surrounding me. A thin crescent moon hangs over the distant horizon, and the silhouettes of half a dozen telescopes rise from the mountain like temples to the night sky. Nearly 14,000 feet below are the warm beaches of Hawaii's Big Island. Up here, however, the temperature hovers near freezing, and the air is so thin that just breathing can be difficult. Before me looms a new white dome, softly glowing.

As an astronomer, I have come to Mauna Kea often. Over the past several years anticipation has heightened around this great dome. It houses the world's largest optical telescope, an instrument of bold design, which tonight is in the midst of its inaugural scientific run. Named the Keck Telescope for the late California philanthropist who made its construction possible, this telescope collects and focuses starlight from throughout the universe with a primary mirror of glass that measures ten meters, or nearly 400 inches, across. (Astronomers today use metric measurements.) The Keck mirror diameter is twice that of the Hale Telescope on Palomar Mountain in southern California—for decades the world's premier optical telescope.

The hundred-million-dollar Keck is part of a revolution in ground-based astronomy. It opens an era of giant telescopes. So many are under construction or planned that by the year 2000 the famous Palomar instrument may be only the world's 15th largest. With far greater surface areas, the huge mirrors will collect much more starlight. But the older telescopes will hardly be out of business. New detectors and new optics have upgraded their vision dramatically. So even before the Keck, we have been observing strange new sights.

Recently, for instance, we have caught distant galaxies of stars in the act of cannibalizing one another, and we have seen that our own galaxy, the Milky Way, may be doing the same thing—consuming its nearest neighbors.

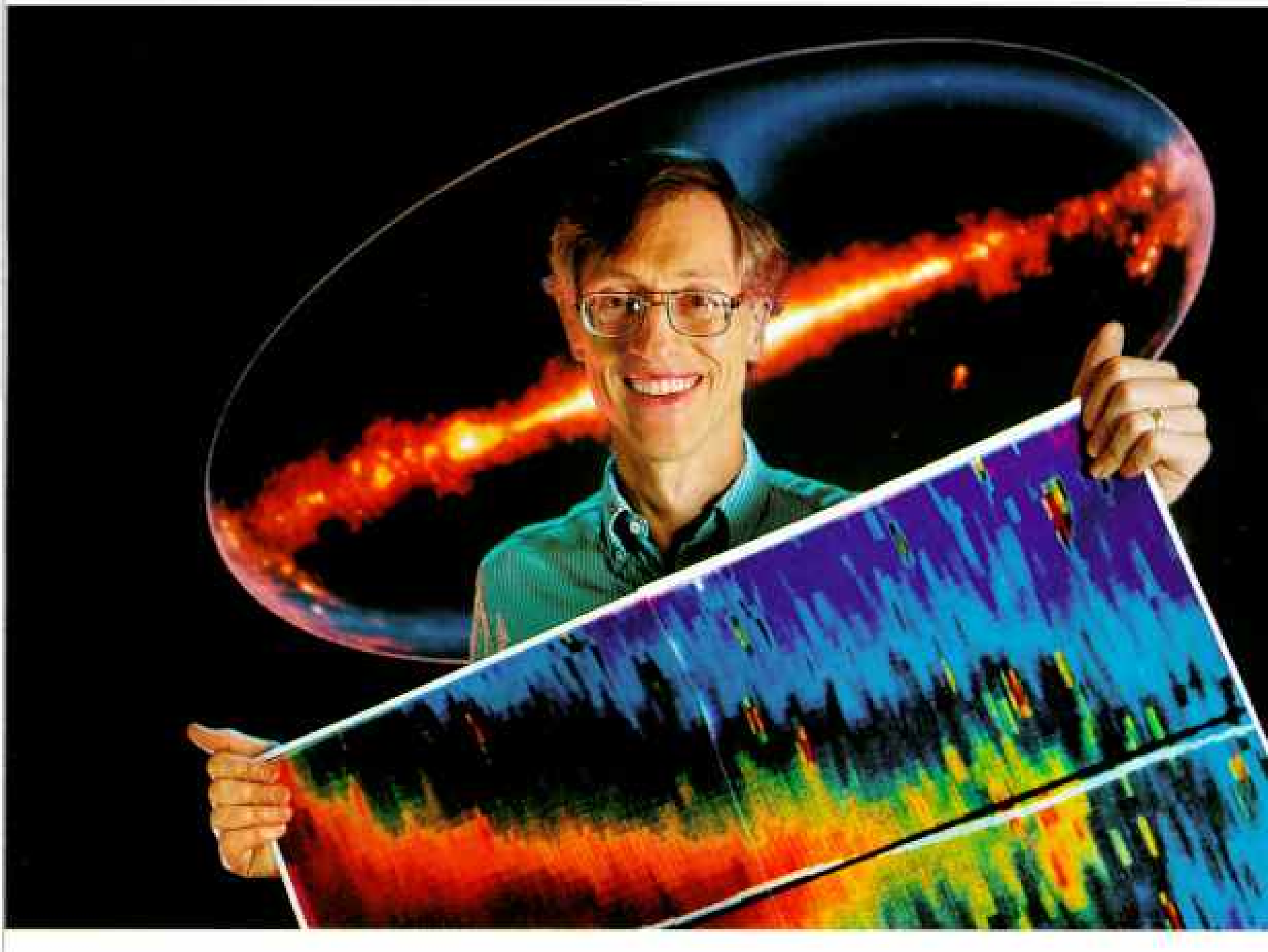
We have begun to look through the obscuring clouds of gas and dust that veil the center of the Milky Way and found evidence that a massive black hole lies swirling at its heart.

We have found immense voids—regions billions of trillions of miles across, from which no light seems to shine and in which no matter seems to exist.

We have determined that our part of the universe is irresistibly sweeping toward some mysterious gravitational source whose location remains unknown.

We have measured from space the afterglow of the big bang, the theorized explosive event that most astronomers believe created the universe. We have found an unevenness in that glow that may help explain how the universe initially clumped into clusters of galaxies.

But perhaps the most tantalizing insight is something we cannot see—the so-called dark matter. Increasingly, observations suggest that galaxies are immersed in huge halos of unseen material. We have no idea what this dark matter is, but theoretically it pervades our every breath, making up perhaps 99



SEEING THE INVISIBLE, the infrared- and microwave-detecting Cosmic Background Explorer (COBE) measures distant temperatures. COBE chief scientist John Mather holds a false-color image of the Milky Way's hot center; behind is the entire galaxy, with the dust in our solar system's plane in blue.

percent of the mass of the universe. Thus, everything we *can* see may be only the froth, the wispy one percent of the real universe.

Still, as the stars come out on top of Mauna Kea this night, the immensity of all that is visible astounds me. High in the south is Sirius, brightest star in the sky and a mere 8.6 light-years, or about 50 trillion miles, away. All those other visible stars also reside here in the Milky Way. They are old friends, really, no farther than a few thousand light-years away.

Until the 1920s we thought our own galaxy was the entire universe. We gradually learned that our Milky Way, with its hundreds of billions of stars, is only one of the larger of a few dozen galaxies known as the Local Group. From Mauna Kea I can see one of the other large galaxies in our group—the Andromeda galaxy, a softly glowing patch 2.5 million light-years away. Its light left when the first humans were roaming the Serengeti Plain.

Beyond our Local Group, and invisible to the naked eye, lies a much greater assembly of galaxies called the Virgo cluster. Centered about 50 million light-years away, it encompasses about 2,500 galaxies.

Much farther still, at the very edges of the universe, burn the quasars. Those torches, which we believe are the disturbed cores of galaxies, can shine with thousands of times the light of a normal galaxy. Born in the early years of the universe, their light is just now reaching us. They may represent a stage young galaxies go through. Since they formed, they have been racing away from us at up to 94 percent of the speed of light.

We do not know how far away the quasars are. Their distances depend on how long they

RECIPE FOR REFLECTION: A 6.5-meter telescope mirror begins as chunks of glass in a mold, which will be spun and heated to 1180°C at Arizona's Steward Mirror Lab. After 80 days' cooling, the mirror is inspected by lab manager Steve Hinman (opposite). Honeycombing the interior reduces weight.

have been speeding away. That, in turn, depends on how old the universe is. Estimates of its age range between 8 and 20 billion years, but most astronomers believe it all began about 15 billion years ago. If so, some quasars, the most distant objects we have yet found, are about 14 billion light-years away.

So many stars. And yet we have learned also that the universe is mostly emptiness. Cold, sometimes flickering with explosive energy, this universe taunts us with mysteries. When did it begin? How will it end? What laws of nature governed its creation and evolution? Are there other universes? If so, are they like ours? Time and again since humans first acquired a sense of wonder, we have asked such questions. And because we think we might be able to understand the answers, that this universe might make sense, we are building ever more magnificent instruments to probe its secrets. As I walk into the dome of the Keck, I see my colleagues about to bring some of those secrets into focus.

"We'll be looking at the faintest and most distant objects in the universe tonight," says Jerry Nelson, an astronomer from the University of California at Berkeley. Nelson conceived the idea for Keck. More than anyone, he was the one who lobbied to get it built. "It's 15 years I've been working on this, so to finally see science coming out of it is pretty exciting."

The control room is pulsing with low-level tension. Like any new instrument, the Keck Telescope has minor technical bugs to work out. Nelson is here to oversee the debugging.

"A decade ago many astronomers had great hopes for observations from space," he says.

Indeed NASA planned a series of great orbiting observatories, including the Hubble Space Telescope. High above earth's atmosphere, which blocks or distorts radiation from space, those observatories promised to capture rich details impossible from earth.

However, the space shuttle *Challenger* disaster and budgetary problems delayed many orbiting observatories. Then, when launched, the space telescope turned out to have a distorted mirror. Even so it has sent back exciting images and other data, but it awaits corrective optics, scheduled to be installed in December 1993 by space shuttle astronauts.

Meanwhile, back on earth, telescope technology was taking off.

"We once thought," says Nelson, "that it was not feasible to build a mirror much bigger than the one on Palomar Mountain. Building a ten-meter instrument of that design would have cost a billion dollars. The mirror would have weighed more than a hundred tons—too heavy to maintain desired optical precision. And the dome would have been too big and expensive. But we've solved those problems—thanks to *(Continued on page 24)*

An astronomer now with the University of Hawaii's Institute for Astronomy, BRADFORD A. SMITH was the imaging team leader for the Voyager spacecraft. His retrospective, "Voyage of the Century," appeared in the August 1990 issue. ROGER H. RESSMEYER, an amateur astronomer since childhood, has photographed six NATIONAL GEOGRAPHIC articles, including "Volcanoes: Crucibles of Creation," in the December 1992 issue.

A short history of the universe

Once upon a timeless, most cosmologists believe, all that is our universe was incredibly small and dense. Neither space nor time as we know them existed.

Nothing is known of this earliest instant. Scientists use the term big bang (1) to describe this moment of creation. Somehow the universe—all matter, energy, space, and time—exploded from the original singularity.

Because time did not yet exist, there is no way to measure this event, but scientists have agreed to start the universal clock at Planck time (2)—a moment defined as 10^{-43} second, which is a decimal point followed by 42 zeroes and a 1. Named for the father of quantum physics, Planck time is the point at which the universe begins to differentiate. Gravity (3) becomes a separate force, tearing away from the other still unified basic forces of nature.

(4) Separation of the strong force (10^{-36} second). Although atoms do not yet exist, the force that will hold their nuclei together becomes an individual entity.

(5) Inflation (10^{-36} to 10^{-33} second). Triggered by separation of the strong force, the universe expands more in this instant than it has in the roughly 15 billion years since.

(6) Quarks and antiquarks (10^{-32} to 10^{-5} second). As inflation ends, the still expanding universe now teems with quarks and antiquarks—the smallest known constituents of matter—along with electrons (L in the illustration) and exotic particles (W and Z). Quarks and antiquarks annihilate each other upon contact. But a surplus of quarks—one per billion pairs—survives. This surplus of quarks will ultimately combine to form matter.

At 10^{-12} second the final two forces split off. Electromagnetism (7)—the attraction of negatively and positively charged particles—is carried by photons, the basic units of electromagnetic energy. The weak force (8) controls certain forms of radioactive decay.

(9) Quark confinement (10^{-5} second). As the universe cools to one trillion K, trios of quarks form protons and neutrons.

(10) Nucleosynthesis (less than one second to three minutes). Cooling continues. Protons and neutrons bind to form the nuclei of soon-to-be-formed atoms.

(11) Energy domination (10^{-32} second to 3,000 years). Because of high temperatures, radiant energy generates most of the gravity in the universe during this period.

(12) Matter domination (3,000 years onward). With cooling, matter becomes the primary source of gravity. Matter begins to clump and form structures. In theory, particles of so-called dark matter (depicted as gray bubbles) would have come into existence by this time. They may account for as much as 99 percent of all matter.

(13) Decoupling (300,000 years). Continued expansion and cooling allow matter and electromagnetic energy to go their separate ways. Nuclei capture electrons to form complete atoms of hydrogen, helium, and lithium. The universe becomes transparent: Radiant energy, or photons, travels freely.

These photons now exist throughout the universe as microwave radiation. They reveal ripple-like concentrations of primordial matter—seeds for the structure of the universe that arose during the era of inflation. The ripples are shown in a 1992 COBE satellite image (14).

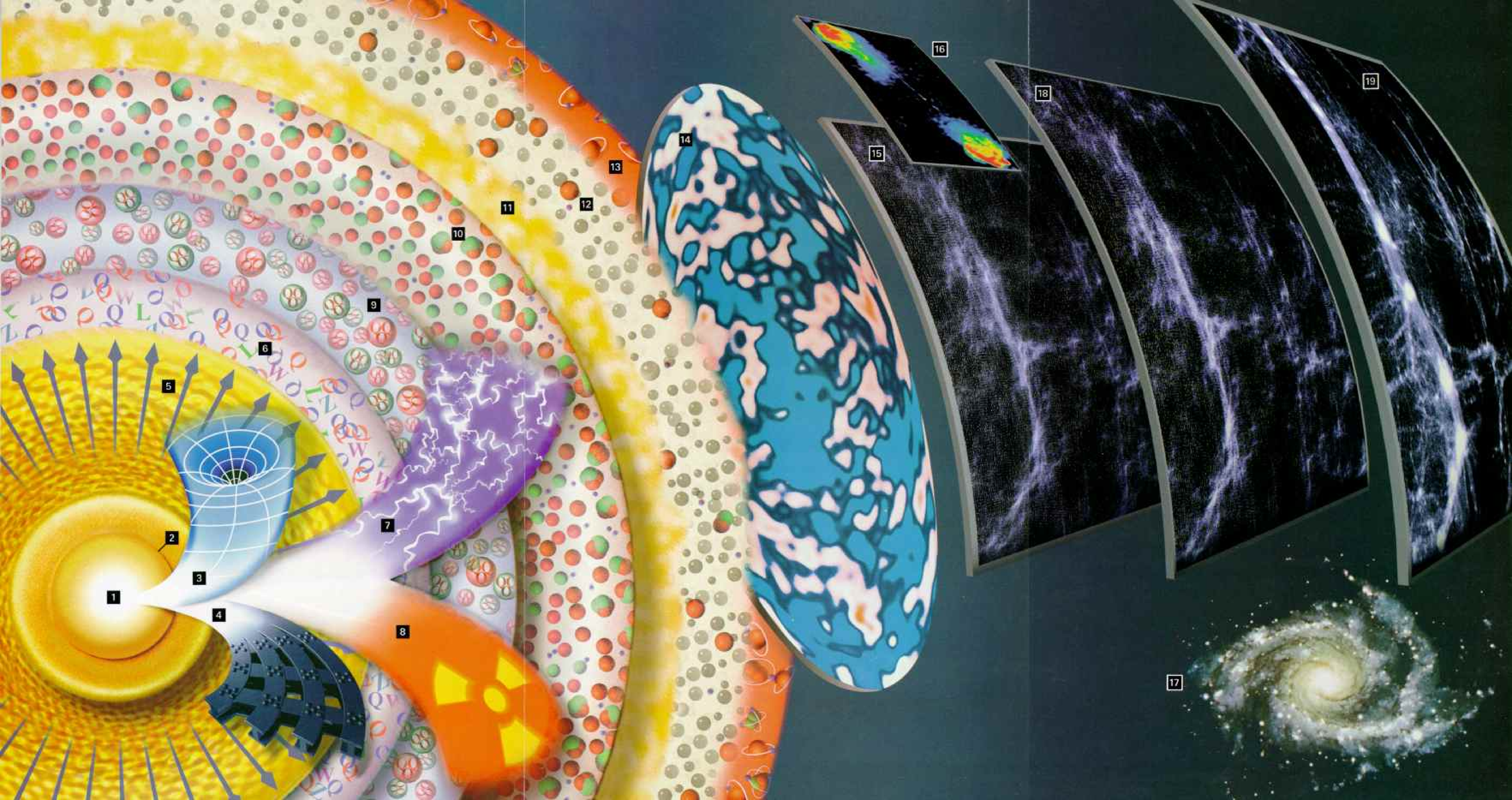
(15) Galaxy formation (200 million years onward). Matter continues to clump in the areas of concentration and over eons is condensed by gravity. This gives rise to quasars (16, pictured in a radio image emitting bursts of energy) and galaxies (17).

(18-19) Continued expansion of the universe. Galaxies cluster in an overall structure of sheets separated by huge voids containing relatively few galaxies.

BIG BANG'S ECHO—a hiss of cosmic radiation everywhere in the sky—was detected by chance in 1964 by Bell Laboratories scientists Arno Penzias, left, and Robert Wilson. The Nobel Prize-winning discovery was made on an ear-shaped satellite antenna.

Illustration text by
WILLIAM R. NEWCOTT
NATIONAL GEOGRAPHIC EDITORIAL STAFF

ILLUSTRATION BY CHUCK CARTER; MICROWAVE IMAGE, NASA/COBE SCIENCE TEAM/DIFFERENTIAL MICROWAVE RADIOMETER; QUASAR IMAGE, NATIONAL RADIO ASTRONOMY OBSERVATORY; COMPUTER SIMULATIONS OF UNIVERSE EXPANSION, ANATOLY KLYPIN, JON A. HOLTZMAN, JOEL R. PRIMACK, ENIKŐ REGŐS, MICHAEL GROSS; GALAXY IMAGE, DAVID MALIN, ANGLO-AUSTRALIAN OBSERVATORY; CONSULTANTS, MICHAEL S. TURNER, UNIVERSITY OF CHICAGO, AND SANDRA M. FABER, UNIVERSITY OF CALIFORNIA, SANTA CRUZ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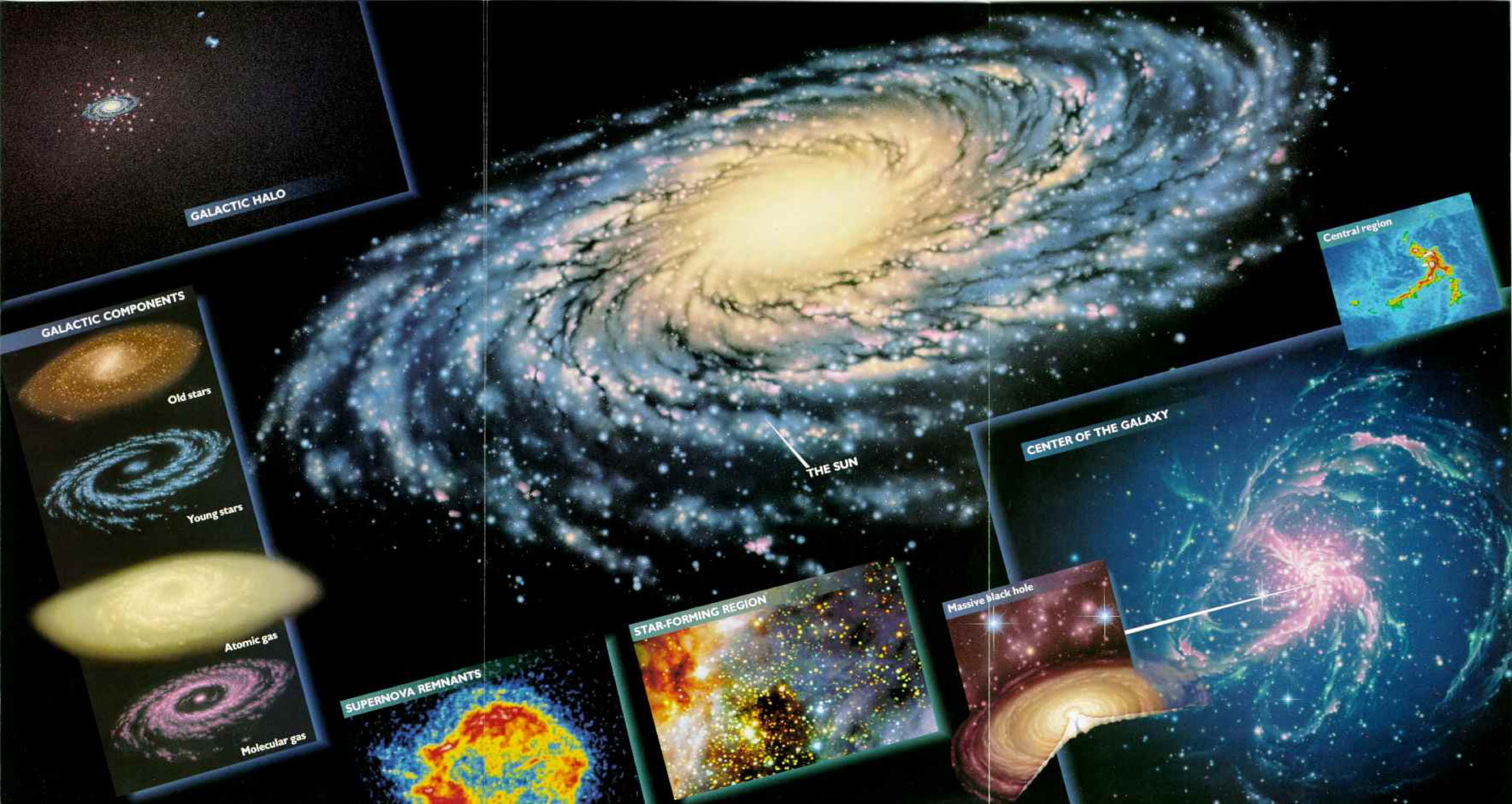

GALACTIC HALO
GALACTIC COMPONENTS
Old stars
Young stars
Atomic gas
Molecular gas
THE SUN
Central region
CENTER OF THE GALAXY
Massive black hole
STAR-FORMING REGION
SUPERNOVA REMNANTS

Guide to the Milky Way

Several hundred billion spinning stars revolve around the center of the Milky Way galaxy. Midway out its arms, stars—including our sun—move at about 500,000 miles per hour, taking 250 million years to make a single circuit.

The large image at left is our most familiar conception of the Milky Way: a Fourth of July pinwheel seemingly frozen in place, flinging a scattering of spark-like stars. Ours is a spiral galaxy, a common type.

To truly see the entire galaxy, a much wider view is required (far left, upper). Surrounding the familiar disk is a galactic halo, which contains isolated stars and about a hundred star groupings called globular clusters. The halo measures at least 300,000 light-years across and probably also includes unseen dark matter. In theory this elusive dark matter exerts a gravitational pull that stabilizes the disk of the galaxy.

From earth we view our home galaxy edge-on, hence its elongated appearance spilling across our night sky. The Milky Way looks like a homogeneous band of stars, but it does have clearly defined elements.

Old stars (far left) are found throughout the galaxy, with the highest concentration in the center. Young stars are found primarily in the galactic arms, which are rich in clouds of hydrogen and dust like those seen in the infrared image of a star-forming region (bottom center). A cloud may contract for more than a million years to form a single star, or it may serve as a star incubator, giving birth to star clusters. Another area of active star formation has been observed at the center of the galaxy.

The most massive stars explode into supernovae at a relatively young age. Remnants of one are seen in an X-ray image.

Atomic gas, including helium and carbon but primarily hydrogen, has been revealed in radio images to exist throughout the galactic disk and far beyond. By tracing the distribution of atomic gas, astronomers have determined the large-scale structure of the galaxy.

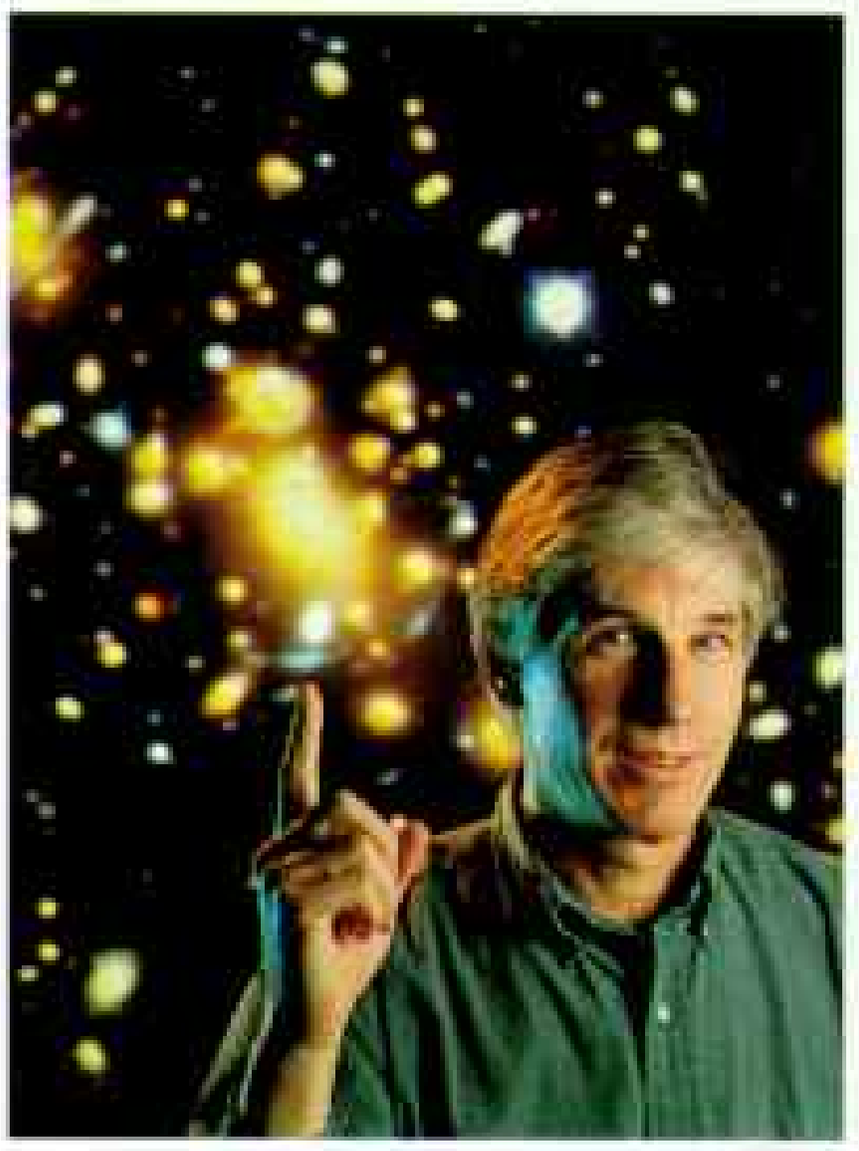
Concentrated in the disk itself is molecular gas—including hydrogen, carbon monoxide, formaldehyde, ammonia, and water. Clouds of molecular gas indicate areas of star formation.

Hidden from earth's view by dust clouds is the galaxy's central bulge. So densely are stars packed into this region that, were our planet to orbit one of them, our night sky would be filled with millions of stars rather than the thousands we now see with the naked eye.

At the heart of the galaxy center, some scientists suspect, is a black hole a million times the mass of our sun. Gas and dust drawn by the gravity of the black hole swirl inward and are accelerated nearly to the speed of light. Heated to extremely high temperatures by friction, the matter shines intensely before being swallowed into the hole, which has such a strong gravitational pull that not even light can escape it.

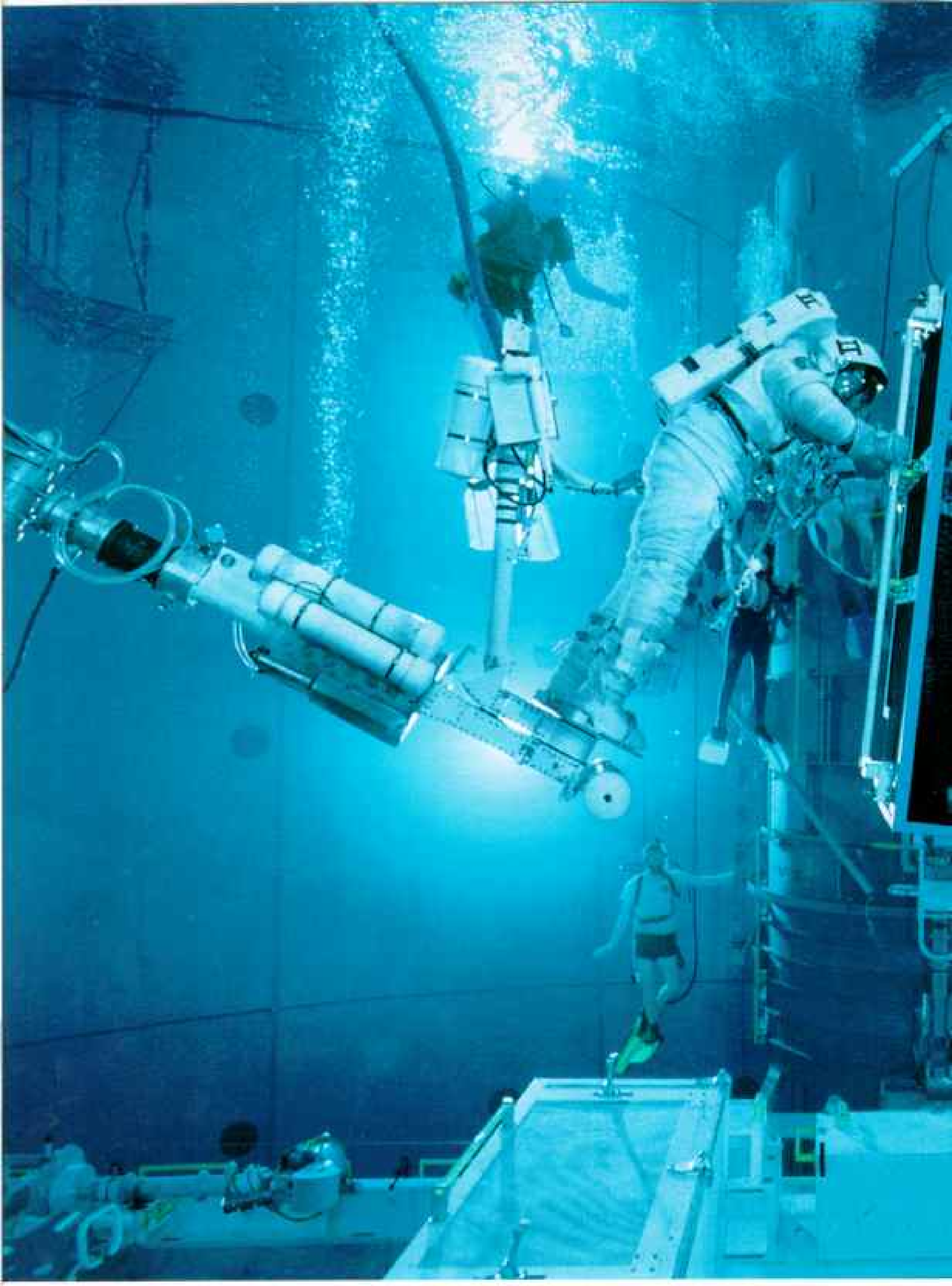
The presence of a black hole has been inferred by measuring the high velocity of stars and gas near the galactic nucleus. This black hole may be near the center of a region of spiraling gas. The spiral appears T-shaped in a radio image (top right) and is visible in an artist's rendering below it. Located in the direction of the constellation Sagittarius, the black hole may lie within the compact radio source known as Sagittarius A*, which is shown as a bright spot just to the left of the T junction.

Some astronomers speculate that a cataclysmic burst in the galactic center within the past 100,000 years swept the region clear of gas and dust. Now the debris is slowly being drawn back to the middle, possibly swirling toward the center's black hole.



DEEP SPACE MIRAGE: A set of round, bluish galaxies appear elongated in an image Bell Labs astrophysicist Tony Tyson helped make. The galaxies' light is bent by the gravity of unseen dark matter between them and earth. Without dark matter, Tyson says, "structure would not have formed in the universe."

PAINTING BY JOE TUCCIARONE; X-RAY IMAGE OF SUPERNOVA REMNANT: EINSTEIN DATA BANK, HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS; IMAGE OF STAR-FORMING REGION: IAN GATLEY, NATIONAL OPTICAL ASTRONOMY OBSERVATORIES; RADIO IMAGE OF CENTRAL REGION: KWOK-YUNG LO AND NEIL KILLEEN, VERY LARGE ARRAY; PHOTOGRAPH BACKGROUND: GARY BERNSTEIN AND TONY TYSON, NATIONAL OPTICAL ASTRONOMY OBSERVATORIES; CONSULTANT: LEO BLITZ, UNIVERSITY OF MARYLAND



REHEARSING FOR RESCUE, astronauts practice underwater in NASA's 1.3-million-gallon simulator tank for their mission to repair the Hubble Space Telescope. Standing on a replica of the shuttle's robotic arm, astronaut Tom Akers guides a copy of the corrective optics unit into the telescope base. Astronaut Jeff Hoffman steadies it.

ROGER H. ARNAMEYER WITH JOSEPH S. STANCAMPIANO, NEX STAFF

Hubble's view from orbit

SQUINTING INTO SPACE, the Hubble Space Telescope has suffered technical glitches, but it has nevertheless produced some remarkable images since its 1990 launch.

Some scientists think the image at left, the center of a galaxy in the direction of the Virgo cluster, perhaps 45 million light-years away, shows a dark disk of cold dust and gas surrounding a black hole. Because light cannot escape a black hole, the brightness at the center of the image is thought to be gas heated by radiation from matter on the verge of falling in.

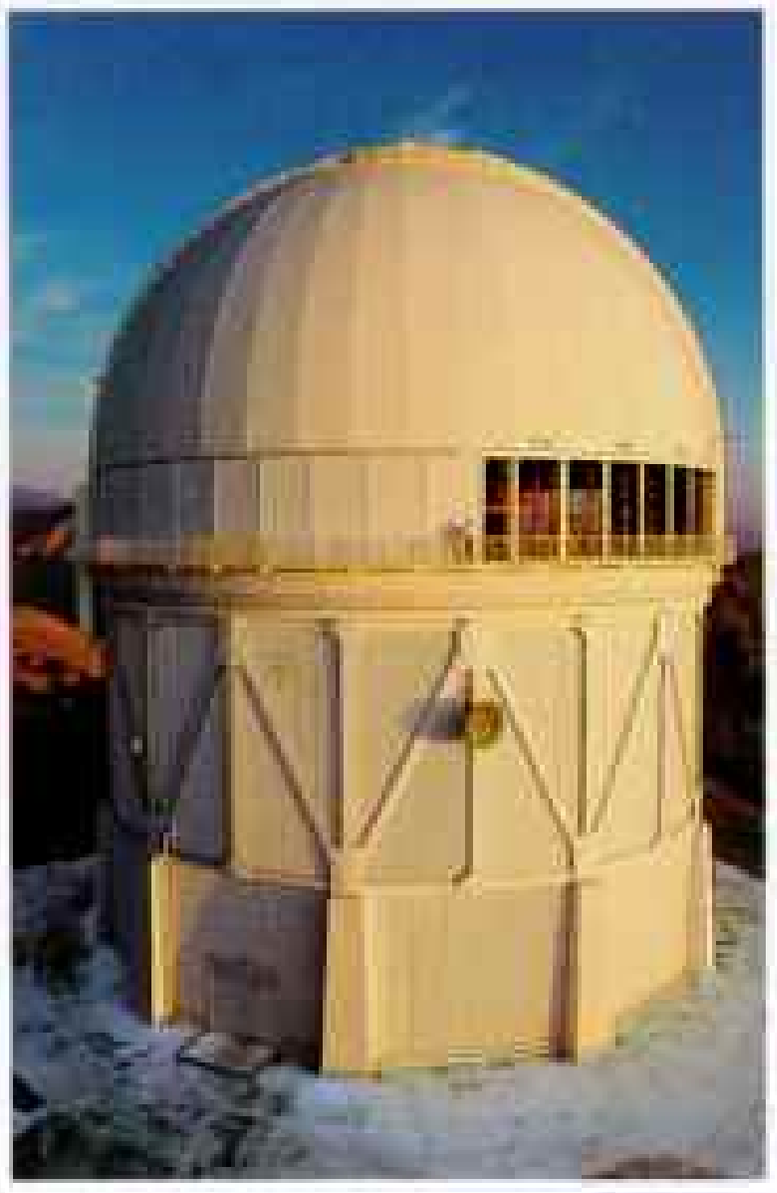
An intriguing mini-spiral (right bottom) was discovered by Hubble inside the galaxy NGC 7252. A mere one-twentieth the size of the surrounding galaxy, it spins in the opposite direction. Astronomers believe the spiral was caused by the collision of two galaxies. The scattered bright spots are groups of stars called globular clusters.

The Einstein cross (center) is an optical illusion that proves the physicist's theory that gravity bends light. The galaxy in the center, 400 million light-years from earth, is a gravitational lens, distorting the light of a quasar eight billion light-years behind it so that four distinct images of the same quasar appear around the foreground galaxy.

The Andromeda galaxy (top, inset) is visible to the naked eye, but the Hubble revealed what appears to be a double nucleus (top) in the Milky Way's twin. The two bright spots—each containing millions of stars—may be the result of a galactic collision, with the dimmer of the pair being the actual center. Or Andromeda may have only one large nucleus, like most galaxies, and a thick dust cloud may simply appear to split it in two.

If the space shuttle crew is successful in correcting the flawed mirror with improved optics, Hubble may yet resolve the mystery it raised.

FROM TOP: (INSET) PALOMAR OBSERVATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY; TOD R. LAUER, NATIONAL OPTICAL ASTRONOMY OBSERVATORIES, AND NASA; NASA/ESA; BRADLEY WHITMORE, SPACE TELESCOPE SCIENCE INSTITUTE, AND NASA. LEFT: WALTER JAFFE, LEIDEN OBSERVATORY; HOLLAND FORD, JOHNS HOPKINS UNIVERSITY/SPACE TELESCOPE SCIENCE INSTITUTE; AND NASA.



CLEARING THE AIR in telescope domes is vital: The smallest temperature differences can distort star images. In a University of Washington water tunnel, astronomers use dye and laser illumination to test an acrylic model for air flow. After such tests, vents were installed in a dome at Cerro Tololo Inter-American Observatory in Chile (above right). Dry desert air lured scientists to Cerro Paranal, Chile (opposite), where the top of a mountain has been removed to build what will be the world's largest optical telescope.

(Continued from page 10) lightweight design and advanced computers."

Telescope operator Barbara Schaefer demonstrates these innovations. Like the captain of a ship, the telescope operator is responsible for the safety of the Keck. If winds come up or if the humidity rises, threatening to condense on the telescope's pristine optics, she will close the shutters of the dome, despite the direst pleadings from scientists.

Schaefer invites me into the ten-story-tall dome. No space is wasted. The dome seems filled by the Keck's light, boxy framing. By comparison the graceful but massive steel mountings of the Palomar 200-inch telescope soar into a vault of largely empty space.

The major breakthrough of the Keck, however, is its mirror. It is actually a mosaic of 36 independent segments. Each mirror segment is a thin hexagon about six feet across, weighing about half a ton. State-of-the-art electronics align these segments to within a millionth of an inch twice a second.

My first glimpse of this huge honeycomb disorients me. To minimize dust accumulation, the Keck designers have employed a novel solution: The big mirror is stored on its side, instead of facing skyward. Suddenly I am confronting a 33-foot-tall curved glass wall. Yet each of the component mirrors is reflecting a slightly different perspective.

"LET'S GET these mirrors aligned," announces Schaefer. She begins pushing buttons on a box that resembles a big TV remote-control unit. The shutters of the dome slide open. The mirror assembly begins to rotate skyward.

In the control room a TV monitor shows us what the mirror is seeing. Schaefer focuses the telescope on a faint star, and 36 separate images of that star—one from each mirror segment—appear on the monitor. She types a command into a keyboard and all the images begin to dance around, slowly at first. Then they rapidly merge into one sharp star. It is time to go to work, and Schaefer soon points the telescope at the remnants of an exploded massive star, or supernova, now colliding with a distant cloud of gas and dust.

Meanwhile, Tom Soifer, an astronomer from the California Institute of Technology, is reviewing images made the night before with a new infrared camera built by colleague Keith Matthews. Soifer is elated.

"Look at this," he says, producing an

image of a graceful arc of fuzzy blobs. They are within an object labeled FSC10214+4724, an unwieldy description of its coordinates in the night sky. "This is the most luminous object in the universe. It shines with the brilliance of a hundred trillion suns, but we've only seen it before as a blurred point of light because it's ten billion light-years away. I've spent hours observing this thing from Palomar. Yet a single 20-second exposure last night beat what we got back there."

Soifer points out how the blobs resemble a group of galaxies very close to one another. "I think they're all colliding," he says.

If so, the Keck is explaining what makes FSC10214+4724 so upset and fiery.

"There must be a very intense starburst," says Soifer's colleague James Graham.

"A starburst—the rapid formation of massive hot stars—is typical of either a young galaxy forming its first generation of stars or older galaxies in collision. The collisions concentrate lots of gas and dust—the stuff from which new stars are made."

Graham, an astronomer from the University of California at Berkeley, has himself just finished processing a new image of the most distant galaxy yet discovered, cataloged as 4C41.17. This new image reveals 4C41.17 in its embryonic state. He points out features never resolved before: "See these splotches surrounding the galaxy? They look like companion galaxies."

The Milky Way also has satellite galaxies, called the Large and Small Magellanic Clouds. We've never known how we acquired those companions. However, the Keck data suggest that some galaxies formed in small tight clusters.

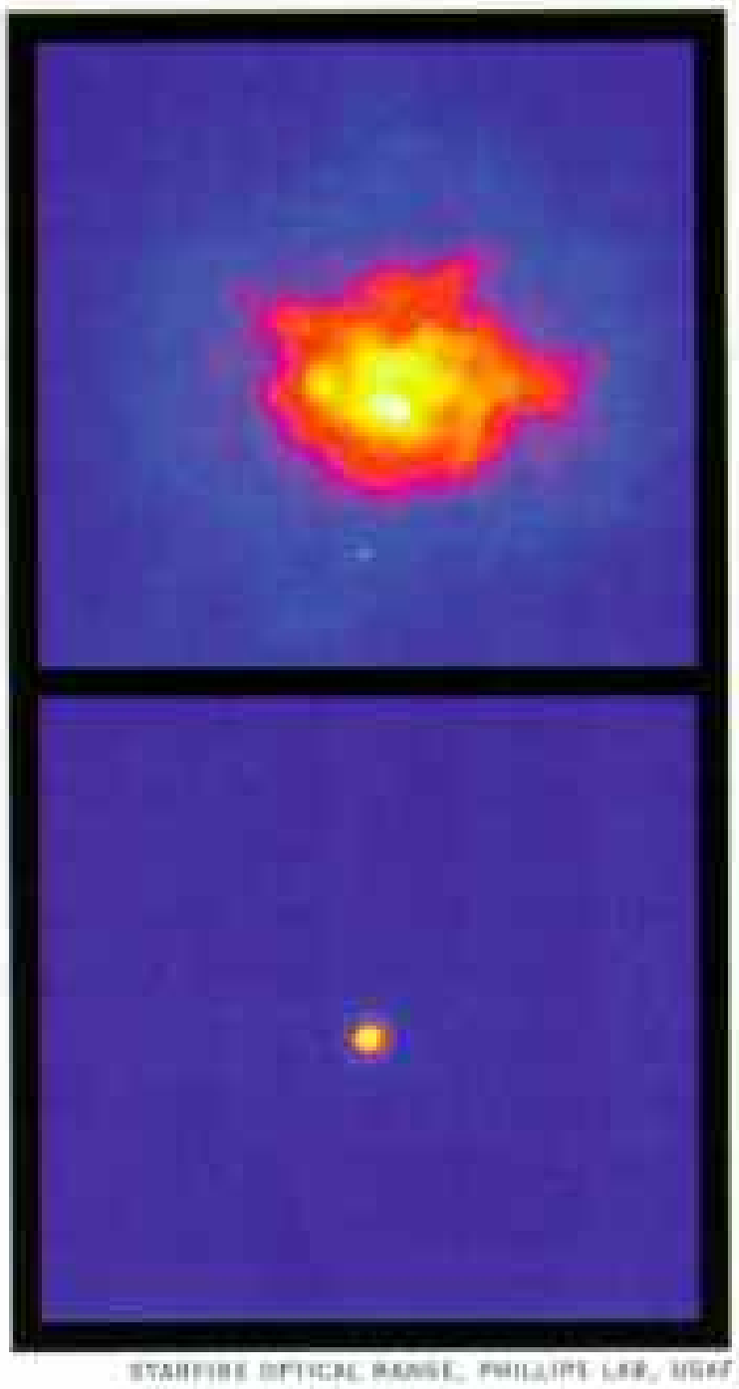
So in its first days of observation the Keck has yielded new data about the stages young galaxies, including our own, went through.

A HEMISPHERE AWAY in Chile another new telescope is being trained on evolving galaxies. The New Technology Telescope (NTT) is the pride of the European astronomical community. Inaugurated in 1990, it is the newest telescope at the European Southern Observatory in the foothills of the Andes.

The NTT's mirror spans 3.5 meters (138

inches)—much smaller than the Keck. What it lacks in size, however, it partly makes up for in intelligence. It is the first telescope built with "active"—or computer-assisted—optics.

To appreciate active optics, consider what a telescope mirror does: It collects light, or more specifically photons, the tiny, basic units of radiant energy. Photons are what we detect in astronomy. Billions of photons a second pour out of an automobile headlight, for instance. Unimaginably more stream from stars. A minuscule percentage of the photons radiated from any star will eventually fall on the primary mirror of a telescope on earth. The bigger the mirror, the more photons it captures. The primary mirror reflects these photons back up to a secondary mirror, which focuses them and feeds them into cameras and other detectors. Active optics align and focus these photons far more efficiently.



STARFIRE OPTICAL RANGE, PHILLIPS LAB., USAF

"We are starved for photons," says astronomer George Miley of Leiden University in the Netherlands, who specializes in the galaxies of the early universe. Of the 50 most remote galaxies known, he and his colleagues discovered more than 30. Tonight he and student Rob van Ojik will be studying one of the faintest.

"The photons we are trying to collect started traveling when the universe was about 20 percent of its current age," he says. "Because they have to travel so very, very far, not many of them are going to make it to our mirror. We can't afford to waste any of them."

Photons get wasted when they don't go into the telescope's instruments. That happens if the mirrors perform less than perfectly. The primary mirror, for instance, may flex slightly out of shape as the telescope points in different directions. The secondary mirror may fall out of precise alignment.

NTT computers, however, regularly monitor the quality of the telescope's images, adjusting alignment and correcting for flexure.

Active optics produce more than clearer pictures. They channel more photons into other instruments on the telescope, strengthening signals too weak to be detected before. Miley and van Ojik, for example, are analyzing the photons from their faint galaxy with a spectrometer. Just as a prism breaks visible light into a spectrum of colors, a spectrometer spreads starlight into its different wavelengths. Certain ones indicate the presence of specific elements in the objects radiating the light.

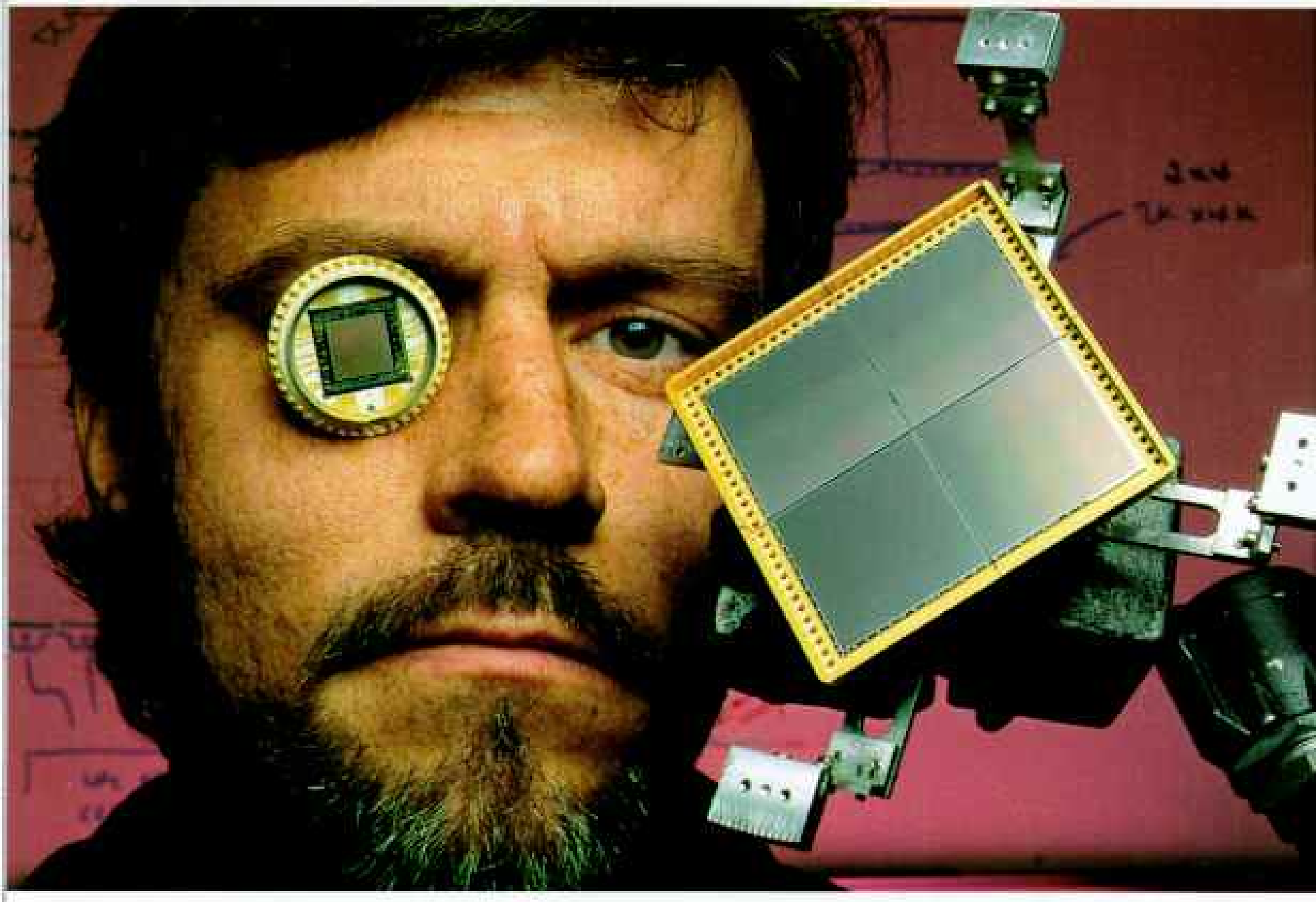
Van Ojik has been watching a video monitor in the NTT control room. A thin white line begins to emerge like a ghost out of the grainy background. He shouts out: "We've got the O-three. We've definitely got it!"

"O-three," or [O III], is chemical shorthand for an ionized form of oxygen created by ultraviolet radiation, which indicates gaseous debris around very hot new stars. The NTT has thus found evidence that this young galaxy—too remote to be studied like this before—is bursting with the turmoil of star birth. Our telescopes are just now getting smart enough to see it.

ALTHOUGH THE NTT'S OPTICS can correct problems with telescope performance, they can do nothing about the nemesis of all astronomers, a phenomenon we call "bad seeing." Skies may be perfectly clear, but if warm and cold air, for example, are mixing above or around a telescope, images will be smeared. The unstable atmosphere acts like the shimmering air over a hot desert road.

However, a different type of "smart" optics—adaptive optics—is letting us overcome even bad seeing. At another European Southern Observatory telescope, I watch engineers testing a system called COME-ON+, an acronym for the three French agencies that developed it. It uses a small mirror to intercept light off the telescope's secondary mirror. Another device measures how much smear the atmosphere is creating. Fifty-two electromechanical devices then subtly adjust the shape of the intercepting mirror to compensate.

The wind is howling outside, and astronomer Jean-Luc Beuzit complains about the



BIGGER IS BETTER when it comes to arrays of light-gathering cells in charge-coupled devices for telescopes. Some 640,000 cells, or pixels, are crammed into the Hubble Space Telescope unit worn like a monocle by astronomer Gerry Luppino. The larger array has more than 16 million pixels. Ground-based telescope images are enhanced by adaptive optics—correcting distortion with a computer-controlled mirror. The star Capella is sharpened (opposite, bottom) with a flip of the optics switch.

dismal seeing as he studies the image of a remote galaxy on a video display.

"Not one of our better nights," he frowns, telling me the seeing is two arc seconds—an astronomical term describing the sharpness or size of an image. The smaller that number, the better the seeing. At Mauna Kea very good seeing is a few tenths of an arc second.

But the image I see seems too sharp.

"Was this taken tonight?" I ask.

Beuzit nods, then adds with a sly smile that tells me I have been set up, "COME-ON+ has corrected it to six-tenths of an arc second."

Six-tenths of an arc second on such a dismal night! What will it do on a good one? Within a few years telescopes on the ground will routinely be capturing images with a sharpness once thought possible only from space.

Despite smart optics, astronomers still crave big mirrors. Of the 13 new giant telescopes being planned or constructed, three will rise on Mauna Kea, three in Arizona, one in Texas, and the rest in Chile.

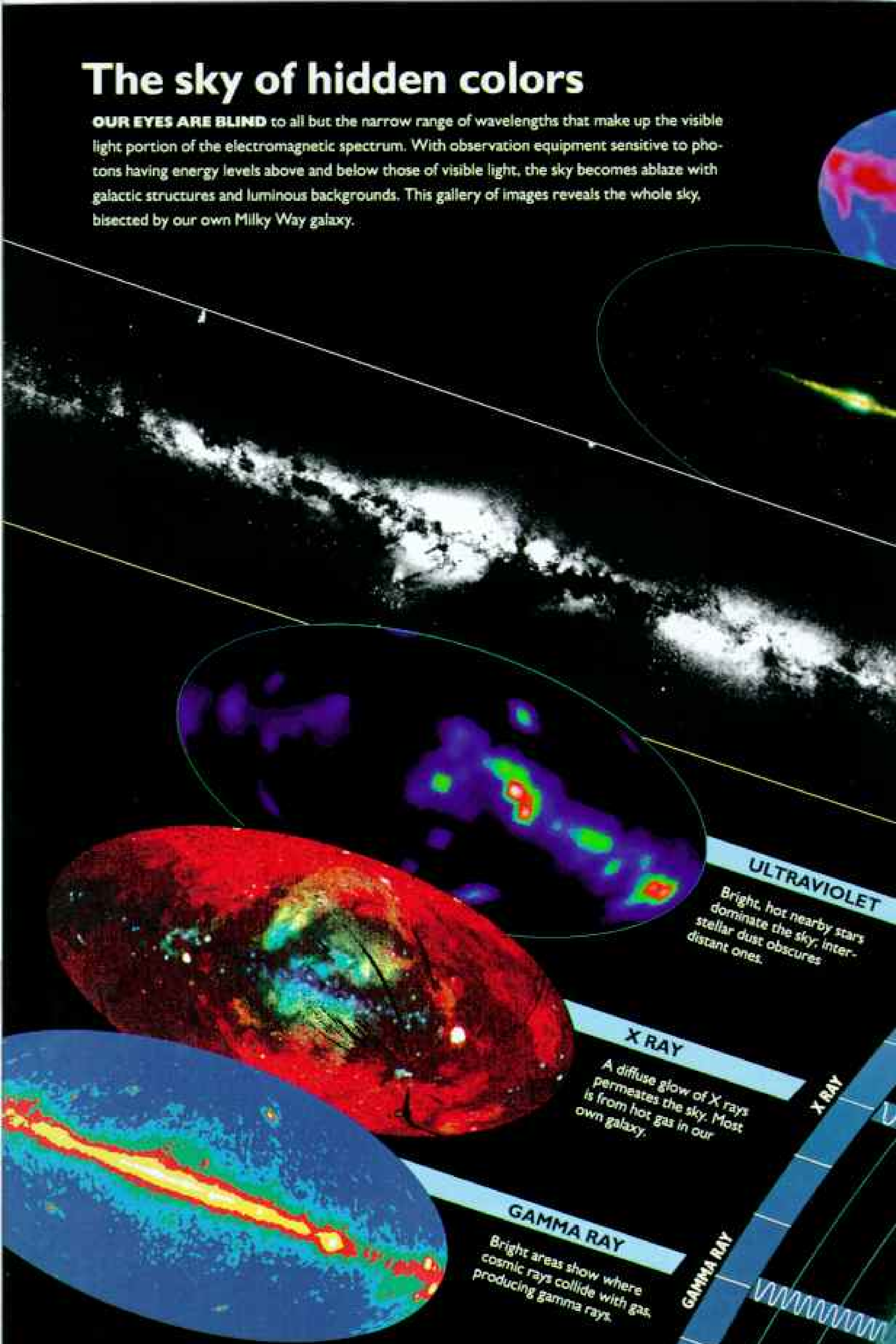
The most ambitious project—to build the world's largest optical telescope—is another European venture, called simply the Very Large Telescope (VLT). Already holes for the foundations of its four independent 8.2-meter telescopes have been dug out of a mountain, Cerro Paranal, in Chile's Atacama Desert. In a few years, when its telescopes start to see first light, European astronomers hope the VLT will vault them ahead of their American rivals for the foreseeable future.

No matter how big we build them, earth-bound telescopes are still limited by the blocking effects of our atmosphere. Certain wavelengths of *(Continued on page 32)*

"PHILOSOPHY IS WRITTEN in this grand book—I mean the universe," wrote Galileo, his scientist's eye struck by the nighttime canopy whose study he revolutionized. Outside the domes at the Carnegie Institution's Las Campanas Observatory in Chile, astronomers are greeted by the Southern Cross constellation, at left, and, at right, the Eta Carinae nebula.

The sky of hidden colors

OUR EYES ARE BLIND to all but the narrow range of wavelengths that make up the visible light portion of the electromagnetic spectrum. With observation equipment sensitive to photons having energy levels above and below those of visible light, the sky becomes ablaze with galactic structures and luminous backgrounds. This gallery of images reveals the whole sky, bisected by our own Milky Way galaxy.



ULTRAVIOLET

Bright, hot nearby stars dominate the sky; interstellar dust obscures distant ones.

X RAY

A diffuse glow of X rays permeates the sky. Most is from hot gas in our own galaxy.

GAMMA RAY

Bright areas show where cosmic rays collide with gas, producing gamma rays.

RADIO

The distribution of hydrogen, the most abundant element in the universe, reveals the overall structure of our galaxy.

MICROWAVE

Blue areas are cooler and pink areas warmer than the universe's average temperature of minus 455°F, or 2.7K.

INFRARED

Less impeded by dust clouds that block visible light, infrared gives a clear view of the Milky Way's central bulge.

VISIBLE

The Milky Way's stars appear as a swath, obscured in places by dust, in our edge-on view.

KILOMETER

RADIO

MICROWAVE

CENTIMETER

INFRARED

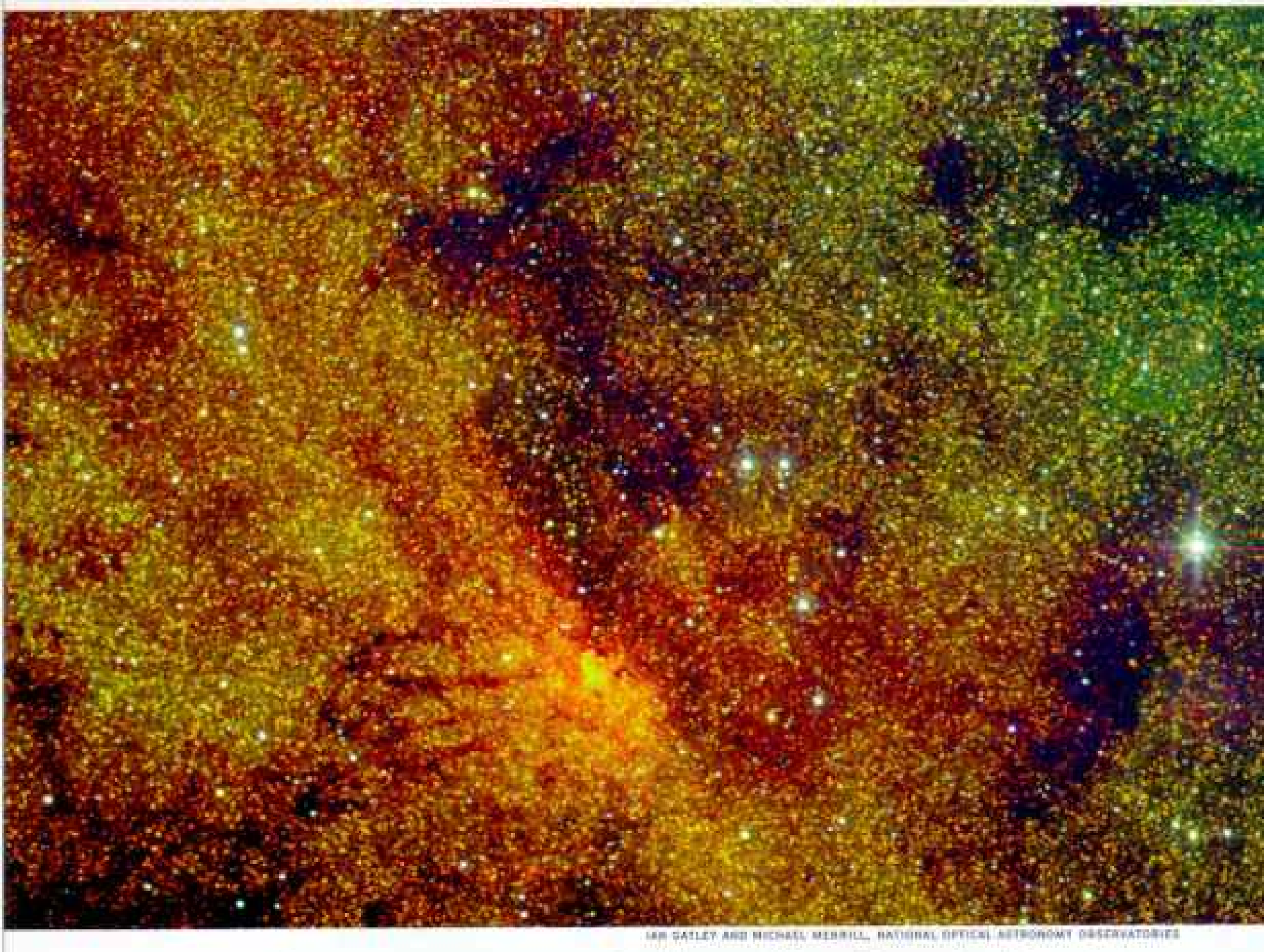
VISIBLE

MICRON

ULTRAVIOLET

ANGSTROM

PAINTING BY NATIONAL GEOGRAPHIC ARTIST WILLIAM R. BOND. FROM TOP: CHRISTINE JONES, WILLIAM R. FORMAN, AND CAROLYN STERN, HARVARD-SMITHSONIAN CENTER FOR ASTROPHYSICS; LAWRENCE BERKELEY LABORATORY, COBE SCIENCE TEAM/DIFFERENTIAL MICROWAVE RADIOMETER; NASA/GODDARD, COBE SCIENCE TEAM/DIFFUSE INFRARED BACKGROUND EXPERIMENT; EUROPEAN SOUTHERN OBSERVATORY; RICHARD C. HENRY, MARYLAND SPACE GRANT CONSORTIUM; JOACHIM TRÜMPER, MAX PLANCK INSTITUTE FOR EXTRATERRESTRIAL PHYSICS; CARL FICHTEL, NASA/GODDARD, COMPTON OBSERVATORY EGRET TEAM



IAN GATLEY AND MICHAEL MERRILL, NATIONAL OPTICAL ASTRONOMY OBSERVATORIES

electromagnetic energy—gamma rays, X rays, and most ultraviolet—will not penetrate it. However, the Hubble Space Telescope, high above the atmosphere, gets an unblocked view of the universe. Despite its much smaller, 2.4-meter (95-inch) mirror and its impaired vision, the Hubble has produced provocative glimpses of the universe. Especially intriguing are its looks into the interiors of other galaxies.

Recently the Hubble confirmed tantalizing hints of turmoil in our nearby neighbor, the Andromeda galaxy. Once thought to be a quiet, almost boring galaxy, Andromeda appears in Hubble images to have a double nucleus. The two centers are only about five light-years apart. Might one be the core of a smaller galaxy that Andromeda has captured with its gravity and is now consuming?

If so, the capture must have been fairly recent, a conclusion astronomers find discomforting. "The nucleus of a captured galaxy would be ripped up in a few hundred thousand years," says astronomer Tod Lauer of the National Optical Astronomy Observatories in Tucson. The odds are heavily against an observer's just happening to see such an event, which may occur only once in a billion years.

What would do the ripping apart? Probably one of the strangest of the beasts in the cosmic zoo—a massive black hole. We now suspect that voracious black holes are not rare phenomena at all but lurk within the centers of many galaxies, including our own.

Black holes are incredible concentrations of matter. If a star like our sun, for instance, could collapse to become a black hole, it would measure less than four miles across; its density would be a million billion times that of gold. However, the black holes thought to reside in the center of many galaxies would be much bigger. As each galaxy came together, perhaps a billion young stars, drawn together by gravity, collapsed into a black hole half the size of our solar system. Such objects would be much less concentrated than a small black hole; their density would be more like that of Styrofoam. Nevertheless, their gravity would be far too strong for even light to escape.

As those galaxies evolved, their black holes would sweep up all the stars, gas, and dust within reach, creating fireworks like those we see in quasars. Then they would quiet down, until a collision provided fresh food.

Black holes feed the speculation over Andromeda's double nucleus. If one of the nuclei is indeed the center of a captured galaxy, it too might have a black hole, entraining its own domain of orbiting stars, gas, and dust. That powerful unit might be more difficult for Andromeda's black hole to consume. Eventually, however, one nucleus would ingest the other. But when? And how?

Another theory is that a thick dust cloud over a single center simply makes it look double. "We're more confused than anything else," says Lauer.

This is the thrill of astronomy today. Our new instruments reveal sights more exotic than we imagined. And, in this case at least, we know that either bigger, better ground-based instruments or a repaired Hubble Space Telescope will soon provide explanations.

Explaining what lies within the center of our own galaxy may continue to prove more difficult. The center is only 25,000 light-years away, but thick dust blocks all visible light. Also, because we are in the same visual plane as the center, we cannot get a good perspective on our own interior.

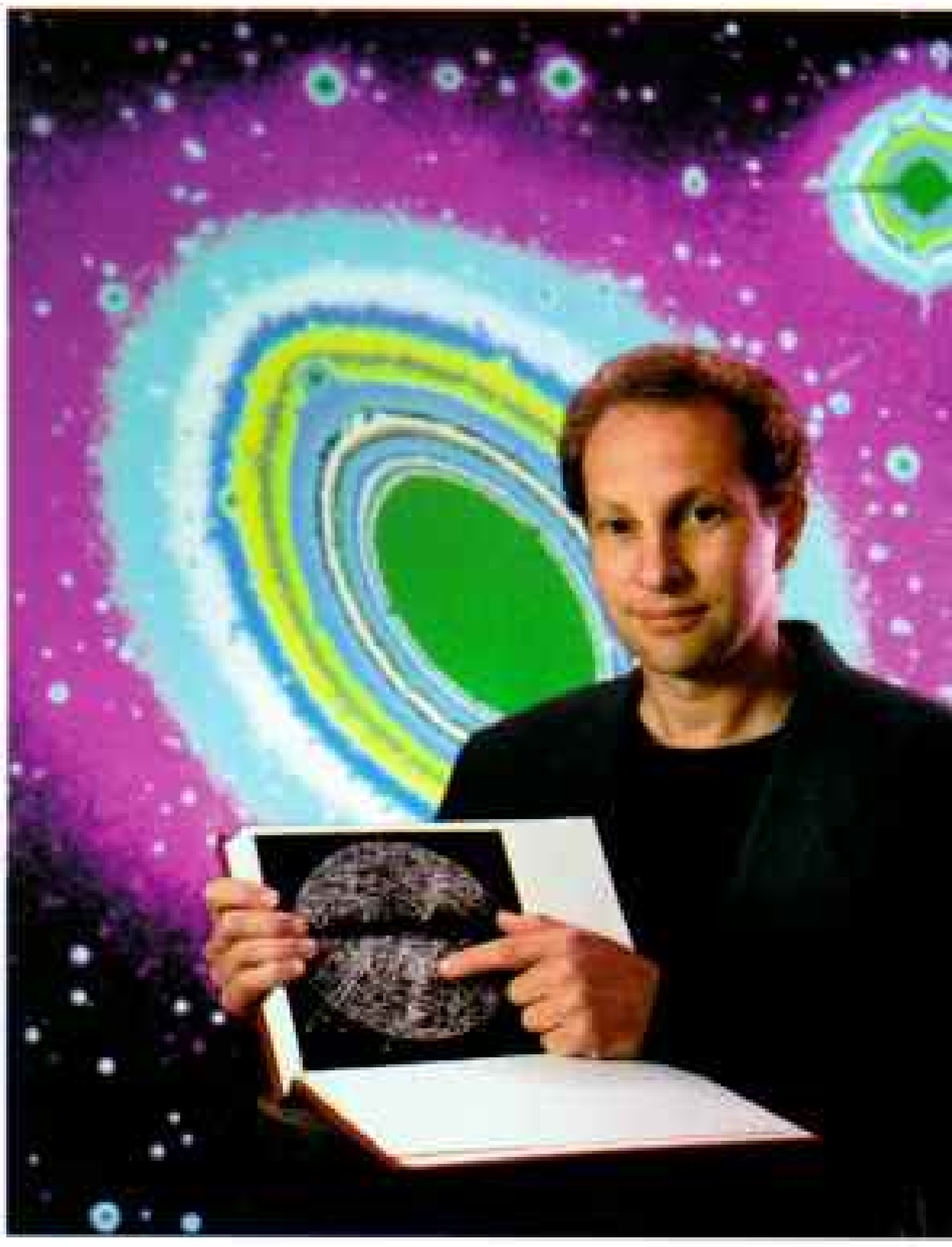
Nevertheless, the velocities of stars swirling around the center have been measured in the infrared with data taken by a group led by Joseph Haller of the University of Arizona. The speeds of those stars suggest they are being driven by something in the heart of the Milky Way, presumably a black hole, with the mass of about a million suns. However, many astronomers believe further evidence is needed before this exciting conclusion can be verified.

With the Hubble Space Telescope dissecting the cores of far more distant galaxies, such perplexity in our own backyard seems ironic.

ALTHOUGH THE HUBBLE garners the most attention, another orbiting observatory has sent back perhaps the most profound data. A satellite called COBE, or the Cosmic Background Explorer, has strongly supported the theory that the universe began expanding in a great explosion nicknamed the big bang.

Cosmologists speculate that before the big bang all of space—the totality of our universe—was an extremely concentrated speck far smaller than an atom. Perhaps our universe was but one part of a foam of tiny black holes, some of which occasionally exploded. No one knows—and we may never know. If our current understanding of physics is correct, all history of that initial, infinitesimal slice of time is irretrievably lost. And our knowledge of the events that followed soon after depends on the insight of theorists, on mathematics, and on experiments using high-energy particle accelerators.

While still a speck, cosmologists calculate, the universe would have had a temperature of a million trillion trillion degrees. Ordinary matter did not exist under those conditions.



A SEA OF SUNS bound together by gravity fills the view when an infrared telescope aims toward the Milky Way's center (opposite). More mysterious waters lie beyond: the Great Attractor, discovered by the Carnegie Institution's Alan Dressler (above) and six other astronomers. All galaxies in our part of the universe—shown in the chart he holds—are being drawn toward this immense mass. One is the galaxy NGC 6861, shown behind him.

Our familiar laws of physics did not apply.

As that speck expanded, it cooled, and the components of the universe we know began to emerge. By the time the universe was one second old, protons, neutrons, and electrons—the building blocks of atoms—had come into being. So had photons. But the stew of matter and energy was so concentrated that photons could not move about within it. Not until the universe was 300,000 years old did light break away from matter and begin to travel freely through our expanded speck of space.

The moment of light's emancipation left a faint haze of photons—an afterglow of the big bang. Called cosmic background radiation, it permeates the universe. The haze is extremely cold now, 2.7 Kelvins, or minus 455°F. First detected in 1964, its structure is being revealed by extremely sensitive microwave detectors, like those carried into orbit by COBE in 1989.

COBE had a major question to resolve: Why are we here?

"Matter isn't distributed evenly in the universe today," explains John Mather, COBE chief scientist at NASA's Goddard Space Flight Center. "It's clumped into stars and galaxies and planets, like earth."

Gravity formed those structures, but there must have been an initial unevenness for it to act on. We should see that in the afterglow of the big bang. Before COBE we couldn't.

"Our earth-based detectors were getting more and more sensitive," says Mather, "but we just kept seeing the same thing—smooth, homogeneous radiation all across the sky."

If COBE saw from space only smooth radiation, then the entire big bang scenario would be threatened. A mild panic set in when the first data came back. The radiation still looked homogeneous. Then over months, as more data were processed, huge patches emerged in which the temperature of the background photons varied by a few hundred-thousandths of a degree. Not much, but enough to silence those who were ready to rewrite the physics of the early universe.

The COBE results have raised some new questions about details of the big bang scenario, but most theorists believe the satellite has buttressed it at its weakest link. Many now regard the question of the mysterious "dark matter" as the most burning issue in astrophysics.

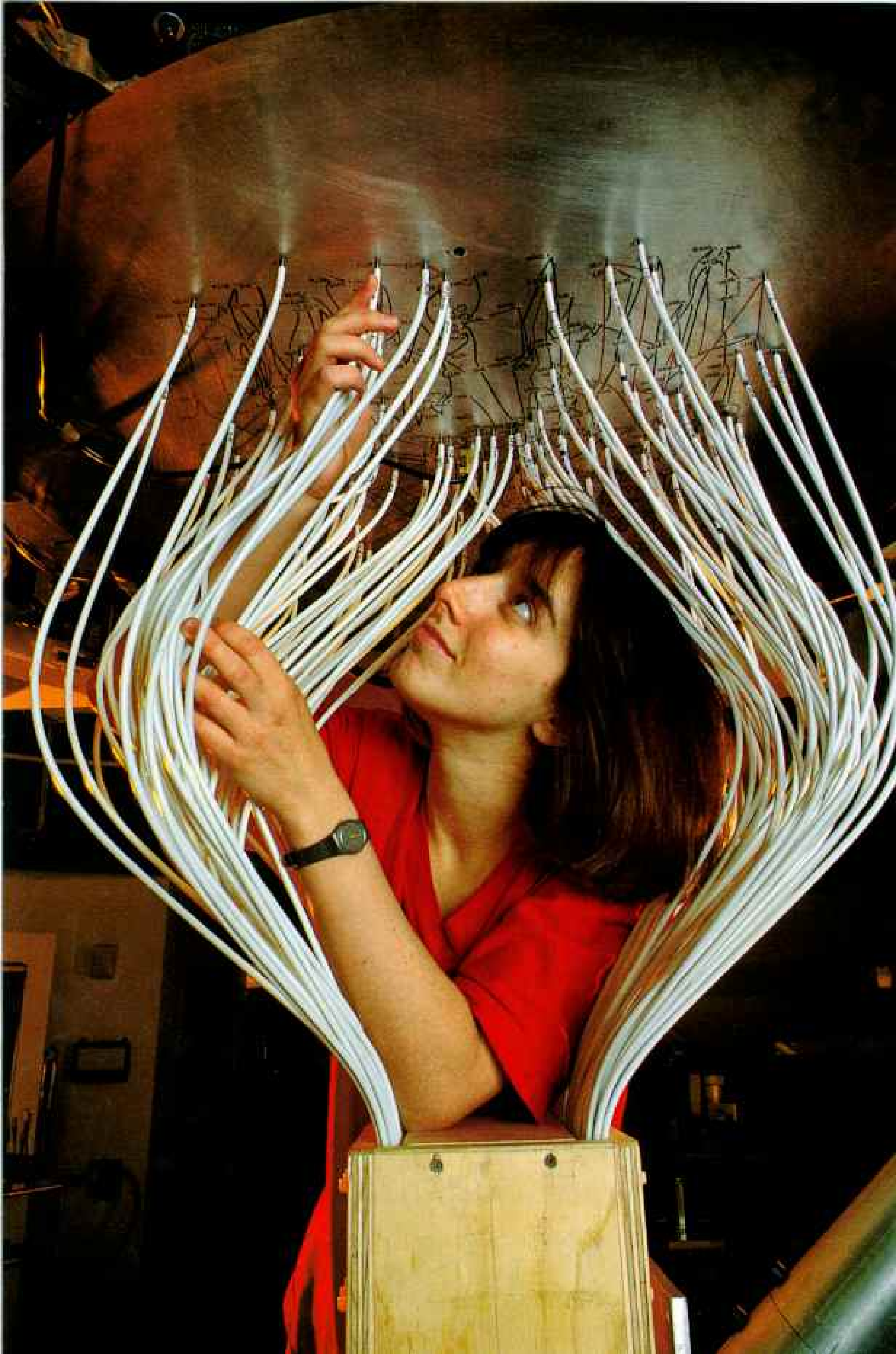
Here again, a new international orbiting X-ray observatory named ROSAT, or Roentgen Satellite, for the German physicist who discovered X rays, has found new evidence for the existence of dark matter. Examining three galaxies known as the NGC 2300 Group, ROSAT detected a huge cloud of plasma, or ionized gas, glowing in X rays around the group.

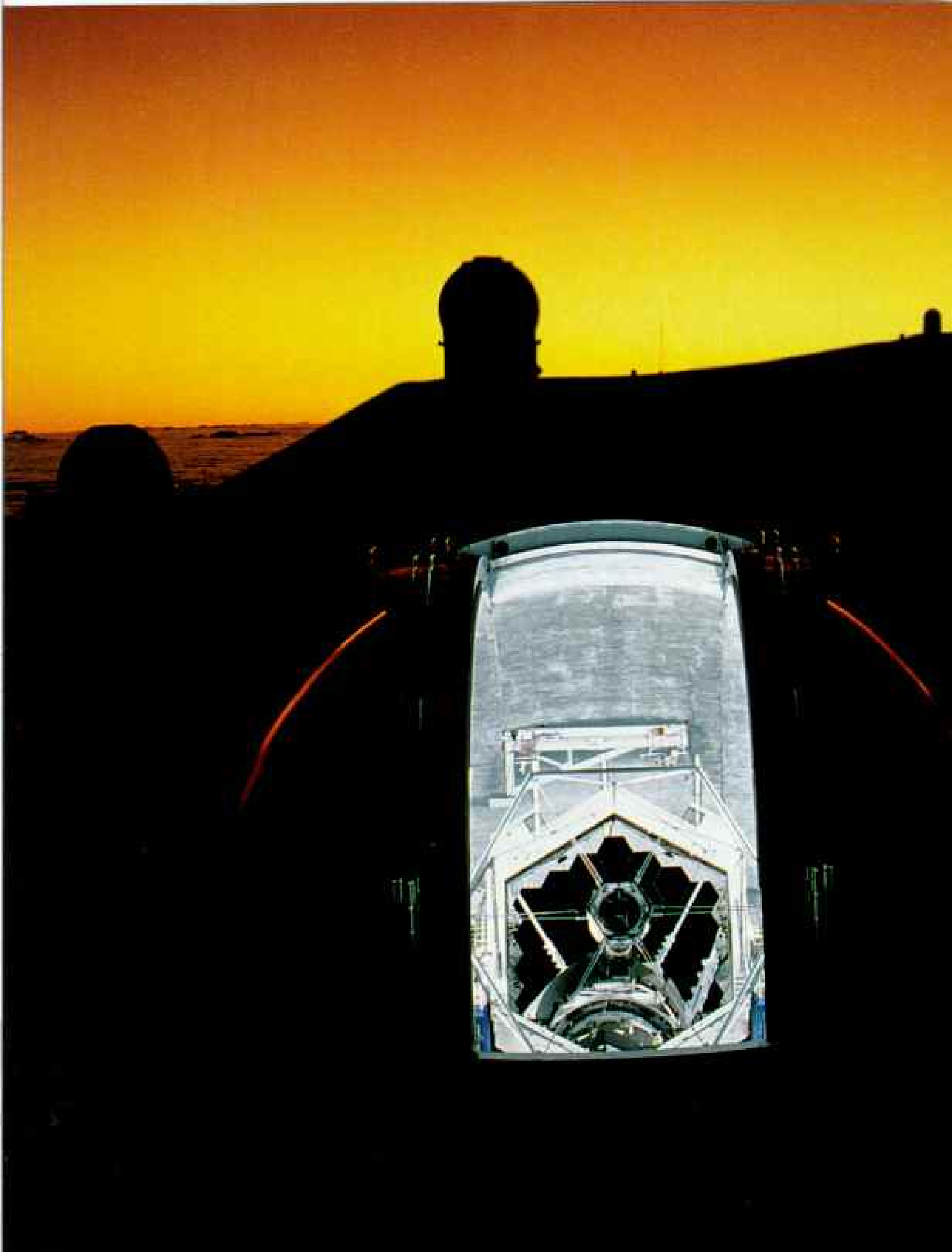
"That cloud," explains astronomer David Burstein of Arizona State University, "is much too immense for the group to gravitationally hold on to—unless the group has 15 to 25 times more mass than we can see."

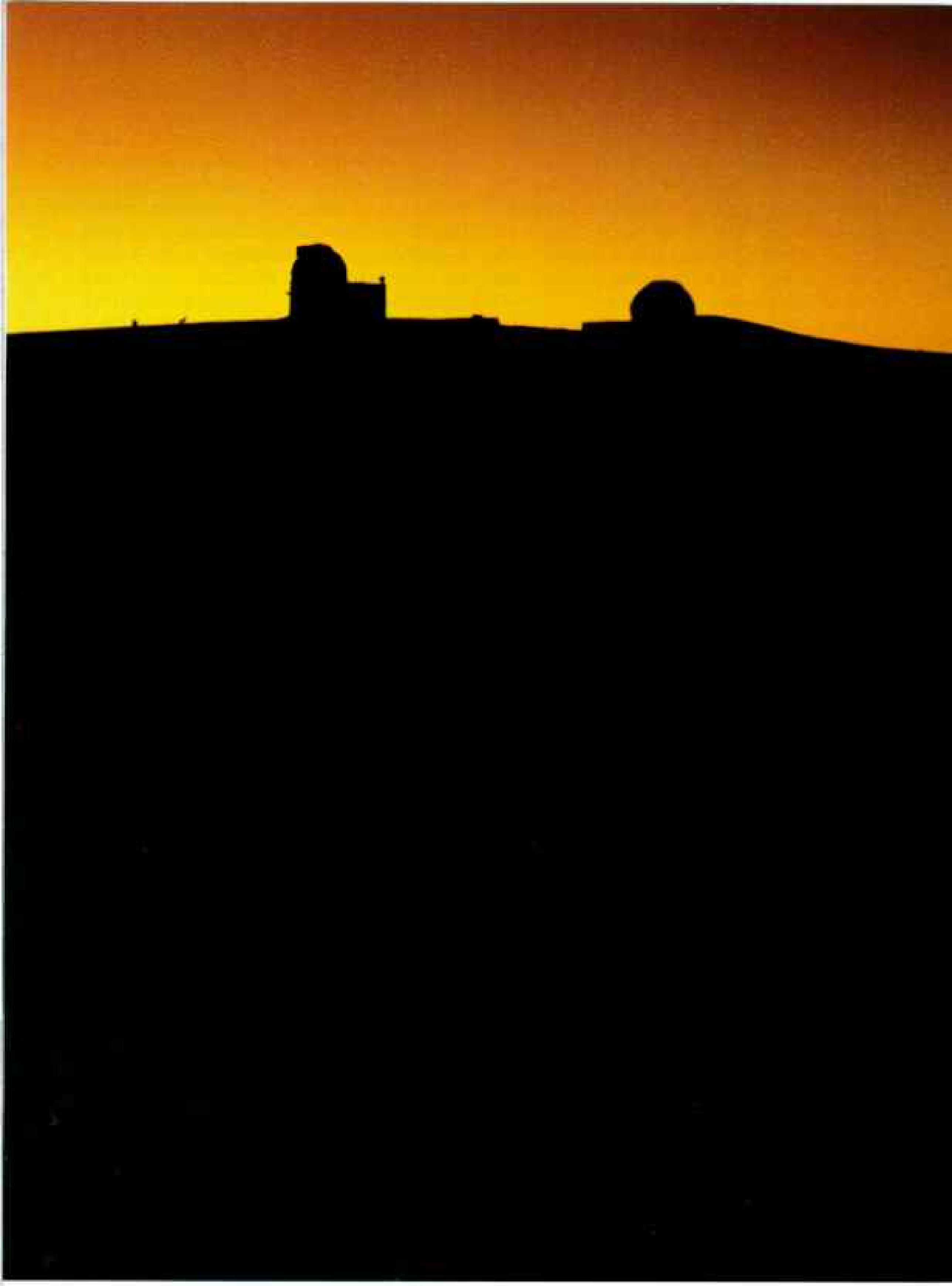
Dark matter—or at least its effects—had been revealed.

It has also recently shown up close to home.

SHEETS OF GALAXIES lie on the borders of vast voids, "as if on the surfaces of soap bubbles," says astronomer Margaret Geller (above), who along with John Huchra has mapped 14,000 galaxies in wedge-shaped regions of space. Targeting 112 galaxies at once, Carnegie Institution astronomer Ann Zabludoff inserts fiber-optic cables into a telescope in Las Campanas, Chile. The holes lie precisely where light from each galaxy will fall.







UNBLINKING EYES aim high atop Mauna Kea, home of the Keck and eight other optical, infrared, and radio telescopes. Four more observatories will soon be in operation. New technology, which enables ground-based telescopes to rival orbiting observatories, is aided by Mauna Kea's elevation of nearly 14,000 feet. The site is managed by the University of Hawaii's Institute for Astronomy.

Astronomer Douglas Lin of the University of California at Santa Cruz has found firm evidence of an immense halo of dark matter surrounding the Milky Way.

He did this essentially by weighing the Milky Way. Lin and colleagues compared pictures taken in 1989 of the Large Magellanic Cloud (LMC), a neighboring galaxy, with images made in 1974. They then measured the almost imperceptible distances some 250 stars in the LMC had moved in those years. That gave them the velocity caused by the Milky Way's gravitational tug on those stars.

"It's like standing in San Francisco and measuring the speed of a person on top of the World Trade Center in New York who takes a single step sideways over the course of the year," says Lin. "It seemed hopeless."

Nevertheless, he persisted. When his team had the velocities, they could calculate the mass needed to exert that pull—the equivalent of about 600 billion suns.

"That's five to ten times more mass than we see in all its visible stars," says Lin.

The missing mass, Lin suggests, lies in a halo of dark matter extending 300,000 light-years or more from our galactic center.

The LMC thus sweeps through that halo. As it orbits us, Lin believes, the LMC has pieces gravitationally bitten off by the Milky Way. "Eventually we will eat it all up," says Lin.

Scientists can only speculate on the nature of the dark matter.

There may be "hot" dark matter—fast-moving particles with negligible mass. To account for all the calculated dark matter, there would have to be about as many of these elusive particles as there are photons. However, such restless, rapid particles would move too fast to clump into any but the largest structures visible in the universe today.

There may also be "cold" dark matter, such as weakly interacting massive particles, or WIMPS. Because they have more mass, they move more slowly and are able to clump. Except through gravity, they simply would not interact with either light or ordinary matter in any yet noticeable way. They presumably would have clumped together before light and matter decoupled, forming gravitational wells into which ordinary matter would fall to form galaxies after it was freed from its bondage with light.

The WIMPS would thus remain a background medium, a sea of particles through which the galaxies, stars, and planets sweep.

At least some of the unseen mass may be nothing more than ordinary matter locked up in substellar-size bodies, nicknamed MACHOS, or massive compact halo objects. Recently two teams of astronomers believe they have found the first examples of what might be many of these objects in the halo of our own galaxy. But MACHOS would have formed relatively late in the history of the universe—too late to supply the dark matter that many theorists believe caused the first galaxies to coalesce as quickly as they did.

WHATEVER this dark matter may be, its very existence has determined the ultimate fate of the universe. The universe today is continuing the expansion that began with the big bang. However, its own gravity is trying to pull it back together. If it has enough mass, it will one day collapse back on itself in what has been called the "big crunch." If it has too little mass, the universe will eventually fly apart.

Most astronomers prefer to think that the universe has exactly enough mass to let it just barely expand forever. However, for that to happen, the universe needs as much as a hundred times more mass than we can see. Thus the dark matter may provide just what the universe needs to keep its balance.

So much still lies out there unseen. Only recently have we begun to glimpse the lumpy nature of the large-scale structure of the universe. In 1989 astronomers Margaret Geller and John Huchra of the Harvard-Smithsonian Center for Astrophysics confirmed, after plotting thousands of galaxies into a three-dimensional map, that most galaxies are clustered in sheets. In between those sheets lie voids—vast bubbles of apparent nothingness.

We have, moreover, realized that the Milky Way, our entire Local Group, and thousands of other galaxies in our vicinity are being pulled at about 360 miles a second toward a huge concentration of galactic matter called the Great Attractor, whose tug indicates it has the mass of about 20,000 trillion suns.

More recently we've discovered that even the Great Attractor is in motion, perhaps drawn toward something with as much as ten times more mass. We are thus like rafts on a cosmic river, streaming toward the unknown.

However, of all the mysteries, none fascinates me more than the question: Are we alone

THE LONG WAIT for signs of extraterrestrial life goes on at the controls of Puerto Rico's Arecibo radio telescope. At 3 a.m. scientists Jill Tarter and John Dreher test a computer that analyzes distant, unexplained signals. "It would be nice if they sent something obvious, like the digits of pi," says Tarter.

in the universe? We must first determine if there are other planets similar in mass to earth and thus candidates for supporting life. A good place to look for them is around nearby stars similar to our own sun.

At Caltech's Owens Valley Radio Observatory astronomer Anneila Sargent is receiving data from an embryonic star in the constellation Taurus. Outside, four ten-meter radio dishes are each collecting signals. Then, using a technique called interferometry, computers are combining the input of all four. The result is a signal as revealing as one from a single radio dish 200 meters in diameter.

"We see a thick disk around this star," says Sargent. "This array of telescopes is so sensitive we can detect carbon monoxide within the disk. That's an important molecule, because it lets us measure the temperature, the velocity, and the way gas and dust are distributed in the disk. We have models of planet formation. So far this disk fits them. I really do think we are watching planets forming."

We still have not actually detected an earth-like planet around another star. Such an object is far too small to see with our biggest telescopes. However, NASA is considering a project called TOPS, or Toward Other Planetary Systems. Its first goal would be linking new giant telescopes, through interferometry, to make the equivalent of a mirror big enough to find stellar environments that might harbor planetary systems. Then the project would put into orbit instruments capable of detecting planets the size of Jupiter or Saturn.

Eventually, a telescope system would be set up on the moon to search for gases, like oxygen and ozone, in the atmospheres of earth-like planets. Both these gases react so strongly with other molecules that they cannot exist freely in nature, except in delicate balance with life. If we found them, we would almost

LENDING AN EAR to the immobile 305-meter-wide Arecibo radio telescope, a revolving directional device aims for a specific star. Will this dish receive the first signals from a distant society? Jill Tarter, who keeps champagne on ice awaiting the big moment, notes: "If we don't look, the chances are zero."

surely know life was present. It would say nothing, however, about how advanced that life would be.

Already, for the past 33 years, scientists have been seeking signs of intelligent life elsewhere in the universe. NASA's Search for Extraterrestrial Intelligence—SETI—was recently expanded under the new name High Resolution Microwave Survey (HRMS).

"We've been looking for evidence of another civilization's technology," says project scientist Jill Tarter of NASA's Ames Research Center. "Maybe others out there have set up radio beacons to say: 'Hello, we're here.' Or maybe there's a multiplanet system broadcasting their versions of the Super Bowl to each other. It's possible we could eavesdrop."

To detect such signals, radio telescopes around the world have been conducting two types of searches, one aimed at nearby stars similar to our sun. The National Science Foundation radio telescope at Arecibo, Puerto Rico, has done 200 out of 2,600 hours of HRMS observing scheduled over the next decade. The other search is a broader all-sky survey.

In the past, HRMS receivers have recorded many suspicious signals. But when astronomers tried to relocate the signals, they found nothing. The new search is computerized. An interesting signal will automatically trigger much faster attention. Tarter says the public will be informed as soon as a signal is verified.

"Everything would change," she says. "I think finding another civilization would have a positive influence. The differences between us and them would be so much greater than those that we on earth squabble over with such horrific results. The discovery might bring us closer together on this planet and give us a more common perspective."

But any hopes for such a profound discovery were dampened recently by Congressional plans to cut off all federal funding for HRMS.

"We're looking for private funds to keep our team together and get our equipment back on a telescope," says a disappointed but determined Tarter. "Somehow we'll find a way."

BACK ON MAUNA KEA, at NASA's Infrared Telescope Facility, I meet Karen and Stephen Strom. The husband-and-wife team from the University of Massachusetts has long been observing star formation. We talk of conclusions that new detectors have made possible.

"We now think that all stars develop disks with planet-forming potential," says Stephen.

Planets probably are incidental to the greater business of making stars. Stars need those swirling disks to feed material inward to their growing cores. A disk also slows a star's spin, keeping it from catastrophically breaking up. Planets form as dust particles in the streaming disks stick to each other and grow like snowballs. Within ten million years, however, the disks disappear. Left behind, all across the universe, would be young solar systems, islands of untold diversity.

"We used to think stars formed alone or in huge clusters," adds Karen. "Now it seems most form in small families of a few dozen. As in human families, the young stars leave their nurseries and drift tens of light-years away."

Outside under the cold dark Mauna Kea skies again, I look up, curious about the rest of our family. How many of us are out there? We must all be about the same age. Have they built eyes like ours to look out on the universe? Across the light-years, are distant beings standing on another mountaintop? And are they too looking out with so much wonder? □

The Great

Swept along by rushing currents, canoeists ferrying sandbags to aid Cedar Rapids residents are themselves rescued as flash floods overtake the Iowa city. Last summer Midwesterners fought in vain as the Mississippi River and its tributaries crumbled one levee after another, taking homes, livelihoods, and lives.

CHRIS STEWART, BLACK STAR

Flood of '93

By ALAN MAIRSON
NATIONAL GEOGRAPHIC EDITORIAL STAFF

JOHN FREIDAH, STATE JOURNAL-REGISTER, SPRINGFIELD, ILLINOIS (LEFT); JEFFREY L. BROWN, JACKSONVILLE JOURNAL-COURIER, JACKSONVILLE, ILLINOIS

Toilworn and tearful—"We worked so hard to save it"—Sandy Suttles weeps on the porch of her parents' flooded Illinois home, where she is comforted by friend Deb Stumpf. Sandbaggers stacked night after night to save the Sny Island Levee (left). When it tore apart, farms melted into mud, and people ran for higher ground.

Ringed by sandbags and pumping fast, the Brake family of Ste. Genevieve, Missouri, braces for the worst. The town's historic district was spared major damage—an island of good news in a sea of woe.

CAMERON DAVIDSON

ON A TYPICAL JULY DAY at Jeff Lorton's farm in East Hardin, Illinois, the chores get divided up something like this: Jeff grinds corn for his 3,000 hogs while his wife, Sandy, gives the baby pigs their shots. The Lortons' teenage boys—J. D., Nate, and Laef—feed and water the livestock while 15-year-old Danielle makes the midday meal: pork steaks, mashed potatoes with gravy, white cake, and ice cream.

But last summer was far from typical. Record rains drenched the upper Mississippi River basin, causing widespread destruction. By late June the Mississippi had jumped its banks in Minnesota, where the National Guard helped battle the worst flooding in 30 years. The disaster moved downstream as the summer wore on. By early July parts of nine states, including Iowa, Missouri, and Illinois, were underwater. By mid-July, when I arrived in East Hardin, the Illinois River was rising to a record level, threatening to bring the Great Flood of '93 to the Lortons' farm.

So Jeff, Sandy, and the kids prepared for the worst. They had already moved their feed, farm tools, and all the furnishings from the first floor of their house to a relative's place across the river, and the hogs had been safely fenced in a temporary pen on higher ground nearby. A few days later the Lortons and I climbed into three pickup trucks and dashed back to their farm to grab a few more belongings.

"I rode over to look at the levee this morning, and the water's coming up too fast," Jeff said, referring to the Nutwood Levee—a 12-mile-long earthen barrier, which was the only thing standing between Jeff's 237-acre farm and the flood.

"The levee's not gonna break, is it?" Danielle asked as we loaded up the trucks.

"Nah," said Jeff confidently as he hustled upstairs. "And if it does, they'll put on the sirens and we'll get out. We'll have lots of time to get out."

We pulled armloads of clothes out of the closets and dumped them in the trucks. We hauled out mattresses and box springs and bedroom bureaus. We tossed blankets and hockey sticks and assorted odds and ends on shelves, on the pool table, on any flat surface a few feet above the second floor.

Just before we left, Jeff looked around the first floor for anything else of value. He saw the kitchen telephone and angrily ripped it off the wall. Then we piled into the trucks and crunched down the gravel drive for the last time. I looked back at the house and saw a wooden sign. "Lorton Family Farm," it said. "Welcome to Paradise."

Running on sweat and spirit, Iowan Pam Christian hefts sandbags to patch a levee that saved some downtown businesses in West Des Moines. More than 1.5 million bags were used in the Des Moines area. "It smelled so bad I was choking," says Christian of the noxious floodborne mud. "But helping out felt great." So did a nap.

BOTH BY BILL GREENE, BOSTON GLOBE

Floods are a fact of life in the Midwest. They usually arrive in the spring, when rain and snowmelt fill the streams and rivers that drain the upper Mississippi River basin.

But last summer, when the soil was still saturated from the spring rains, something peculiar happened: The jet stream swung south, and cool, dry air dropped down from Canada, colliding with warm, moist air pumped

Long-shot disaster

The millions of people who live along the upper Mississippi and its tributaries have long known that the generous river—source of transportation, recreation, and fertile bottomland—had a mean streak. But few had imagined it could rage as it did last summer. Like a marauding army, the water invaded by day and by night to overwhelm all in its path, lay waste, and retreat, leaving in its wake death, destruction, and a colossal mess. Some 50 people were killed, and damages were estimated at more than ten billion dollars. Rain and floodwaters spread over 23 million acres north of Cairo, Illinois. Downstream the Mississippi's channel was wide and deep enough to keep the flow within its banks. Soggy Midwesterners took small comfort from official pronouncements that the disaster was "in excess of a 100-year flood"—placing at less than one in a hundred the chance of a similar flood happening in any given year. With the ground still saturated and many levees unrepaired months after cleanup got under way, more heavy flooding added to the fear that the Great Flood of '93 would cause havoc in '94.

Reservoirs along the upper Missouri captured much of the runoff in Montana and the Dakotas—saving communities downriver from even worse flooding.

Record-shattering rainfall was caused in part by a Bermuda high that expanded into the southeastern U. S. and stalled, blocking the Pacific storms that normally cross the nation's midsection. Meanwhile the jet stream had plunged farther south than usual. Cool, dry air collided with warm, moist Gulf air pumped north by the Bermuda high. The result: prolonged torrential rain.

Total precipitation in feet (April-August 1993)
- More than 3
- 2-3
- 1.5-2

Rivers affected (selected)
- Record flooding
- Major flooding

River stage
- City
- Peak-stage date
- Peak 1993 stage
- Flood stage

Levees eligible for federal funding
- Effective levee
- Overtopped or breached levee
- Dam and reservoir affected
- Water-supply plant affected

Fifteen percent of the country's freight moves by river barge, with a dozen or more of the 195-foot-long barges tied together and guided by towboat. Principal highway for this traffic, the Mississippi was closed to shipping above St. Louis for two months, idling millions of tons of grain, fertilizer, and coal. The flood also scrambled train schedules by washing out tracks and bridges.

Lake Superior

MICHIGAN

WISCONSIN

MINNESOTA

IOWA

ILLINOIS

INDIANA

KENTUCKY

TENNESSEE

MISSOURI

KANSAS

OKLAHOMA

ARKANSAS

Duluth

St. Paul
June 26
19.3 ft
14 ft

Minneapolis

Mankato

Mankato
June 21
20.1 ft
12 ft

Sioux Falls

Sioux Falls
July 7
23.8 ft
18 ft

Estherville

Estherville
June 30
15.4 ft
7 ft

La Crosse

Green Bay

Rockton
June 30
12.4 ft
8 ft

Madison

Milwaukee

Clinton
July 5
20 ft
15 ft

Rockton

Waterloo

Des Moines
July 11
20.7 ft
12 ft

Cedar Rapids

Clinton

Chicago

Gary

Des Moines

Omaha

Nebraska City
July 23
27.2 ft
18 ft

Rock Island

Lincoln

Nebraska City

Peoria

Quincy
July 13
22.1 ft
17 ft

Nauvoo

Keokuk

Meyer

Quincy

Hardin
Aug. 3
23.2 ft
15 ft

Springfield

Kansas City
July 27
18.9 ft
12 ft

St. Charles
Aug. 2
40 ft
33 ft

West Quincy

Hannibal

Jacksonville

Kampsville

East Hardin

Jerseyville

Grafton
Aug. 1
20.2 ft
14 ft

Hull

Hardin

Area covered by satellite images on pages 65-7

Grafton

Portage Des Sioux

St. Louis

Topeka

Topeka
July 25
34.9 ft
28 ft

Kansas City

Hermann

Columbia

Valmeyer

St. Louis
Aug. 1
40.8 ft
30 ft

Jefferson City

Tabo

Ste. Genevieve

Kaskaskia Island

McBride

Jefferson City
July 30
30.6 ft
23 ft

Cairo
Aug. 7
45.8 ft
40 ft

Springfield

Carthage

Cairo

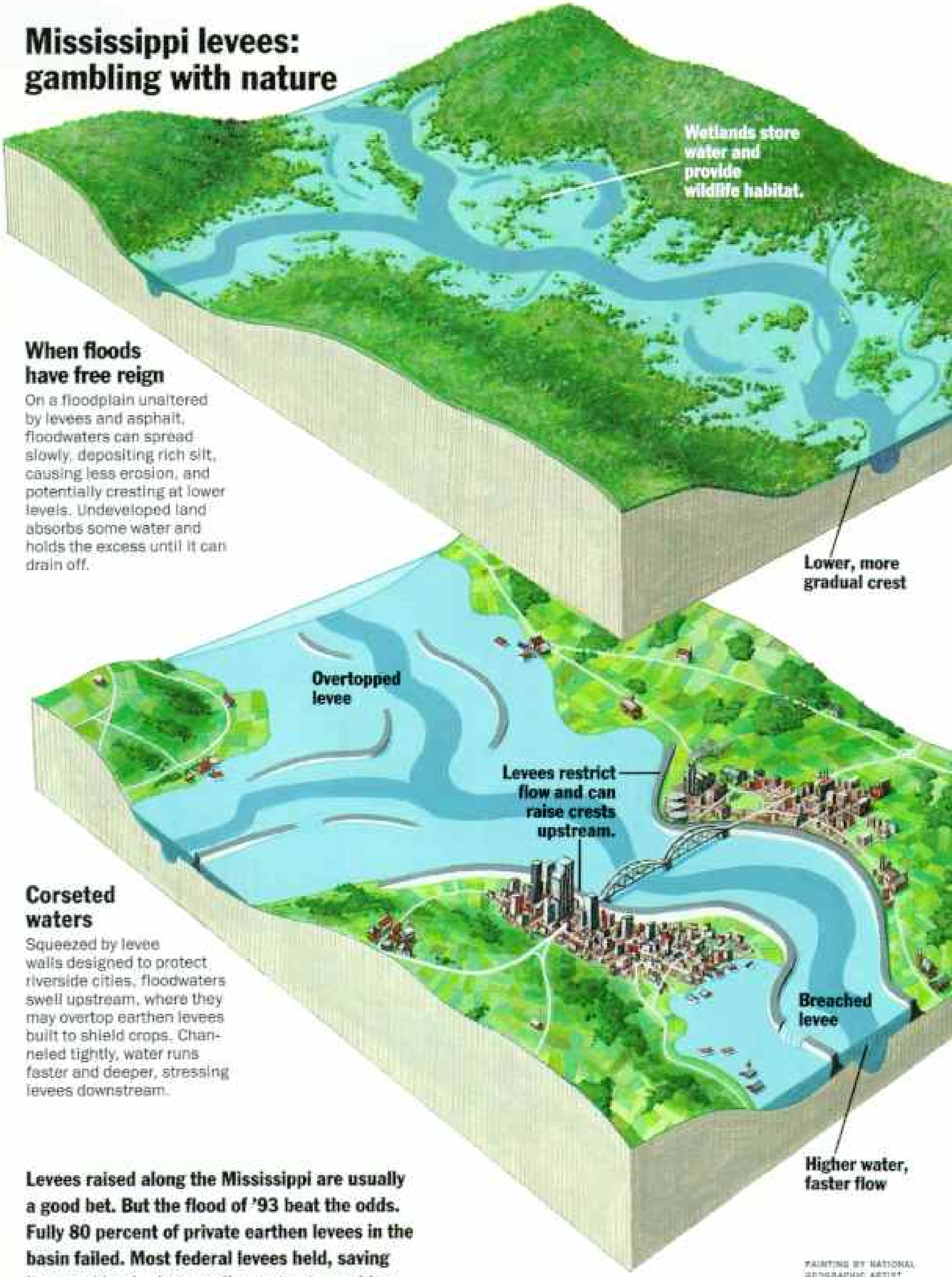
New Madrid
Aug. 8
34.8 ft
24 ft

New Madrid

Miami

0 50
MILES
RICE CARTOGRAPHIC DIVISION

Mississippi levees: gambling with nature



When floods have free reign

On a floodplain unaltered by levees and asphalt, floodwaters can spread slowly, depositing rich silt, causing less erosion, and potentially cresting at lower levels. Undeveloped land absorbs some water and holds the excess until it can drain off.

Corseted waters

Squeezed by levee walls designed to protect riverside cities, floodwaters swell upstream, where they may overtop earthen levees built to shield crops. Channeled tightly, water runs faster and deeper, stressing levees downstream.

Levees raised along the Mississippi are usually a good bet. But the flood of '93 beat the odds. Fully 80 percent of private earthen levees in the basin failed. Most federal levees held, saving lives and land—but sending water toward less protected fields and towns. An old debate flares again: whether to rebuild the levees or let a more natural floodplain face the next big flood.

PAINTING BY NATIONAL GEOGRAPHIC ARTIST CHRISTOPHER A. KLEIN

National Geographic, January 1994

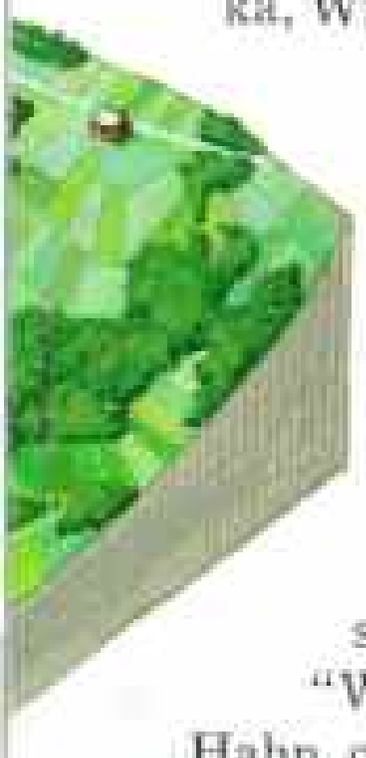
north into the central plains from the Gulf of Mexico. The resulting thunderstorms would normally have swept off to the east but were blocked by a high-pressure system called a Bermuda high, which had stalled over the East Coast. The storms stayed put, and the rains kept coming . . . and coming.

Places like Cedar Rapids, Iowa, got doused with nearly three feet of rain from April through July—a year's worth in four months. Concordia, Kansas, had more than twice its normal rainfall in the same period. The summer of '93 was the wettest on record for Minnesota, Illinois, Iowa, and the Dakotas and was much wetter than normal for the entire region.

With the rivers running high, the U.S. Army Corps of Engineers could no longer operate its locks and dams on the Mississippi, so it began closing them in late June, stopping all barge traffic north of Cairo, Illinois. Normally placid rivers became so treacherous that the Coast Guard prohibited virtually all boat traffic on 500 miles of the Mississippi between St. Paul, Minnesota, and St. Louis, Missouri. In Des Moines, Iowa, the Raccoon River overran its banks and knocked out the city's supply of drinking water for more than two weeks (see following article). Circumstances like these prompted President Bill Clinton to declare a major disaster in large parts of Illinois, Kansas, Minnesota, Missouri, the Dakotas, Nebraska, Wisconsin, and in all of Iowa.

CAMERON DAVIDSON

Rapids rage at an overtopped Illinois levee as floodwaters race south to engulf the town of Valmeyer and 65,000 acres around it. "The corn's brown and good for nothing. We need a bumper crop next year," says farmer Allan Englerth.

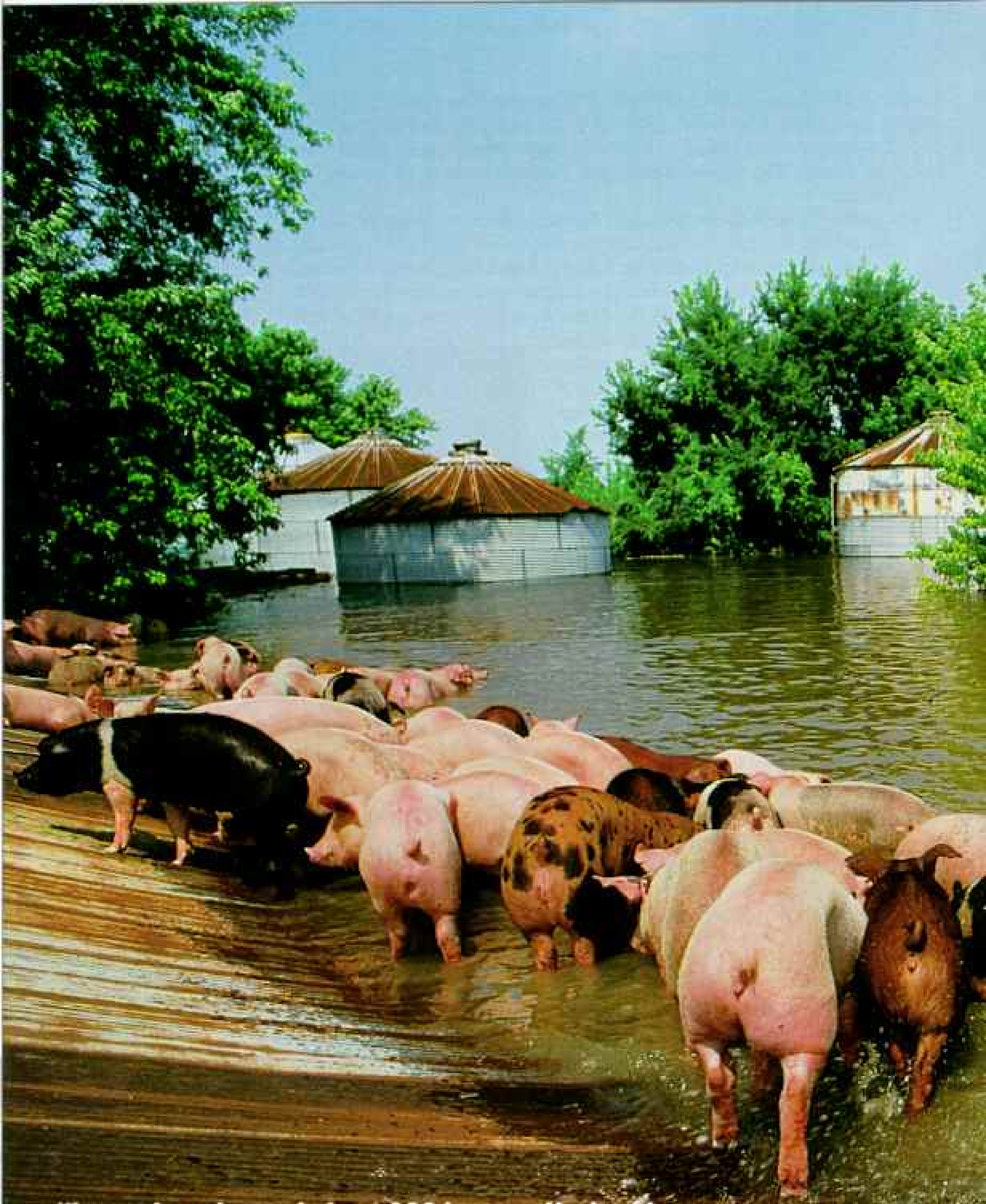


Mid-disaster, I stopped by the Army Corps of Engineers' Emergency Operations Center in St. Louis. Telephones jangled continually, a television was tuned to the local news, and the walls were covered with oversize maps showing river levels and major levees. It was as if a full-scale military campaign was being waged up and down the river.

"We're trying to advise people as this thing unfolds," said Emmett Hahn, chief of the operations center, pointing to his assistants working the telephones. "One of them is responsible for allocating sandbags. One is in charge of water pumps. One coordinates our helicopters for reconnaissance flights. And one does situation reports."

Hahn told me he'd already worked 38 consecutive days, and he looked it. His face was gray and gaunt, and his eyes were bleary from lack of sleep. The freak weather, the size of the flood zone, the fact that the Mississippi and Missouri Rivers were going to meet and crest at the same time, creating even higher water—it was enough to keep anyone awake.

"This is like watching a disaster movie like *The Towering Inferno*," said Hahn. "You leave the movie thinking, 'That was exciting, but it would never happen in real life because you couldn't have all those events at one time.' But that's what's happened."



"I must have hugged about 300 hogs on Kaskaskia that day," says Randolph County Sheriff Ben Picou, who wrestles panicked pigs—some stranded five days—from the roof of a barn. Fifty died as the Mississippi rolled over the Illinois island.

JIM RICHARDSON

PAUL CHILDRESS

A disaster movie . . . maybe that was the inspiration for the message I had seen scrawled on a blackboard at a National Guard Armory: "The Mississippi," it said. "Coming soon to a town near you."

MORE THAN A WEEK before Jeff Lorton and his family had cleared out their bedroom closets, the fear of flood had gripped their community. The Illinois River, which separates the town of Hardin from the farms of East Hardin, normally flows 20 miles south before emptying into the Mississippi River. With all the rain, the Mississippi was already far too full, so it backed up along the Illinois River, which swelled like a blocked blood vessel.

People here fought the flood on two fronts. On the east side of the river

they filled sandbags and stacked them, mile after mile, on top of the Nutwood Levee to build it higher. Usually the levee stands 21 feet above the river, but by mid-July water was licking the top. National Guardsmen pitched in to help, as did local housewives, farmers, children, retired folks, businessmen, and inmates from a nearby correctional center. Trucks and all-terrain vehicles would have been a big help hauling sandbags to critical spots on the levee, but they stood idly by: The earth was so saturated that engineers feared the vehicles' weight would cause the levee to collapse. It was slow, strenuous going.

"I did more physical work yesterday than I've done since I did a 26-mile road march in the Marine Corps," said Capt. Pat Smallwood of the Illinois National Guard. He looked over his company, sweating in the sun. "These people are really kicking butt. No whining, no complaining."

On the other side of the river, where there was no levee, people battled block by block, building by building, trying to keep the river at bay. The Hardin Drive-In, a local restaurant, looked like a bunker. It was surrounded by water and by sandbags that almost reached the roof. I could see someone scurrying around inside, monitoring the water pumps that pushed the river back out faster than it seeped in.

"We've already lost the nursing home, the medical center, and the grain elevator," Mayor Bill Horman told me. "Now we're just trying to keep the secondary roads open so people can get out of the county."

To that end, orange trucks from the Illinois Department of Transportation barreled into town, dumping tons of crushed stone on low-lying roads to elevate them and keep them dry. Park Street, one of the main routes out of town, was more than six feet high.

Concerned that the rising river might contaminate the town's well, the Calhoun County Health Department instructed people to boil their tap water before using it. Tetanus shots were recommended too; the river had run into sewers, which backed up through toilets and bathtubs, down the halls, and out into the streets.

"We're telling parents to keep their kids out of the water, but it's so inviting when it's so hot," said nurse Judy Zahrli, who was giving free tetanus shots in the hallway outside the school cafeteria.

Inside, local women served home-cooked meals, brought from all over Calhoun County, to 1,500 people a day. Gena Sievers brought her barbecued pork; Evie Nolte made scalloped potatoes; the pickled beets and

Bob Ernst calls home (opposite) from McBride, Missouri, as water rolls toward town from a busted levee ten miles away. McBride was still dry (lower left) ten hours after the break, but by 5 p.m. the water had arrived. "It's a total loss," says Bud Holland of his home (below, at far right), which eventually filled with 12 feet of water. "I figured on spending the rest of my life there, but it didn't take the river long to change my mind."

JIM RICHARDSON (ABOVE AND LEFT)

the brownies were courtesy of Vera Tepen; and Mary Schneider brought fresh tomatoes from her garden.

The daylight had disappeared, but the heat lingered when I joined 20 people sandbagging at the corner of Park and Franklin Streets. Porch lights from houses glittered on the water and broke the darkness. We worked in pairs—one person held an empty bag, the other shoveled in sand. We heaved the bags onto a forklift, which trundled down the street with a full load, shored up a bunker, and came back for more. For a while I worked with Al Parker, from the house on the corner. Then with Kristine Blahut, who saw the flooding on television and drove seven hours from Indianapolis with a friend to help.

The National Guard coordinated the delivery of truckloads of sand. A neighbor brought us sandwiches and cold drinks. And from a radio in the pickup truck parked on the sidewalk came song after song, two of which I still remember: "Fool on the Hill," by the Beatles, and the Animals' "We Gotta Get Out of This Place."

Sheets of river water churn brown as they rumble off the shoulder of a highway north of Hermann, Missouri, after exploding through a breached levee a quarter mile away. "It sounded like a freight train for a couple of days," says Carl Humm, whose house sits safely on a hill overlooking the highway. When the rampaging water receded, it left a road stripped of blacktop, with potholes 45 feet deep.

We shoveled and sweated. Midnight came and went. Thunder and lightning rolled in from the west. Then more rain. The river crept up the street. It didn't look particularly powerful or menacing, more like the edge of a big puddle—shallow, calm, seemingly harmless.

THE NEXT DAY—July 18—water overtopped the Nutwood Levee on the other side of the river. On a hillside overlooking the levee district, local residents gathered to watch the flood. They were subdued, though not visibly depressed. Stretched out on the grass with cold beer and sandwiches, they chatted and commiserated as the disaster unfolded before them.

In the distance the Illinois River spilled over the levee's low spots, then sliced through the sodden earth like hot tea through a mound of sugar. The gash widened and brown water spread over the fields of corn and soybeans, around houses and barns. It inched north toward East Hardin, flushing out a deer, which raced away from the flood's leading edge.

"Crop insurance?" said one farmer when I asked about his coverage. "If you've farmed 70 years and never had this problem, you don't figure you

JIM RICHARDSON

need it. The levee is the crop insurance." The farmers beside him stared out at the water, poker-faced.

That evening the river's long, dark fingers slid over the road leading to the Joe Page Bridge. Slowly, deliberately, the river closed its hand around lawn ornaments, abandoned cars, mobile homes, and a few businesses.

Back in Hardin the next morning, four people on Cemetery Hill were gazing over more than 11,000 acres of flooded farmland they call the Bottoms.

"Whose house is that?" said one, pointing to a distant rooftop poking out of the water.

"I'm glad it ain't mine," said another.

"I heard Jim and Peg's caved in."

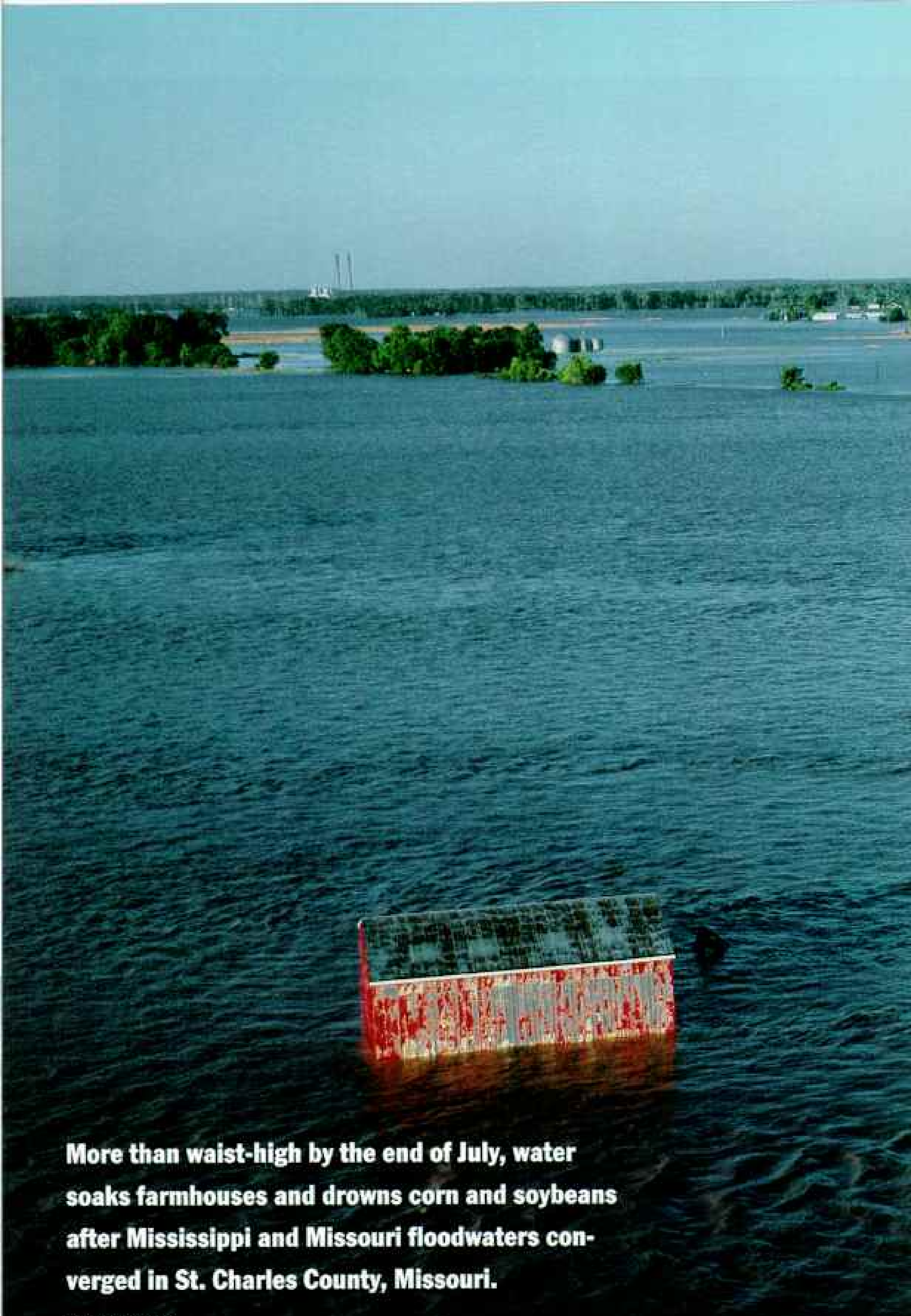
"I heard Papa's Pizza fell off its foundation."

Down at the canteen, Jeff and Sandy were anxiously trying to find out what had happened to their farm. Ed Hazelwonder, a neighbor, had just returned from inspecting the flooded area, and Jeff pulled him aside.

"How high on my second story?" asked Jeff.

"It's almost up to the window," Ed answered.

Jeff looked at Sandy. "It's over that stuff *(Continued on page 68)*



More than waist-high by the end of July, water soaks farmhouses and drowns corn and soybeans after Mississippi and Missouri floodwaters converged in St. Charles County, Missouri.

CAMERON DAVIDSON

NICK RICKMAN

Currents of anxiety charged St. Louis the night of July 31. All eyes scanned the lightning-etched skies as storm after storm struck the area. On every mind was the floodwall. Designed to protect against a 52-foot crest, it resisted a river swelling to 46, 47, 48 feet.

The next morning the Mississippi crested at 49.6 feet, but sighs of relief were bittersweet: Downriver a levee had been overtopped, opening a drain for St. Louis but submerging 14,000 acres of farmland south of Columbia, Illinois.

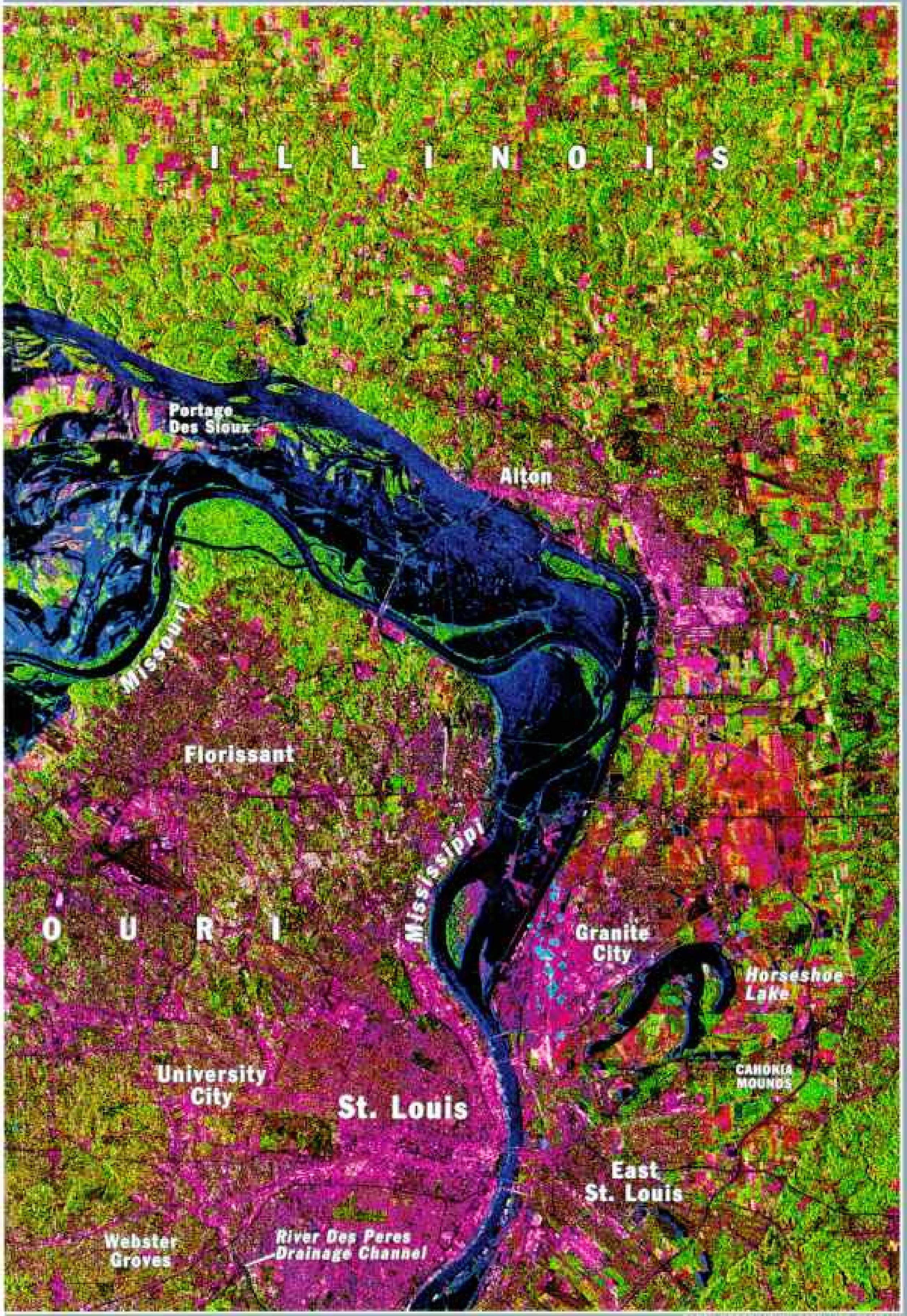
A space-age look at the flood

You "cannot tame that lawless stream," wrote Mark Twain in 1883. "Cannot save a shore which it has sentenced."

The Mississippi flows 2,350 miles from its headwaters at Lake Itasca, Minnesota, to the Gulf of Mexico. Draining 31 states and two Canadian provinces, the river system nourishes farmland and generates energy for homes and industries. Sometimes, though, when conditions are ripe, it turns on those it serves.

A satellite image from late August 1982 (right) shows the confluences of the Illinois and Missouri Rivers with the Mississippi near St. Louis. An image of the same area in mid-July (facing page) captures three rivers out of control. Water spilled over floodplains, engulfing entire towns. Weary of assaults inflicted by the rivers, groups in some 50 towns are considering relocating to safer ground.

GEOGRAPHIC RESOURCES CENTER, UNIVERSITY OF MISSOURI


ILLINOIS
Portage
Des Sioux
Alton
Missouri
Florissant
Mississippi
Granite
City
Horseshoe
Lake
CAHOKIA
MOUNDS
OURI
University
City
St. Louis
East
St. Louis
Webster
Groves
River Des Peres
Drainage Channel

(Continued from page 61)

we left in the bedrooms," he said grimly.

Her lip trembled. "Nathan's stuff is lost?"

Jeff didn't answer but dashed off in search of a boat while I waited behind with Sandy.

"I dreamt about the flood," she said. "I woke up hoping it was just a dream. I literally pinched myself. I didn't want it to be true."

That afternoon we went back to the Lortons' farm, docking our boat outside the second-floor window. Jeff punched out the screen, climbed inside, and waded through thigh-deep water, high-stepping over the carpets, which had floated free of the floor.

"I can still shoot a game of pool," Jeff yelled when he saw that the top of the billiard table was still above water. Out in the boat, I listened to him sloshing around and tried hard to think of something comforting to say to Sandy, who sat tearfully behind me. But what do you tell someone who has 14 feet of water in her house?

Jeff returned with a cardboard box filled with family photo albums, yearbooks, and football trophies his boys had won. Then we puttered back toward town, across the bottomlands, brushing the tops of ruined cornstalks, past concrete septic tanks floating free on a lakelike expanse, past empty sandbags that the flood fighters never had a chance to fill.

PAUL CHILDRESS

Later in the summer I would return to Hardin, but for the moment I followed the flood south toward St. Louis. The three rivers that converge near here—the Illinois, Missouri, and Mississippi—seemed to function as one live, pulsating organism with a will of its own, rising here, falling there, breaking this levee and sparing that one. Water might push and probe and knock over a community's defenses, then suddenly reverse direction and flow upstream through yet another levee break. Although you couldn't predict exactly when an area might flood and precisely who would get hit, certain patterns were immediately apparent.

"The majority of the people affected by this flood are poor," a disaster-relief expert told me. "They live where land and housing are cheap—in low-lying areas. That's the nature of the beast."

The suffering was immense—an estimated 50 people dead, 72,000 homes and 36,000 square miles affected, and more than ten billion dollars' worth of damage to crops and property. Yet the flood didn't cause violent, wholesale destruction or bring the Midwest to a sudden stop.

"After Hurricane Andrew a wide area was absolutely devastated," said Roger Schrage, relief operations manager for World Vision, which provides humanitarian assistance around the globe. "With a flood you may have a totally functioning society a hundred yards away, with supermarkets, medical services, and communications."

I knew what he meant. When I arrived in south St. Louis late in July, there were roadblocks and National Guardsmen along the River Des Peres Drainage Channel, which had flooded and forced the evacuation of thousands of homes.

A few blocks away a convenience store was open. So was a pawnshop and a gas station. And just 15 minutes from where people were building a levee of crushed stone along Germania Street, I saw tourists in downtown St. Louis at the Gateway Arch, gawking at the river, and baseball fans strolling into Busch Stadium to root for the Cardinals against the Mets. Life went on.

Yet no matter where people lived, whether their basements were wet or dry, they all seemed to have water on the brain. Where was it raining? When would the river crest? Any levee breaks recently? Every day the *St. Louis Post-Dispatch* featured a full-page spread on the flood, which included area-by-area summaries, phone numbers to get or give help, and a map with bar graphs listing the water levels along the rivers. When television weathermen pointed to a heavy thunderstorm in North Dakota or Iowa, everyone downstream knew that another surge of water would pulse through the system and eventually get to them. In the interim, people had time to prepare—and time to worry.

"Hurricanes are devastating, but at least they're over with quickly," said Ronald Van, a community-relations official with the Federal Emergency Management Agency (FEMA). "This is cruel. It just sits around."

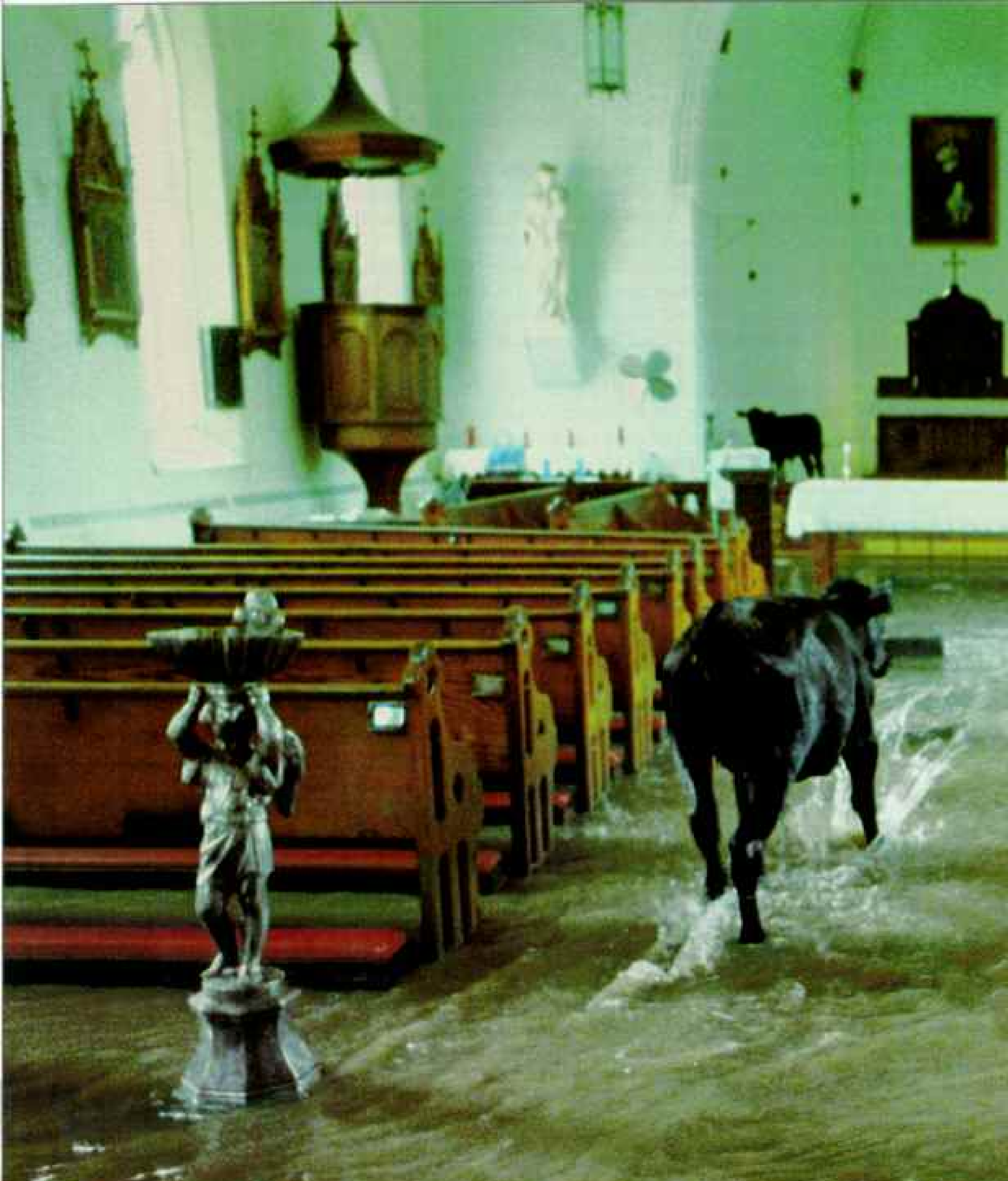
STE. GENEVIEVE, MISSOURI, is located right beside the Mississippi River, 55 miles south of St. Louis. Because it was situated in the lower end of the flood zone, the city had extra time to heighten and extend the levee that protects the downtown district.

Flying over the town with National Guardsmen, I saw the levee—a wall of crushed stone topped with sandbags that snaked through the streets, following the contour of the land. When I walked through the historic district later that day, most everything was closed—the 18th-century homes, the antique shops, the bed-and-breakfasts. With the levee looming 15 feet above Front Street, Ste. Genevieve felt like a walled ghost town.

The people hadn't fled, though. I found many of them at the parking lot behind the Catholic church, filling sandbags, while others were gathered at City Hall for the daily noontime meeting. Mick Schwent, the city's emergency-preparedness director, updated everyone on the key numbers—the height of the river and the height of the levee. The National Guard commander announced new deployments of troops. Other people reported on food deliveries, electricity and telephone service, tetanus shots, and the supply of sandbags and plastic sheeting. And what's this complaint about news photographers getting in the way?

"We told them to sandbag before taking pictures," someone shouted.

"You think that when you lay someone to rest, they'll be there for eternity," says Ray County Coroner Dean Snow. Yet when the Missouri River inundated a cemetery in Hardin, Missouri, coffins floated away. National Guardsmen recover a decades-old steel vault, among 700 vaults and caskets washed out of the 180-year-old cemetery. "We may never find them all," Snow says. "For the families, it's like grieving all over again."



"The good Lord was born in a stable, so I didn't feel he'd mind," says Coast Guardsman Dale Mobley, who helps herd drowning cattle into an Illinois church. As the makeshift ark filled with 13 feet of water, the cows were towed to safety.

DAVE WEAVER

"No need to let up now," Mick said. "That's what it's going to boil down to—walking these levees and watching these levees. We've won some battles, but we haven't won the war."

The rain came again that night, prompting the local radio station to go live with a bulletin: "We have an urgent request. It's raining, and that can create a problem with the levee if we don't keep up. We need sandbaggers and people with pickup trucks to haul bags."

The people turned out. Some helped build the levee higher; others walked along the top of it with flashlights, looking for soft spots, bubbles, or leaks.

"Don't worry about a slow trickle of clear water," said Bob Holst, a Ste. Genevieve cop, before I set out with three volunteers on a midnight levee walk. "But if the water's cloudy, that means material's getting washed out of the levee underneath you. Get off the levee and call us."

We grabbed four flashlights, one walkie-talkie, and one life jacket (I was the nervous one), then drove to the north end of town. We scrambled up the stony side of the levee and walked along the top in silence. We tried to inspect every square foot for half a mile or so, sweeping our flashlights back and forth in the darkness.

"Here's a leak," I said to Clem Joggerst, who came over for a look.

"It's OK. The water's clean."

As the water pumps droned on, we walked through the empty town, the roofs of houses on one side of us, the Mississippi on the other. Utility poles marched off into the distance, toothpicks on the flood. Every hour we reported back to City Hall by radio: "This is levee walker number two—condition green," Steve Marshall would say, signaling that we'd found no problems.

For a force of nature so threatening to so many, the river seemed oddly quiet beside me. It was flat, motionless, yet I knew it was leaning hard against the levee, pushing at the stones with all the weight of the summer storms. When I thought about that, the levee felt fragile—so I tried to think about something else. I was relieved when our shift ended at 3 a.m.

Ste. Genevieve emerged from the flood of '93 in relatively good shape. In part, the town was lucky: The nation's largest lime operation and seventh largest quarry are located just outside town, and they provided tons of crushed stone for the levee. The city was well organized too, mobilizing and deploying people and provisions with great efficiency.

"We're running a paramilitary operation," said David Angerer, the city administrator who served as the town's supply officer during the emergency. "I can't wait to get back to mundane stuff like dealing with stray dogs, streetlights, and property-line disputes."

With rising water sloshing around the wheels, a worried Eleanor Bowman peers over the side of a pickup truck in Hardin, Missouri. "It's going to be a long time," she says, "before people around here don't panic every time it starts to rain." The emotional strain visits at all times of day and night. Many flood victims report recurring dreams of filling sandbag after sandbag, only to see the bags washed away by the relentless water.

THE WALL THEY BUILT in Ste. Genevieve was a hastily constructed addition to more than 2,000 miles of levees on the upper Mississippi and its tributaries. Even before the flood began subsiding, critics of this system were pointing out its shortcomings: Out of 1,576 public and private levees in the river basin, 70 percent failed last summer. These structures, say the critics, straitjacket rivers that God intended to meander and, as a result, actually exacerbate flooding.

"Water that was formerly allowed to spread over many thousand square miles of low lands," observed civil engineer Charles Ellet, Jr., "is becoming more and more confined to the immediate channel of the river, and is, therefore, compelled to rise higher and flow faster."

Ellet wrote those words in 1853, but flood experts echoed them throughout the summer of 1993. At a public forum in St. Louis, I heard one of them,

a hydrologist named Jay Lehr, suggest that we think twice about rebuilding broken levees.

"Every levee is obsolete as soon as it's built, because it's based on the land as it currently exists," he told a crowd gathered at the county library. "But as soon as you build a new town or clear-cut a forest, you change the numbers, you change the amount of water that goes into the river, and therefore you're facing an almost insurmountable engineering task."

To contain the ever increasing volume of runoff into the river, we've built the levees higher and higher. The earliest ones on the Mississippi, for instance, built in 1717 to protect New Orleans, now loom 20 feet above the river. And although the Army Corps of Engineers says levees don't make the Mississippi flow faster, some watermen argue otherwise.

"We were running 600-horsepower boats when we started our business in '72," Ronnie Inman told me. Inman, who ships limestone from Ste. Genevieve downriver to New Orleans and Mobile, said that as the Mississippi has been constricted, its currents have grown more powerful. "Now we're running 1,200-horsepower and just holding our own. Yes, we're running bigger barges, but the currents are bigger too."

The other side of the story was crisply explained to me by K. C. Ringhausen. I met him on the East Hardin side of the Joe Page Bridge, where he was staring at his flooded fruit-packing plant.

"The problem isn't the levee," he said. "The problem is the weather. We usually get just a few inches of rain in July. This year was different."

In other words, the levees did what they were designed to do, but they were never meant to control a flood like the one last summer. So the criticism of the levee system wears a bit thin on Maj. Gen. Stanley Genega, director of civil works for the Army Corps of Engineers. The corps designs, constructs, and inspects about a fifth of the levees in the region. Genega bristled when I repeated an environmentalist's criticism, which characterized the corps's flood-control efforts as a "military campaign against nature."

PAUL CHILDREES

"It's a catchy phrase," he said. "But any look at the river that does not also consider the structures that provide for recreation, water supply, navigation, and the farm economy doesn't meet the mark. We've got all those interests to consider, along with flood control.

"There's no intent on the part of the Corps of Engineers to line the Mississippi with concrete," he said. "But do we want to relocate St. Louis and New Orleans? Some of these levees breached because they were built to hold water for days or a week, and they were asked to hold water for months."

To the critics who say the corps shouldn't rebuild its levees that failed, Genega says there's an expectation and an obligation to repair them as quickly as possible.

Levees and dams have long been the pillars of federal flood-control policy in the United States, and in the main they've done their job well, perhaps too well. People moved onto the land reclaimed by levees because the soil was fertile and the property was cheap. But in the process the reconstituted river lost its bordering floodplain—the wetlands that would have held water when the river overflowed.

As the flooding continued through summer, a national debate on flood control and wetlands policy captured the headlines.

The *St. Louis Post-Dispatch* called on Congress to spend more money on the Wetlands Reserve Program, which pays farmers to restore and protect wetlands on their property. The program's original goal was to restore one million acres by 1995, but only 50,000 acres are enrolled in the program to date. A thousand farmers are waiting to sign up another 200,000 acres.

A columnist writing in the *Wall Street Journal* asked why taxpayers should provide billions of dollars in flood aid when only 13 percent of the homeowners who live in flood-prone areas bother to buy federally subsidized flood insurance.

"Those who don't buy aren't stupid," he wrote. "They know that the

JIM RICHARDSON

government will step in with disaster relief." His recommendation: Stop subsidizing the National Flood Insurance Program and let insurance premiums rise to reflect the risks of living on a floodplain. Those who can't afford the insurance and who know the government won't bail them out, won't live on floodplains.

IF YOU KEPT PEOPLE OUT of floodplains, there would be no Grafton, Illinois. A low-lying strip of land that just barely overlooks the confluence of the Mississippi and Illinois Rivers, Grafton is unprotected by floodwalls or levees. So when the rivers rise and creep into Grafton, residents do what they've always done—retreat.

Most of them had already fled to higher ground when I arrived there in July, but I found one elderly couple still at home. Ginnie Eller greeted me with a warm smile and told me about the biggest flood she'd seen in Grafton, back in 1973.

"I'll show you where the water came up to then," she said, ushering me toward the back of the house.

"No, you won't," said her husband, Al. "It's underwater." Outside the sliding glass doors, the river was 15 feet deep. Boats cruised by, making waves that lapped at the backyard deck before rolling into the flooded basement, jostling some logs that banged loudly on the floorboards. And the water was still rising.

"I think it's going to take a miracle this time," said Ginnie.

"She's got everyone praying for us," said granddaughter Sheri Richards, who had come by to help pull out the carpet and move furniture out to the front lawn, which was still above water. Chairs, a sofa, end tables, fans, a television were all on the grass outside. So were the refrigerator and freezer, sitting beside a storage shed and humming away in the 90-degree heat.

I asked the Ellers why they didn't sandbag the house.

"We live on the river," Sheri answered. "Let it come."

That live-and-let-live attitude no longer satisfies Grafton's mayor, Gerald "Windy" Nairn.

"This is the sixth big flood we've had in the last 20 years," Nairn told me. "We keep losing our sewers, houses, and businesses, and this time we almost lost our water plant. I bet we've lost $40,000 in sales tax this year. So we sat down and decided we need a plan."

High, dry, and unreachable, Memorial Bridge stretches in silence over the Mississippi between West Quincy, Missouri, and the tantalizing lights of Quincy, Illinois. With the ramp to nearby Bayview Bridge also underwater, local officials arranged ferry, airplane, and helicopter service to link the two states. More intrepid commuters made the trip in private boats.

On tiptoes in dirty water, Harold Verdot and daughter Crystal salvage little from the family's trailer in Taos, Missouri. "We went out there by boat," says Harold, "and swam in through the door."

RICH SUGG, KANSAS CITY STAR

Mocking an American icon, the Mississippi moves inland one mile to swallow a five-foot McDonald's entry sign in Missouri. Upriver in Portage Des Sioux, shoppers buy food fast before their market goes under. Store owner Don Delaney—whose inventory was uninsured—faced a grim cleanup: "We found catfish and a lot of frogs." Some 3,200 Missouri businesses were flooded.

The plan is to move much of the town from the floodplain to higher ground—"if the money's available," said the mayor. He claims that 40 percent of the homes and businesses will qualify for a federal buyout, which would help pay for Grafton's rehabilitation. The estimated total cost: 25 million dollars.

"It's big money," said David Fingerhut, a consultant to the mayor. "But per head, it's a bargain. The Red Cross, the Salvation Army, the National Guard—they'll all save money. And if you're a business person or homeowner, what's your choice? The water starts going down, maybe you get a little FEMA money or flood insurance, and you clean up. Now if you use that money and go back into your house and next year you've got the same situation, is that a prudent investment?"

Al and Ginnie Eller didn't think so.

"We talked about leaving after the '73 flood, and I think we'll leave after this one," Ginnie told me. "We're too old to fight it any more."

Her son, Jerry, had heard such talk before. "River communities are funny," he told me. "It floods and everyone says they're gonna move. But when the water goes down, they fix up their houses so they can sell 'em. Then, four months later, the place is lookin' pretty good, so they stay. It's a vicious circle."

WHEN I RETURNED TO HARDIN in late July, the whole town seemed on edge. The farmland east of the Nutwood Levee was still underwater, and a storm had finally knocked out the remaining sandbag fortifications downtown. Although the rains had finally stopped, the floodwater lingered, hanging around like a smelly, boorish, uninvited houseguest. It buckled floors, soaked through walls, and frayed people's nerves.

"We can't get to the next phase of recovery until the water's out of the houses," said Carol Theler, a volunteer who ran the Red Cross Relief

BILL GREENE

Center and Shelter nearby. "We go to Plan C, then Plan D, then Plan E. We're running out of letters of the alphabet. Everybody's frustrated."

With high water still blocking the Joe Page Bridge, Hardin's residents were forced to commute long distances on and off their peninsula. What used to be an 18-mile trip to the nearest good-size town, Jerseyville, now required a hundred-mile detour, much of it over unpaved country roads.

To shorten the supply line, the National Guard flew a chopper to Hardin several times a day, airlifting food, drinking water, disposable diapers, insect repellent, and, one day, a couple of detectives from Kansas. They had an arrest warrant for a murder suspect, but they couldn't find him.

"Things are getting a bit tense," said resident Jill Smith, who had stopped by the grade school with her video camera to get some shots of all the free food available in the gymnasium. "I think they should start putting tranquilizers in the water."

The public pool was shut. The county fair had been canceled. And many local businesses were struggling—or had closed.

"Business stinks," said Corbett Miller, co-owner of the local Ford dealership. "We laid off half our crew and haven't sold a new car in the county since the beginning of July."

Down at the county offices, treasurer Curt Robeen looked glum, surrounded by stacks of property-tax notices. They had been stamped and ready to mail for at least two weeks.

"I'm afraid to send them out," he said.

MARK CARDWELL, REUTERS

THE WATER finally began to retreat from Hardin in mid-August. On the east side the river was draining out the same way it had come in—through a hole in the Nutwood Levee. In downtown Hardin the river slowly slipped back into its bed.

Yet it left its muddy mark behind. A skirt of dried scum stained the sides of every building touched by the river. Trees, stripped of their leaves, were naked from their waists down. Houses sagged and stank, as if they'd aged a hundred years in just a few weeks.

On Kennedy Street I found Dennis and Beth Kronable cleaning up her mother's house. Although four feet of water had filled the first floor, the walls were ruined up to the ceiling; the insulation had wicked the water high above the flood line, dappling the white drywall with green and black splotches of mold.

Dennis and Beth peeled away the drenched drywall, soft as an overripe banana skin, and pulled out the insulation. They removed mud-caked kitchen appliances and bathroom fixtures, hosed down the floors, and shoveled out debris.

Luckily, they had some help from the Southern Baptist disaster-relief program, which had sent volunteers from North Carolina to Hardin a few weeks earlier. They had arrived with a tractor trailer equipped to prepare

hundreds of meals every day, giving the local women at the canteen a much needed rest.

"Those guys," said Beth, " 'angels from heaven,' we call them. I don't know what we'd do without 'em."

They would probably rely on the Red Cross, the Salvation Army, or the gaggle of government agencies—FEMA, the Small Business Administration, the Soil Conservation Service, among others—that had come to Hardin offering disaster relief. Soon Washington would authorize 5.7 billion dollars to help flood victims in the Midwest.

A fetid gumbo of algae, soybeans, and rotting cornstalks fills houses in Hull, Illinois, where a Chicago volunteer scoops out mud and mildewed debris in a slow cleanup effort. Despite major losses, some people will return to the town.

"We wouldn't think of moving," says neighbor Jeanie Cox, whose husk-draped mailbox was one of the few structures left undamaged. "This is where our history is. We just have to hope that this will never happen again."

SOME PEOPLE in East Hardin would go right back to their old homes and rebuild, using whatever assistance they could get.

For instance, I met Gene Snyders at a Red Cross disaster-assistance center, where he was applying for vouchers to buy food and clothing. His trailer had been wiped out, but he planned on moving back to the Bottoms as soon as he could find another trailer.

"I've got 46 years in that place," he said, looking me square in the eye. "That's home to me. I'm not crazy about moving somewhere else."

Ruth Johnson, also from East Hardin, wasn't certain where she would live but knew one thing for sure—she would never return to her old house, where she had lived for almost 20 years with her husband and four children.

"Even if we have to start broke all over again, we will not go back. That house is dead," she said. "I will leave it in its watery coffin, and I won't go back."

By the time I caught up with Jeff Lorton again, he looked happier than I had seen him all summer. He had just purchased 15 acres of land on the top of Rocky Hill, where, high above the floodplain, he planned to build a new home.

We hopped in my car and drove away from the river, up a steep road for a mile or so. Near the top of the hill we stopped and got out. A bulldozer was plowing a path for Jeff's new driveway.

"That's my old place way over there," he said, pointing through the haze to the Bottoms, still underwater. "We'll keep the hogs down there, and we'll work down there, but we'll live up here."

RICK RICKMAN

He turned and faced the bulldozer. "My driveway will come up this way," he said, tracing the path with a sweep of his arm. "And I'll put the new house right here." We were standing on his future front lawn. "The house'll be exactly like our old one, except I'll move the living room so we'll have a better view."

That's Jeff's plan, anyway. It all depends on when—and if—his flood insurance policy pays off.

If he's lucky, then sometime soon a typical summer day with the Lortons should look something like this: After Jeff, Sandy, and the boys finish their morning chores, they'll drive up Rocky Hill for their big midday meal. Off to the east, they'll see hills, green with foliage, and farmers riding tractors in the fields below. Cars will come and go across the Joe Page Bridge, and barges will work the Illinois River. And the river itself will be back within its banks, muddy and meek and right on course, slipping silently beside the floodplain it had briefly reclaimed.

It promises to be a beautiful view—as long as the weather holds. □

National Geographic EXPLORER will air a film on the Mississippi flood on Sunday, January 23, at 9 p.m. ET on TBS Superstation.

Des Moines, Iowa

Riding Out the

By BILL BRYSON

IT HAPPENED with terrifying swiftness on a Saturday afternoon. After the wettest spring and summer anyone in Des Moines could remember, a downpour dumped as much as eight inches of rain in just four hours into the watershed of the already ominously swollen Raccoon River in northwestern Iowa. The result was far worse than anyone had expected. A 27-foot crest of water—15 feet above flood level—rolled through the city on a collision course with the equally engorged Des Moines River.

Watching the news reports on television from 4,000 miles away in England, my adopted home, I had a particular reason for wanting to go there. Des Moines is my hometown.

I arrived on Friday evening, July 16, six days after the flood struck, to find a city wearing the air of a long-standing siege. National Guard trucks laden with sandbags rumbled through nearly empty streets. Lines of people filled water bottles from big plastic tanks and collected supplies from a relief center.

Fleur Drive, the main thoroughfare between the airport and downtown, a street I had driven along more times than I could count, was barricaded just short of where its four lanes plunged disconcertingly into water. Beyond the barricades, where normally there stood two large parks, there was nothing but a mile-wide expanse of silvery water, surreally dotted with stranded treetops. The modest Raccoon, normally plodding on its meandering course half a mile from here, had become a fierce and swift-flowing Amazon.

I got out of my car and walked to the barricade, dumbstruck by the sight of a familiar landscape so utterly transformed. Water lapped at sandbagged businesses along Bell Avenue and made an island fortress of the stately brick waterworks plant, which had been knocked out by the flood, making Des Moines the largest U. S. city ever to be entirely without running water.

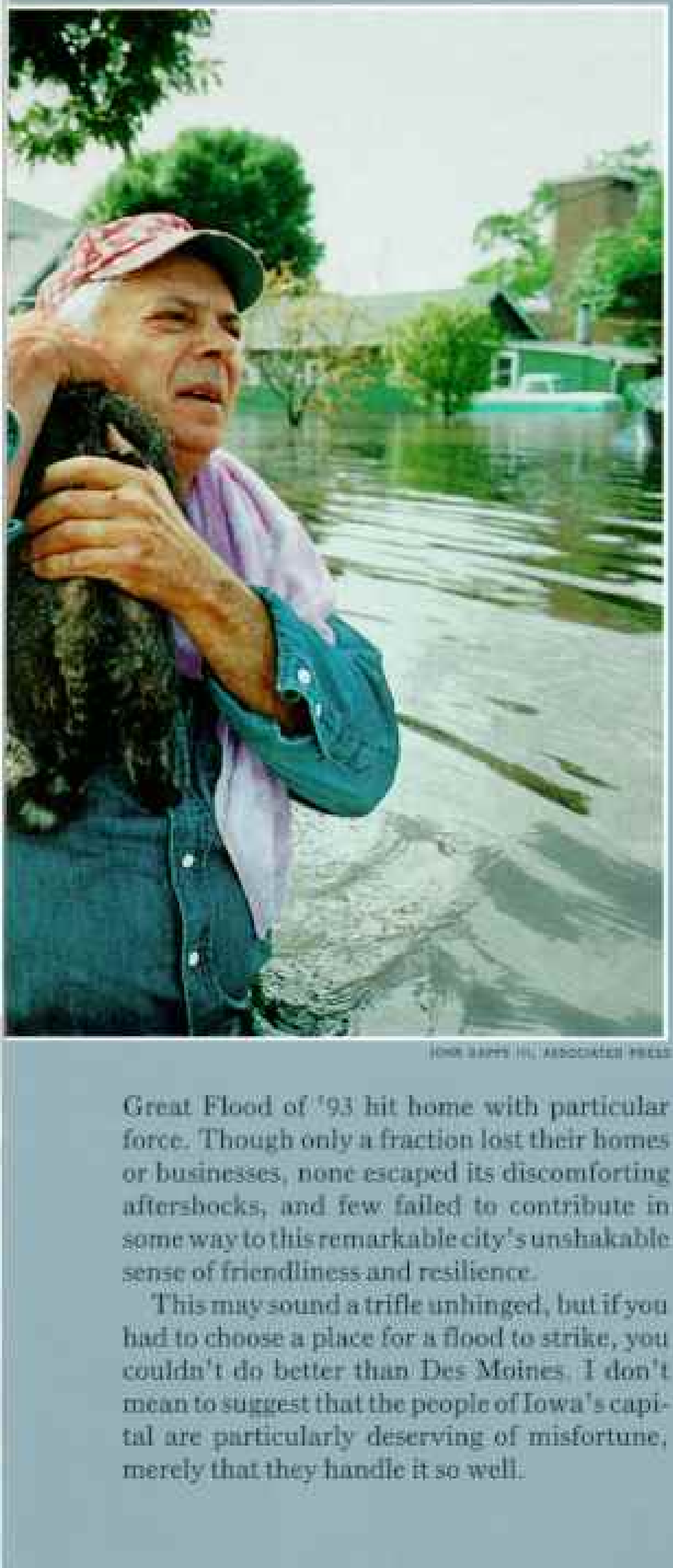
After a minute I realized a National Guardsman posted at the barricade was standing beside me, staring thoughtfully at the scene before us. "You see these things on TV," he remarked at length, to himself as much as to me, "but, you know, it doesn't really hit home until . . . well, until it hits home."

I knew precisely what he meant. For a quarter of a million people here in central Iowa, the

BILL BRYSON, who described his Iowa childhood in his book *The Lost Continent*, is a frequent contributor to NATIONAL GEOGRAPHIC. In September 1993 he wrote about Britain's hedgerows.

Worst of Times

Photographs by JODI COBB NATIONAL GEOGRAPHIC PHOTOGRAPHER



JOHN AMES III, ASSOCIATED PRESS

Braving strong currents—and claws—Larry Katz rescues longtime pal Tom in West Des Moines, Iowa. "I almost cried," says Katz, who found Tom atop an overturned chair. Relief was rare here last July, as swollen rivers shot through town. Thousands lost homes, tap water, treasures—yet kept their civic pride.

"Awful as it's been, it's also been oddly wonderful," my mother told me when I finally reached home. "It's made the city into one big family." She was part of the lucky majority safely away from the scattered flood zones, though even she had been the beneficiary of anonymous goodwill. Containers of water had begun appearing on her porch every morning, left by some silent, thoughtful neighbor. "I don't even know who to thank," she said in a tone of small wonder.

Again and again as I explored Des Moines's once familiar streets, I found myself cut off from childhood haunts by acres of unexpected water. Birdland Park, where my brother and I played tennis, the wooded railroad tracks a mile from my childhood home where my friends and I used to walk the rails, Sec Taylor Stadium, the ballpark named for the legendary local sports columnist where I spent contented evenings on a privileged perch beside my sportswriter father in the press box, and a dozen other places that lived on in the endless summer of memory—all were now submerged or stranded by the blundering and expansive floodwaters.

I grew up in this place and knew that Iowans are by nature uncommonly—I might almost say helplessly—friendly, trusting, and obliging. But nothing in 20 years of living there had prepared me for such a display of their virtues.

Where I had expected to find despair and frayed tempers, I found instead almost universal good humor. "We've had people from every walk of life show up here offering to help."

The Great Flood of '93 hit home with particular force. Though only a fraction lost their homes or businesses, none escaped its discomforting aftershocks, and few failed to contribute in some way to this remarkable city's unshakable sense of friendliness and resilience.

This may sound a trifle unhinged, but if you had to choose a place for a flood to strike, you couldn't do better than Des Moines. I don't mean to suggest that the people of Iowa's capital are particularly deserving of misfortune, merely that they handle it so well.

Maj. Les Morrall, director of a Salvation Army emergency relief center, told me. "Yesterday we had a lawyer and doctor unloading trucks and a district judge mopping the floor." We were standing in an 80,000-square-foot store that a few days earlier had been untenanted and empty. Now half of it was filled with stacks up to ten feet high of emergency supplies of every description donated by companies and individuals from all over the nation. "By tomorrow we expect this place to be completely filled," Morrall said.

I asked my brother, Mike, if he could account for the unending friendliness of Iowans. As the editor of a pair of small Iowa newspapers, the *Waverly Democrat* and *Bremer County Independent*, he has his finger on the pulse of the state as well as anyone. "Iowa has always had a small-town ethos," he said. "All those qualities that most people associate with rural life and small communities, like openness and trust and a willingness to bend over backward to help others, are still valued here."

Even victims with the most heart-wrenching stories seemed irrepressibly upbeat. With the local water plant out of commission for nearly two weeks, collecting water from emergency supply points became part of the daily routine. One morning while filling an eccentric assortment of jugs and containers for my mother, I fell into conversation with Sgt. Michael Smith of the Iowa National Guard, who was there ostensibly to maintain order but—disorderliness being an unknown concept in Iowa—was helping people like me fill their containers without soaking themselves.

Entirely in passing, Sergeant Smith mentioned that he had been working as a volunteer sandbagger when he learned that a levee near his home had been breached, and the neighborhood was flooding. "We lost pretty much everything," Smith said. "My wife and I managed to salvage some clothes and the kids' bikes, but that was about it." It gets worse. His father-in-law's house was flooded out too. "Hasn't been a real good week one way and another," Smith said laconically, adding that he and his wife, Betty, would waste no time in applying for flood-relief assistance to rebuild their house.

It wasn't just locals who pitched in. "I was collecting water," an old friend told me, "and I discovered that the man handing it out was from Akron. He'd loaded a truck with bottled water and brought it all the way from Ohio—all at his own expense. You begin to feel like saying, 'Who *was* that masked man?' "

One of the first—and worst—hit of the city's several thousand victims turned out to be a person I had known since junior high school.

Craig Laws was manager of Johnnie's Vets Club, a locally famous, long-established restaurant that suffered the double misfortune of being nearer the Raccoon River than any other business in its part of town and in a low-lying area. Laws and a small army of colleagues and friends spent a frantic several hours trying to beat the approaching flood by bolstering a floodwall around the building, but the river proved too much for them.

"At 3:20 p.m. the water started coming over the wall, and we scrambled to higher ground," Laws said. "Twenty minutes later it was over. All you could see was the rooftop."

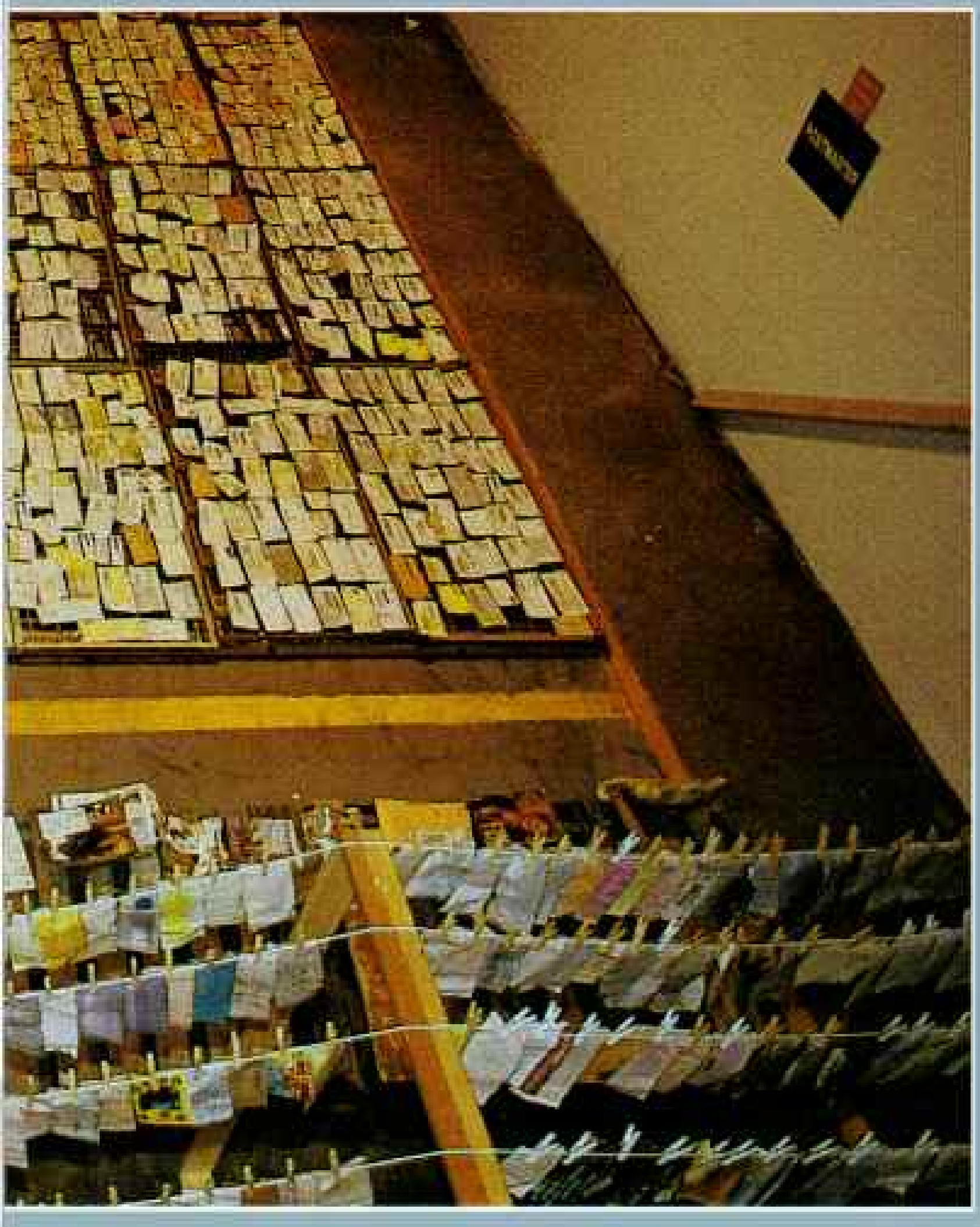
If you lack firsthand experience of a flood, it can come as a shock to discover just what river water can do to a structure. Never having dealt with anything more disastrous than a burst water pipe, I had the decidedly naive idea that once the floodwaters receded, most victims would need do little more than open their doors and windows to get some air circulating, maybe towel up a few puddles and lug carpets and furniture out to the yard to dry.

It isn't like that. An unleashed river causes frightful devastation. It smashes furniture, buckles joints, washes out foundations. As a final indignity, it leaves behind a slick, noxious coating of grayish sludge over everything. For days I wandered streets where stunned people, smeared with mud, pulled unidentifiable objects from their houses, piled them by the curb, and went back for more.

The smell was stale and sewery—nearly unbearable—and it hung heavily over whole neighborhoods. That these were streets I had driven or biked along in earlier, more peaceful times made it all the more wrenching.

"You know what the worst thing is?" one victim asked as she dumped an armload of crumbly plasterboard by the roadside. "Worms. Big, long, wriggly night crawlers. They're everywhere. You pull back a bedspread and find worms in your bed, and, believe me, that's *real* discouraging."

All together some 2,100 residences and 350 businesses in greater Des Moines suffered severe flooding. But the effects spared no one. Thousands of workers were put on leave as the city was brought to a halt by the absence of



Not snow, nor heat, nor gloom of night but a rain-induced sewer backup stayed delivery of some 30,000 pieces of Des Moines mail. "I think we bought every clothespin in town," says postal worker Lora Yahnke, who helped sort and dry the wet mail in a garage. Such jury-rigging kept most city services afloat.

DAVID PETERSON, DES MOINES REGISTER

In the ruin of her mother's home, Patty Savage finds pictures—and solace: "I had Him in one hand and Mom in the other, and just feel glad she's alive." Tyler Smith, ten, squeegees his family's drive, undaunted by a sea of mud "like chocolate pudding." Says Tyler, whose family has moved across town, "I'm looking forward to getting away from water."

water. With no water there could be no fire cover, and with no fire cover the mayor, John "Pat" Dorrian, ordered all but essential businesses to shut. Overnight, downtown Des Moines took on the aura of a ghost town and would stay that way for nearly two weeks.

STROLLING through the sunny, lifeless streets of the downtown one afternoon, I wandered into the Kirkwood Hotel. In the 1950s my sister and I sometimes used to meet my mother there after a day at the movies. We chose the Kirkwood because its lobby had the most comfortable seats in town. It still does, come to that, but on this day there wasn't anyone to sit on them. The normally busy Kirkwood lobby had the silence of a crypt.

"Kind of spooky, isn't it?" remarked Sandy Coppola-Losh, the manager, gazing wistfully at its emptiness. "We had three feet of water in the basement," she went on, "but the loss of business has been much worse."

For most, however, the main problem was learning to live without water. Things like freshly laundered clothes and long, hot showers became the stuff of dreams.

When I heard that Camp Dodge, home of the Iowa National Guard, was offering free showers to all comers from its private water supply, I drove out to the camp, eight miles beyond the city limits, to have a look—and, I quietly hoped, a shower.

"We've had 5,000 people pass through here in less than a week," Spec. Dodie Davies told me. "The first night there were so many cars coming up the road it was like *Field of Dreams*."

She logged me in—I was visitor number 547 that day—and offered me a small bar of soap wrapped in paper. The male shower room at Camp Dodge proved to be basic Army barracks issue—a single open room with a dozen nozzles. I took my place gratefully under the one unoccupied nozzle. It wasn't the steamiest or most elegant shower I have ever had, but oh my, after four hot, sticky summer days in Iowa it was refreshing.

As I lathered up, the man beside me offered the intelligence that the soap we were using had been donated by a nearby motel. "The manager thought some people might forget to bring their own. Just wanted to help, I guess."

I remarked, not for the first time, how extraordinarily thoughtful everyone in Des Moines seemed to be.

"You won't find better," agreed the man, switching off his shower and wiping water from his eyes. "I guess that's why we put up with all this crazy weather." □

- THE HORIZON broadens for Japan's southernmost main island. Once considered a backwater, Kyushu now hustles for a bigger piece of the Pacific Rim's economic pie. Ready for the future, the new Fukuoka Dome sports a roof that opens like a fan. A cheerleader whips up the crowd at the opening baseball game.

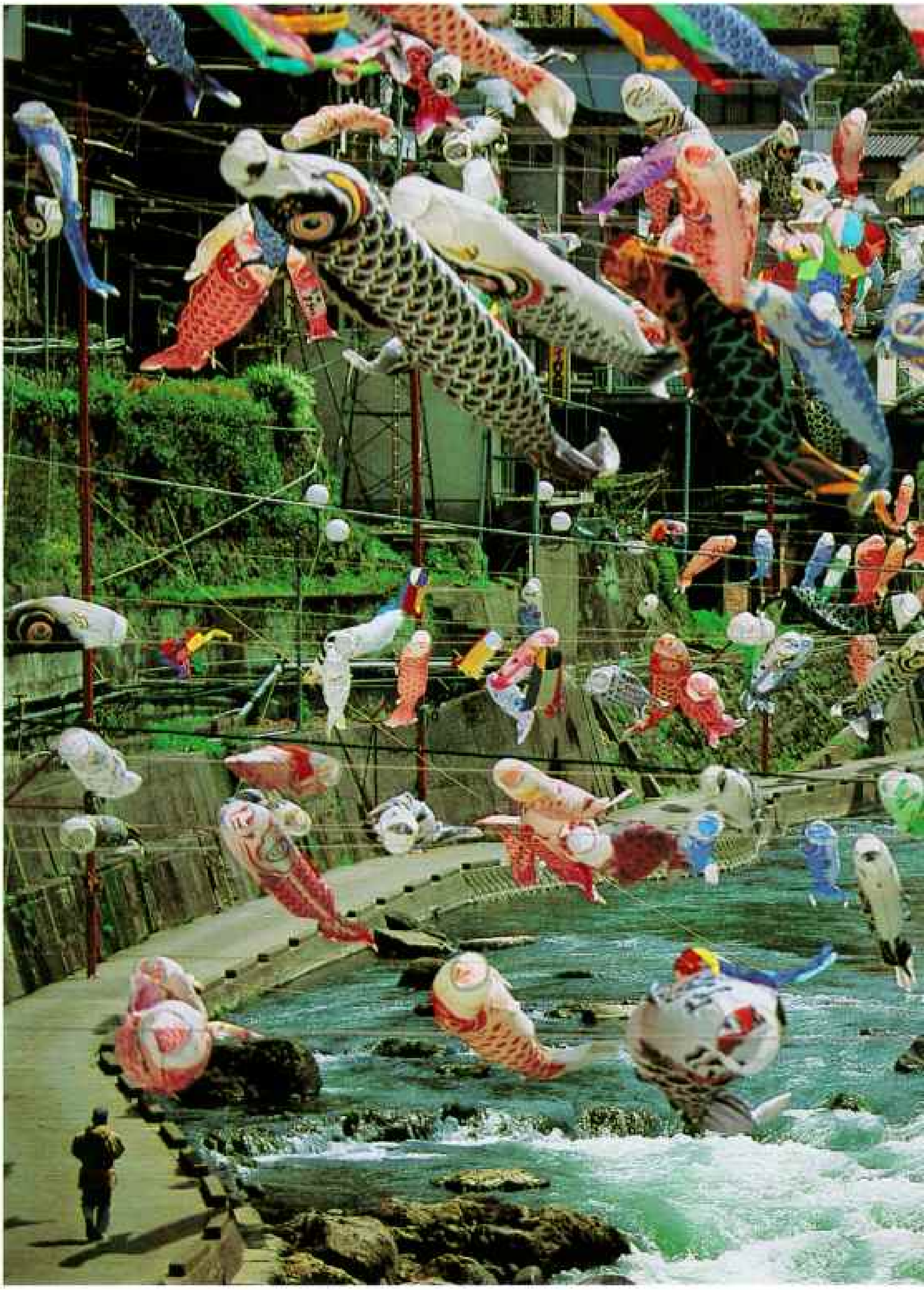
Japan's Southern Gateway

Kyushu

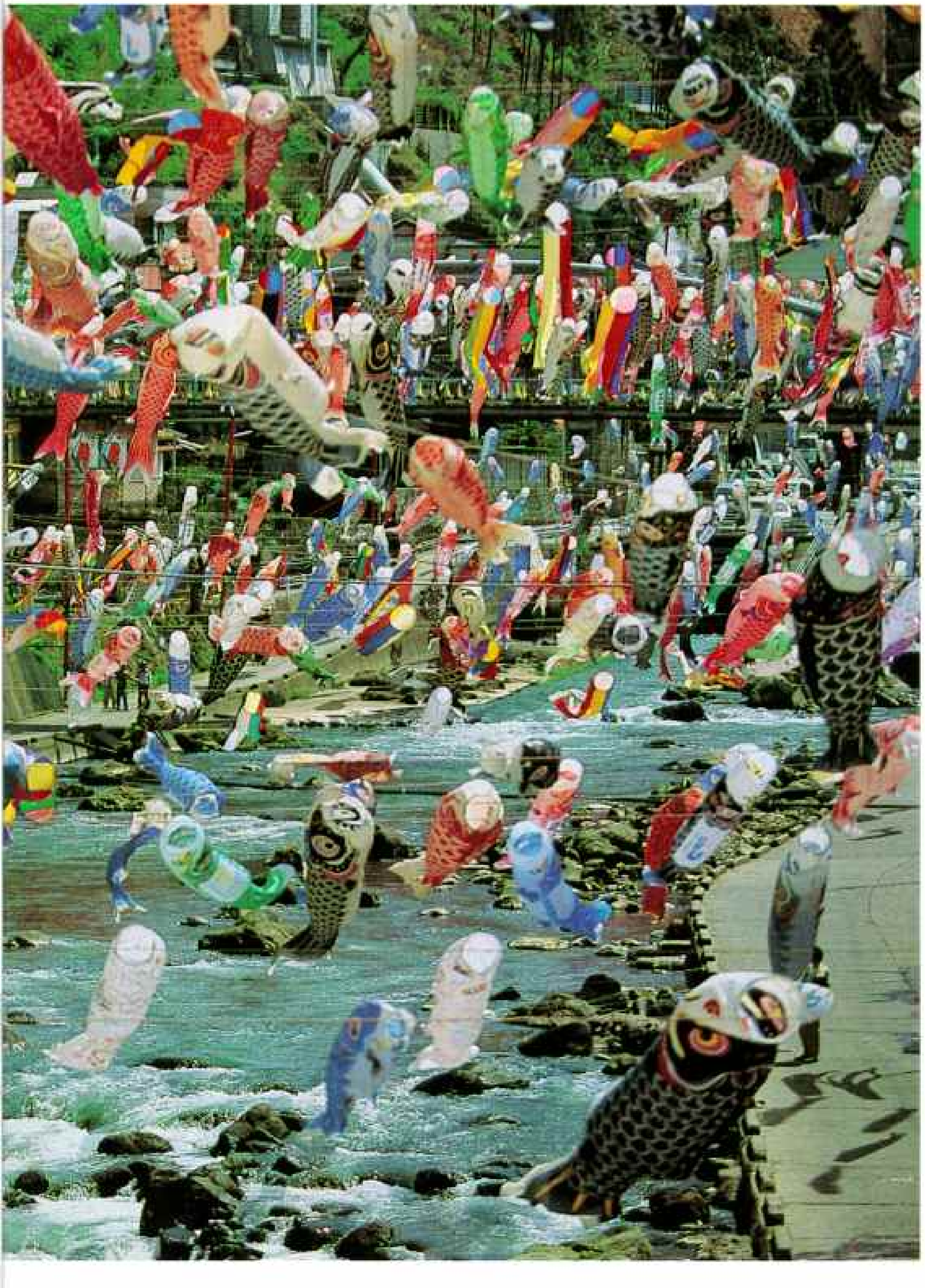
s h u

By TRACY DAHLBY

Photographs by MICHAEL S. YAMASHITA



● SCHOOLS OF CARP, or *koinobori*, fly at the Tsuetate spa in Oguni in celebration of Children's Day, the last in Japan's Golden Week of holidays. That festival spirit is the local response to government



exhortations for communities to focus enterprises in a "one village, one product" program. Oguni features its hot springs in hopes of igniting a tourist bonanza.

● SUCCESSFUL LUNAR LANDING pleases a father and his children posing for a snapshot at Space World in Kitakyushu. The theme park trades on Japan's infatuation with space, especially keen in

Kyushu, home of the nation's two launch sites. One Japanese national served as payload specialist on the U. S. space shuttle *Endeavour,* and another is scheduled to ride in *Columbia* this year.

● TREASURES IN HAND, a family carries bowls in the thatch-roofed village of Sarayama, where potters work in a style called Ontaware. Japan's ceramic tradition blossomed in the 1600s when naturalized Koreans began producing delicate porcelain made of kaolin clay from Kyushu to meet growing domestic and European demand.

It was my first attempt at hitchhiking in 20 years, and we were getting nowhere fast. My partner, Tomosuke Noda, and I had haunted the same remote strip of highway in the mountains of central Kyushu for an hour now. The sun was shining hotly. We had counted dozens of cars zipping past, spraying us with gravel but coolly ignoring our outstretched thumbs.

Tomosuke, an outdoors writer and my oldest Japanese friend, was nibbling a blade of razor grass and smiling with thinly disguised impatience. Then a grinning, wild-haired farmer shot by, waggling his hand at us in rejection, and something snapped.

"You're scaring them," said Tomosuke, referring to my 6-foot-7-inch foreigner's frame, which loomed over the roadway. "For god's sake, go sit down or something."

That hurt. But before I could point out that Tomosuke, with his pencil-thin, gigolo's mustache and rakish peaked cap, hardly presented a beacon of reassurance to the wary motorist, a dusty white hatchback screeched to a stop in front of us. *"Notte kudasai!"* shouted the young man behind the wheel. "Hop in!"

Yet another crisis in Japanese-American relations averted, we gathered up our gear and crammed our bodies into the tiny car. In a flash our savior, Gunji Oshikawa, a 21-year-old electronics technician from the nearby city of Nobeoka, was flying down the road as it twisted and dipped high above the churning rapids of the Gokase River.

Watching the scenery whiz by in psychedelic streaks of green and white, I couldn't help but muse at how things had changed since Tomosuke and I had passed this way in 1974. I had been studying Japanese and living in Tokyo, when Tomosuke, a Kyushu native, offered to show me around this southernmost of Japan's four main islands, with its active volcanoes, its long, shimmering coastlines, and a people so passionately hospitable that, on one occasion, we were forced to flee a creaky old farmhouse at daybreak, having

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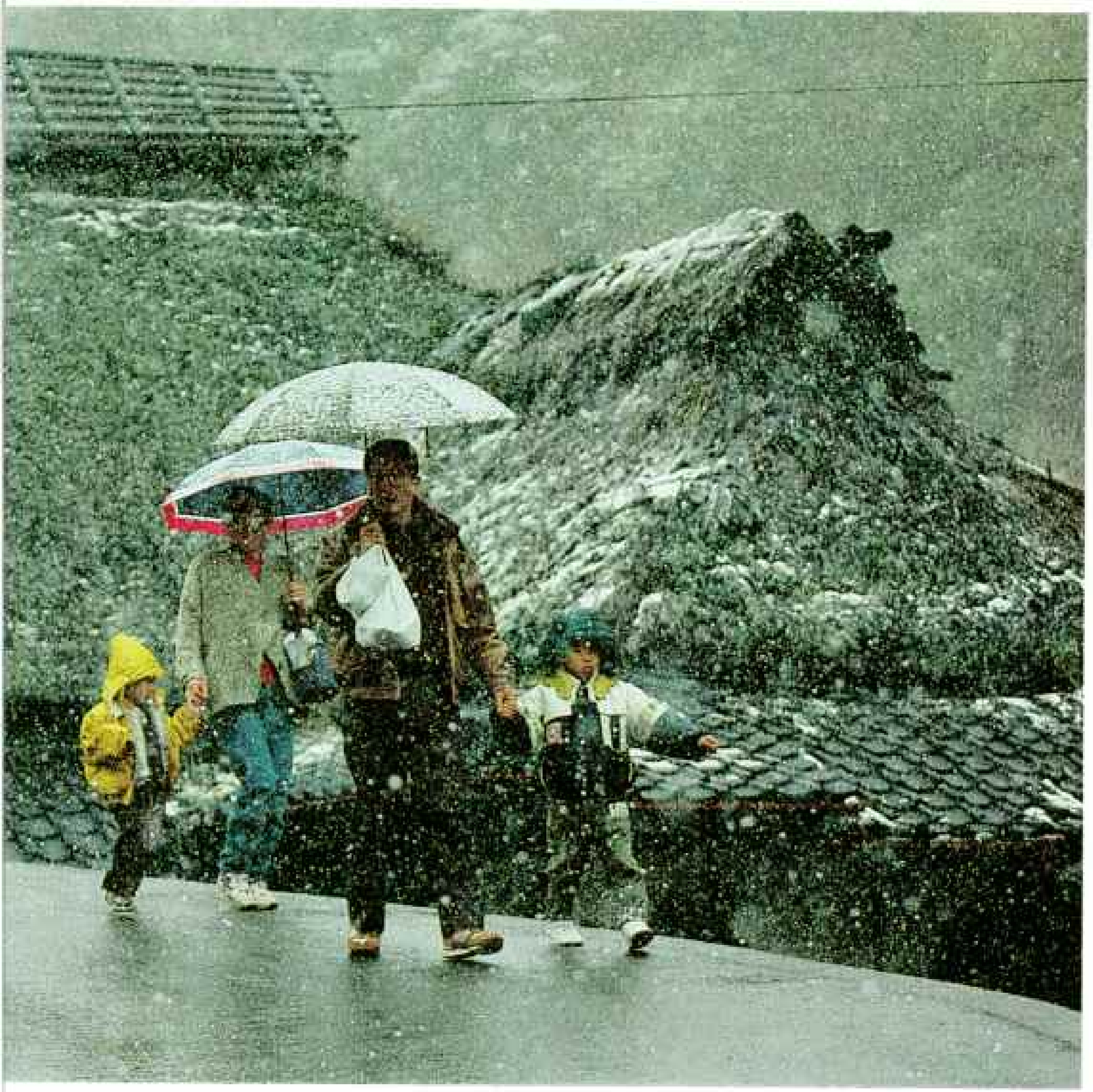
New York-based writer TRACY DAHLBY is a former Tokyo bureau chief of both the *Washington Post* and *Newsweek* and has reported on Asia for many years. This is his first article for the magazine. Photographer MIKE YAMASHITA's most recent NATIONAL GEOGRAPHIC story was on the Mekong River (February 1993).



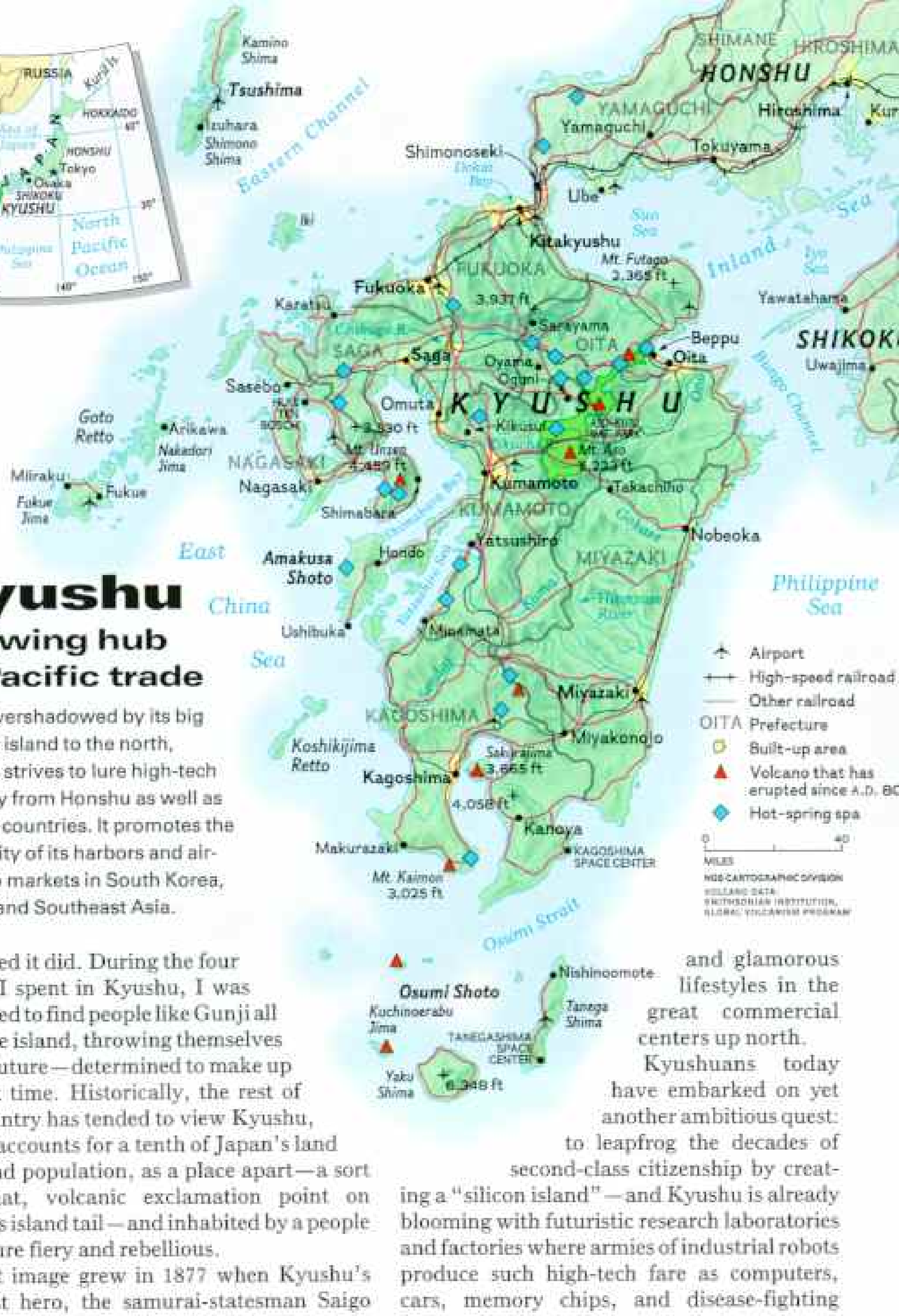
been taken into unofficial custody by an eccentric group of young farmers. Now, two decades later, it seemed people couldn't care less.

"Everybody's in a big hurry these days," said Gunji, natty in a crisp pin-striped shirt and French necktie. He was himself hurrying back to his head office, 30 miles away. There he would grab a fresh stack of work orders and return to the hills, where, as an expert in outfitting banks with the latest in computerized teller machines, his services were in big demand.

"The smallest bank branch in the tiniest town is going on-line," Gunji told us. Just then, we rounded a hairpin curve and swerved to miss a cement truck, and the loose circuit boards beside me on the backseat danced wildly, sending up little clouds of dust.

Even as we drove, Kyushu was merging with the great data superhighways, endless loops of fiber-optic cable that have now begun to link Japan's major cities and the world beyond. These electronic arteries not only would bring fancy financial services to this area—once so poor it was called *Nippon no Chibetto*, the Tibet of Japan—but would no doubt one day confront farmers with the blessings of electronic shopping and 500 cable channels as well.

"Shinjiraren!" marveled Gunji. "It boggles the mind!"



Kyushu

Growing hub of Pacific trade

Long overshadowed by its big brother island to the north, Kyushu strives to lure high-tech industry from Honshu as well as foreign countries. It promotes the proximity of its harbors and airports to markets in South Korea, China, and Southeast Asia.

Indeed it did. During the four weeks I spent in Kyushu, I was surprised to find people like Gunji all over the island, throwing themselves at the future—determined to make up for lost time. Historically, the rest of the country has tended to view Kyushu, which accounts for a tenth of Japan's land area and population, as a place apart—a sort of squat, volcanic exclamation point on Japan's island tail—and inhabited by a people by nature fiery and rebellious.

That image grew in 1877 when Kyushu's greatest hero, the samurai-statesman Saigo Takamori, led a bloody rebellion against the national government he had helped create only a decade earlier. His goal was to prevent too much of the country's power and wealth from accumulating in its new capital, Tokyo. His flamboyant failure to do so would oblige generations of Kyushuans to leave home to chase their dreams of high-paying jobs and glamorous lifestyles in the great commercial centers up north.

Kyushuans today have embarked on yet another ambitious quest: to leapfrog the decades of second-class citizenship by creating a "silicon island"—and Kyushu is already blooming with futuristic research laboratories and factories where armies of industrial robots produce such high-tech fare as computers, cars, memory chips, and disease-fighting monoclonal antibodies.

Whether they will ultimately succeed where Saigo failed, nobody yet knows. But Kyushu now produces 40 percent of Japan's integrated circuits—a tenth of the world's market. In the past decade hundreds of corporations, Japanese and foreign, have set up factories here, tapping the island's reservoir of cheap land

● PLASTIC TUNNELS act as greenhouses for sweet potatoes and other crops growing below Mount Kaimon in Kagoshima Prefecture, renowned for its produce. The nation places a premium on Kyushu's stretches of agricultural land. A net importer of food and two-thirds mountainous, Japan supports 124 million people—nearly half the number living in the U. S.—in an area smaller than California.

and well-educated workers and counting on its proximity to the rising economies of Asia to pull them into new global markets.

"Tokyo has always been our magnet," a leading local politician told me, but now the poles are shifting. The Cold War over, pent-up entrepreneurial energies are battering down old ideological barriers throughout the region. Guangdong Province in southern China, for example, boasted a growth rate of nearly 20 percent in 1992, one of the highest in the world. Kyushu's largest city, Fukuoka, a hundred minutes by air from Tokyo, is closer to Pusan (40 minutes), Seoul (65 minutes), and Shanghai (85 minutes).

"Why go through Tokyo any more?" asked the politician.

Besides, the freshest ideas for dealing with the rest of the world in a relaxed, open manner, he insisted, were not coming from reserved, cautious Tokyo but from the south, where, he said, "We've got that frontier spirit!"

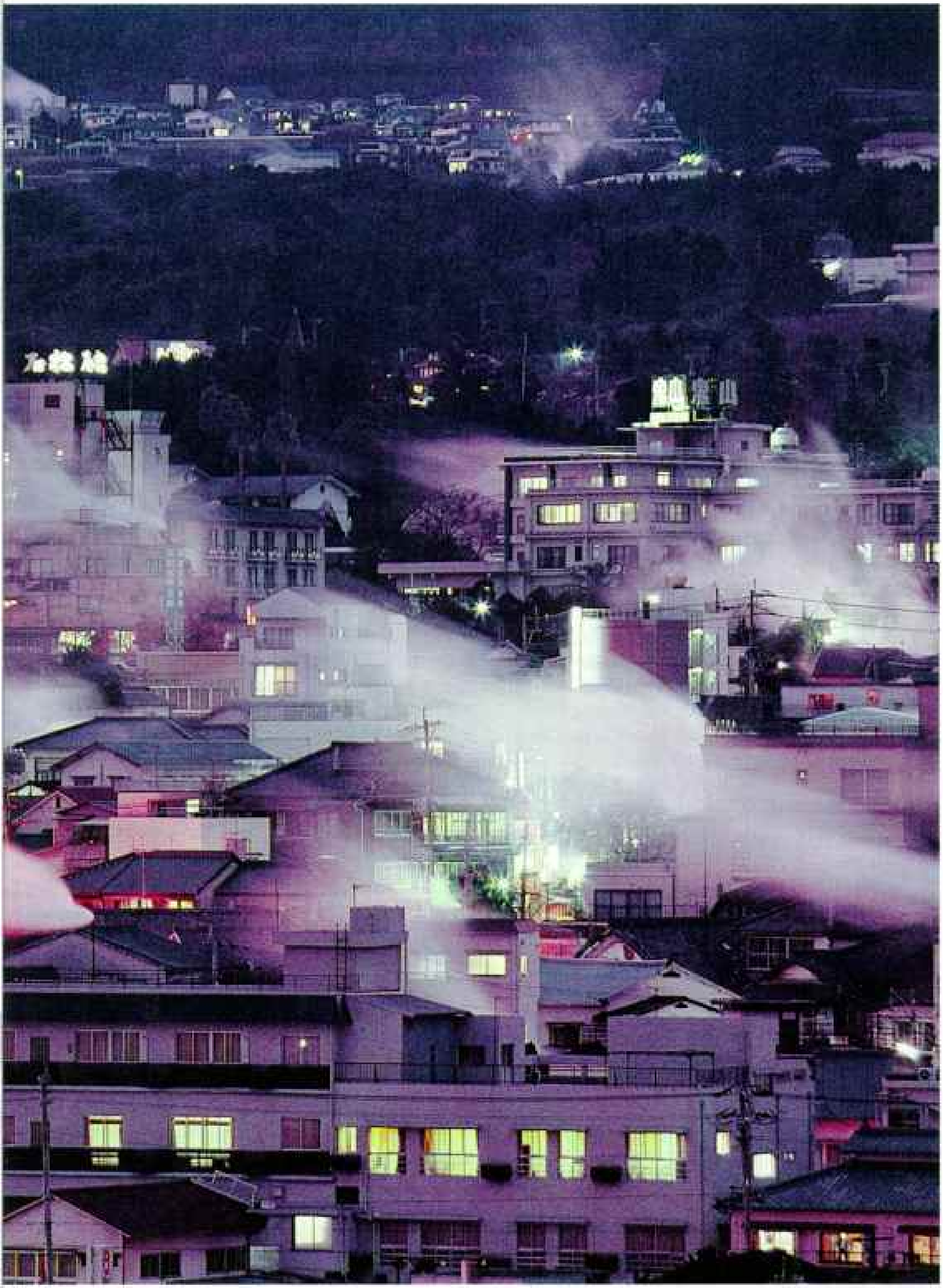
I SAW EVIDENCE of that spirit at work in Fukuoka. Tramping its broad, leafy boulevards one rainy Sunday with Hideko Takayama, an old friend who was helping me with my badly corroded Japanese, we came face-to-face with the notorious *Kamome-zoku*, the Seagull gang.

"There they are," whispered our guide, city official Akinori Kato, pointing to a gaggle of teenagers standing on a street corner in front of Mister Donut. They were dressed in the latest "grunge" fashions from the United States—the boys in strategically ripped blue jeans and faded bomber jackets, the girls sporting aviator sunglasses and T-shirts tattered with peekaboo holes.

Akinori explained that these young "rebels" got their name from the Seagull Express, a popular local train that links Fukuoka to outlying towns and villages.

"Every Friday night," he said, "hundreds of kids from the countryside hop on board for

● VEILS OF STEAM drift over Beppu, Japan's most famous—or infamous—hot-springs resort. Tourists flock here for the *onsen* (spas), sand baths, and steaming mud pools. Some love Beppu; some



loathe it: The city has a reputation for cheap tourist attractions and tawdry nightlife, an image it tries to reverse as it builds a new 28-million-dollar convention center.

a glimpse of the big city," with its 1.3 million people, video-game parlors, and cavernous discos, and for the chance to cruise its boisterous student quarter, *Oyafuko-dori*—Street of Disrespectful Sons and Daughters.

As we approached, the Gulls scattered at the sight of Akinori in his blue, police-style windbreaker, and we had to chuckle. Freshly laundered, the teenagers looked about as unruly as a group of middle-aged insurance agents waiting for a bus.

Still, the Gulls are an important symbol of a gradual shift in Japan's center of gravity. Fukuoka, a booming commercial center, is now exerting a powerful cultural magnetism too. "We're a fashionable, international city!" declared 18-year-old Chikara Kawaguchi when Hideko nabbed him on the steps of the Maria Club, a gaudy, gold-leaf dance pavilion that was preparing for an event mysteriously billed as Body Conscious Night.

Chikara well understood how Tokyo had once bedazzled his parents in the dark ages that had been their youth. "But nobody feels that way any more," he assured me.

Yet in some respects, creating a new cultural identity has meant recapturing an older one. By the seventh century Fukuoka was a model free-market enclave, welcoming traders and envoys from China and Korea. The glories of Japan's ancient traditions—its pottery techniques, Buddhist statuary, and Chinese letters—all flowed through here on their way from their places of origin on the Asian continent.

"While the rest of Japan was turning away foreigners," Atsuko Kato, Fukuoka's spirited deputy mayor, told me when I visited her at city hall, "we acted as its window on the world."

But what the Japanese call *kokusaika*—internationalization—demanded sacrifice, Dr. Kato said, even if, in her opinion, few Japanese really wanted to break with their cozy, homogeneous ways. "Not that we here in Kyushu know exactly how to proceed either," she said, "but you can't shut the door on foreigners if you want to be international, now can you?"

Hustling ever forward, Kyushu has stumbled badly at times. Following World War II the Chisso Corporation made a bid to turn the sleepy fishing port of Minamata into a world-class producer of chemical products. In the process, as photographer Mike Yamashita sadly recounted, the company dumped large quantities of methylmercury into the bay, poisoning millions of fish and thousands of humans and creating an unmitigated environmental calamity.

But Minamata wasn't alone. In Kitakyushu one afternoon a city official showed me a jar filled with a brown-green sludge that reminded me of the oozings I had once seen my father produce from the crankcase of our troubled 1957 Plymouth. "The water in our bay looked like this in 1970," he told me. "That's why the newspapers called it the Sea of Death."

Until then Kitakyushu had been one of modern Japan's liveliest workshops, the site of its first Western-style steel mill in 1901, and proud of its slogan: "*Kemuri wa hanei no shirushi*—Smoke is the symbol of prosperity."

When the smoke congealed into a "rainbow dust" that laced the sky with a kaleidoscopic toxic haze, city officials adopted a new symbol: the steam shovel. Yard by yard the giant clamshell diggers chewed away at the sludge lining the bottom of Dokai Bay until, by the late 1980s, the fish had returned—this time healthy and with all fins intact—and it was declared one of the cleanest industrial waterways in Japan. Now the city is known for its nonpolluting industries.

I FOUND the employees of Toto Ltd., one of the world's largest producers of toilets, hard at work perfecting their own vision of the future when I visited the company's massive Kitakyushu plant. Standing on the factory floor, I watched in awe as industrial robots spritzed long lines of freshly molded commodes with pastel glazes before they marched stolidly into the glowing red jaws of a giant furnace to be fire-hardened. All this activity, spokeswoman Yoko Okamoto told me, was aimed at a simple goal: to make life more comfortable and environmentally correct.

The centerpiece was the company's hot-selling toilet-bidet, the controls of which resemble a small electronic keyboard and, thanks to a microcomputer buried inside, offer an array of jets and sprays—all using no more water than an ordinary toilet.

Company researchers had also discovered the alarming fact, said Ms. Okamoto, "that women flush the toilet repeatedly to cover up unladylike noises." She added, quite seriously, that "this excessive use of water has become a big problem." Environmental

- A ONE-TWO PUNCH from Mount Unzen in 1991 clobbered the home of Fuminori Honda in Shimabara with rocks and hot ash, then swamped it with mud when rains washed down the volcano's ash-covered slopes.

  Honda treads a floor of dried mud while revisiting the house, since razed. It sat more than a hundred yards from the Mizunashi (No Water) River, a seasonally dry riverbed that was widened and paved to funnel mudslides into Shimabara Bay. Scores of homes were lost when mud breached the channel's concrete walls.

● ELBOW ROOM for a crowded nation, Aso-Kuju National Park entertains riders in the Aso caldera, measuring 11 by 15 miles. Inhabited before the park was created, the caldera cradles towns, villages, and extensive farmland. Roads and railways serve more than 50,000 residents.

disaster looming, Toto engineers devised the Sound Princess, a convenience that employs state-of-the-art electronics to simulate a loud flushing sound at the touch of a button—without using a single drop of water.

KYUSHU'S MARCH TO THE FUTURE has bestirred more serious trepidations too. This was the case in Sasebo, a normally tranquil city of 250,000 people that has served as a United States Navy facility since the end of World War II. Six months before I arrived, an American sailor, radioman Allen R. Schindler, was beaten to death in a public toilet by two of his shipmates because, it was alleged, he was homosexual.

Yet the murder, which had grabbed headlines in the U. S., didn't worry the regular patrons I met one evening at Tadashi Eda's sushi bar as much as *endaka*—the dizzying rise in the yen's value—which has meant American sailors, paid in eroded dollars, were spending less and less in local shops, bars, and restaurants.

Things were different during the Korean War, 54-year-old Eda-san told me. "You could hear the big guns booming over there in Korea—they were that close," he remembered, as he jabbed his gleaming sushi knife toward the far wall. "Our economy was booming too. Half the people on the streets were Americans, throwing money around, and the town was noisy and full of life."

But the world had changed, and now the dangers that had once excused a foreign navy occupying prime real estate seemed far less compelling.

The Cold War might well be over, U. S. base commander Frank "Ty" Giesemann acknowledged when I talked with him at his office overlooking the turquoise waters of Sasebo Harbor, "but the world is not a safer place." There is still North Korean belligerence to deal with, for example, including the disturbing evidence that Pyongyang is trying to build nuclear bombs.

"Our ships in Japan can get to potential hot spots in the Indian Ocean and the Middle East much faster than ships from San Diego can," said Captain Giesemann. "We've got to be prepared."

That sounded prudent, but the crowd at the sushi bar shook their heads in disagreement. To them, said one man, it boiled down to a matter of cold, hard economics: "We simply can't make a living off the *gaijin* [foreigners] any more."

Japan has sunk into its deepest economic recession since the war. But that didn't stop doting mothers and fathers from throwing open their wallets the day I visited Huis Ten

Bosch, a reproduction of a 17th-century Dutch city north of Nagasaki and one of Kyushu's newest and most technologically advanced tourist attractions.

It was spring break for the kids, and families were tramping the theme park's brick lanes, inspecting its four miles of canals and its architectural clone of a Dutch royal palace—built with ten million bricks imported from the Netherlands.

I joined two hundred or so visitors inside a computer-driven diorama, one of the park's nine interactive media shows. We watched a violent rainstorm lash an old Flemish village and cowered as simulated lightning flashed and thunder rolled and were whipped by enough spray from rising tides and bursting dikes that I suspected the wily engineers from Toto Ltd. were somehow involved.

Things Dutch began flooding into Japan late in the 16th century and continued coming even after its feudal rulers closed the country to foreigners in the early 1600s. For the next two centuries, Dutch traders were confined to Dejima in Nagasaki Harbor, which remained Japan's only opening to the West.

Now Huis Ten Bosch—house in the woods—has become an important vantage point for people like Noboru and Manami Suzuki, because it was there that they were

spending their honeymoon. "We thought about going to Europe," Noboru told me, "but we wanted to go out at night without becoming crime statistics or having to deal with a foreign language."

That very urge to taste the wider world's glamour without any of its inevitable mess or danger is what worries Nagasaki Mayor Hitoshi Motoshima. In 1945 Nagasaki became the second city in history to be hit by an atomic bomb. Yet today, Motoshima believes, the Japanese have lost sight of the events that led to that tragedy, and such myopia could hinder them as they try to mesh with a rapidly changing world.

In 1988 Motoshima, a gregarious man with an impish grin, broke a long-standing taboo by publicly suggesting that the late Emperor Hirohito bore responsibility for wartime decisions that sent millions of soldiers to conquer Asia in his name. For his daring, Motoshima was shot in the back by a right-wing extremist. "The Japanese," he told me, "have to realize they are not yet truly international people."

KYUSHU'S oldest tourist attraction is also the source to which many Kyushuans attribute their native feistiness: their volcanoes. Built on a geothermal cauldron, the island percolates with countless *onsen*—hot springs—whose waters are fired by giant subterranean magma flows and whose steamy spas have for decades lured workaholic Japanese in need of a soothing tub or a romantic interlude.

Yet nobody has ever devised a more ingenious method of making the waters pay than Ryuji Hirasawa. Deep in the mountains of Oita Prefecture, Hirasawa-san presides over a clutch of concrete ponds where he uses the hot water to speed up the natural aging processes of thousands of *suppon*, or snapping turtles. All this for the benefit of connoisseurs in Tokyo who eagerly pay as much as 7,500

● THE APING OF AMERICA can be found along almost any roadway. In Kagoshima Prefecture a glowering Hollywood icon houses a parlor devoted to *pachinko*, a game akin to pinball that pays off in small steel balls. These are redeemed for prizes such as lighter flints, bottles of soy sauce, jewelry, and T-shirts, which are often traded back for cash at off-site exchange booths.

Equally garish is a street in suburban Fukuoka, a corridor that, for chaotic development, outdoes even the jumbled commercial strips of the U. S.

yen—roughly $75—for the chance to dine on the delicate, chicken-like flesh.

I found Mr. Hirasawa, a compact man with thick eyeglasses who was tucked into the carapace of a rubberized white apron, standing amid a pile of handwoven baskets containing turtles sorted by size for their one-way trip north. He told me it took mother nature three years to grow a turtle to adulthood. "I do it in one," he said proudly.

His snappers would normally hibernate as long as four months a year. "Keep the water at 31°C [88°F]," he said, "and turtles forget about sleeping altogether and eat anything that's put in front of them."

What's the toughest thing about raising turtles? I asked.

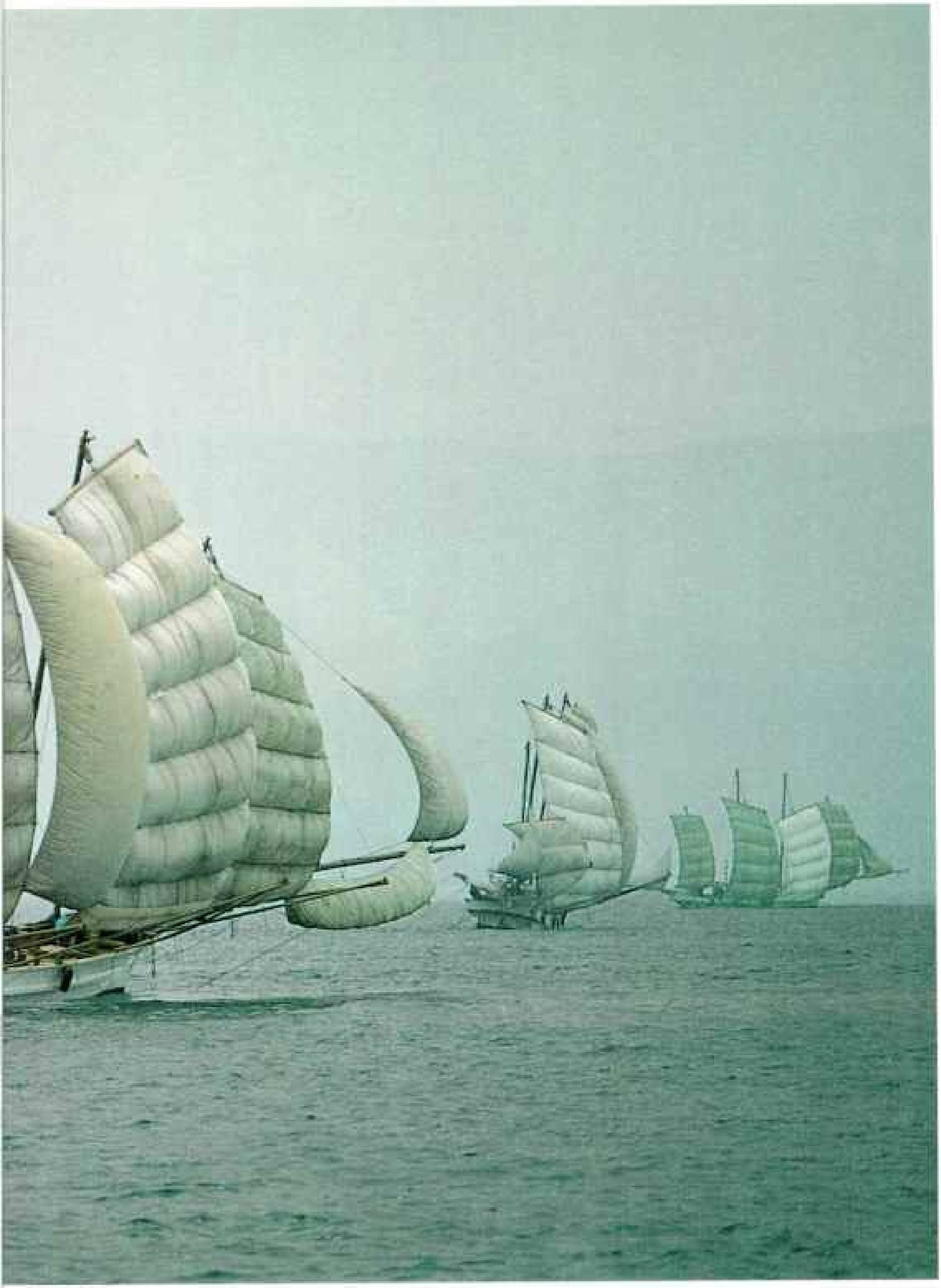
"They die," he said grimly. Natural hot springs are extremely volatile, he explained, and despite every effort to control the temperature, it can spike without warning. "You can imagine what happens then," Mr. Hirasawa said, shrugging: "Instant *onabe*"—turtle stew.

Had he ever considered going back to doing whatever it was he did before he had gazed into his future and seen it filled with turtles? "I used to drive a truck," he said, smiling wryly. Besides, there was the sheer romance of raising turtles to be considered, "like being part of something brand new."

Kyushu's most enduring challenge is what the Japanese call *kaso*—or depopulation. A large percentage of the island's high school graduates still leave their native towns and villages for work or school off the island. Yet the 4,400 inhabitants of Oyama, a tiny farming village in Oita Prefecture's outback, have invented a formula that helps the pitchfork and the microchip coexist.

Exhibit A is OYT, a cable-television station occupying an electronic bunker in the basement of the town office. As I entered the studio, I traded my street shoes for the customary Japanese slippers, which barely covered the

● GHOSTLY FORMS of vessels called *utase bune* haunt Yatsushiro Sea on a misty day as they trawl for prawns, crabs, and small fish. Introduced centuries ago, utase bune are now all but extinct.



Only three dozen families still sail the 60-foot craft, designed to drag nets to leeward as they ride the prevailing northerly breezes. To add income, fishermen offer rides to tourists.

tips of my size 15 feet. I stepped into a narrow control room where wall monitors flickered with the familiar images of CNN International's Headline News and professional basketball and baseball games from the U. S. Then there was something that looked suspiciously like school commencement exercises.

"Exactly right," said Robert Watson, a 34-year-old American who works for the mayor's office. The Class of '93—all 69 of them—had graduated that very day from Oyama Junior High and would top prime time that evening.

The whole idea, said Robert, was to build local self-esteem by combating the bleak, condescending images the Tokyo-dominated national media use in their portrayal of life in the countryside.

Oyama first made headlines in the early 1960s by defying Tokyo's long-standing policy aimed at boosting rice production. Villagers dug up their paddy fields and embarked on a revolution summed up in the off-beat battle cry: "Plant plums and chestnuts, and to Hawaii we will go!"

That incentive campaign, which sent many of the town's adults on Hawaiian vacations subsidized by the village cooperative, achieved two important goals, town planner Kazumi Koda told me. First, it anticipated

● CRIES OF *KAMPAI!*—Cheers!—rise from fishermen toasting their first big catch of the season: 170 yellowtail netted off the island of Fukue Jima. Fishing and farming are increasingly shunned by Kyushu's young people as *kitanai, kiken,* and *kitsui*—dirty, dangerous, and demanding.

the economic takeoff that would encourage consumers all over the nation to ornament their bland rice diets with the fruits, vegetables, and herbs Oyama produced. Then there was the magic of Hawaii. "It sounds naive," said Mr. Koda, "but back then going there was a very big deal. It showed our young people that if they stayed on the farm and worked hard, they could realize great things."

Chasing such dreams, the villagers made theirs one of the most prosperous hamlets in all Japan and inspired *machizukuri*—local revitalization—programs all over Kyushu.

Yet Oyama's communal successes have brought home a new irony. Once again the village is feeling the bite of the dreaded kaso and is losing its young people to the freedom of the big cities. "They are beginning to resent the intrusion of the community into every aspect of their lives," explained Robert. "What they want now," he added, "is to have lives of their own—not as members of a group but as individuals."

I WAS REMINDED of this yearning for more individualistic lifestyles when I arrived in Kumamoto, home of one of Japan's famed "technopolis" centers for research and development, six of which have sprouted in Kyushu in the past decade. There I met Takao Higashimachi, a senior researcher in the center's applied electronics division and a good example of what Kyushuans refer to as "U-turn" persons—the growing number of young and middle-aged professionals who eschew the higher salaries and prestige of jobs in Tokyo and Osaka for a chance to return to the more relaxed ways of their native island.

Mr. Higashimachi, a shy, bespectacled man of 47, ushered me into a room, quiet as a library, where, I was told, the industry of tomorrow was taking shape.

There were no thundering forges or churning sprockets—only a half dozen men in overalls who appeared to be fighting off the urge to fall asleep as they stared into computer screens where an electronic landscape of lines, rectangles, and cones slowly twisted and turned.

Frankly, if this was the future, it struck me as a little dull. But Mr. Higashimachi was brimming with excitement. He showed me a plastic soy-sauce packet so aerodynamically efficient that it could be emptied easily in a single squirt.

Such revolutionary advances were the result of computer-aided engineering, he told me, which makes it possible for nearly anything the human mind can imagine to be "built" on a computer screen without having to be physically constructed first.

Mr. Higashimachi spent 12 years in the rat

race up north working for a giant electronics firm. Back home in Kumamoto, amid the greenery and the silence, he said, "you can think your own thoughts"—critical to the future of Japanese industry as ever more information-intensive functions replace manufacturing muscle.

KUMAMOTO HAS one of the largest populations of hundred-year-olds in Japan, a nation that prides itself on having the world's longest life spans—82 for women, on average, 76 for men. The locals attribute this to hard work, healthy diets including plenty of fresh vegetables, and *mokkosu*—dialect for a state of mind hovering somewhere between the merely stubborn and the devoutly cantankerous.

In the spirit of mokkosu, older Kyushuans gripe that encroaching urbanization has robbed life of its color and snap. I raised the issue with Yoshihiro Noda, a 67-year-old with a head of wispy white hair and a laconic grin, when we were seated on the veranda of his farmhouse just north of Kumamoto.

"Life is more comfortable than when I was growing up," he said, as we watched the sun dip behind the emerald hills that bordered his rice fields. But he added mischievously: "Too bad people have become so boring!

"Our village has a big electronics plant here now employing 1,200 people," he explained. "Golf courses are popping up, and we've got plenty of tax money rolling in. But something's missing. The young people stumble around with a dazed look on their faces." The old folks, whose stories of village life were once the riveting source of entertainment and wisdom, can't compete with MTV.

When Yoshihiro was a boy, he sat in the charcoal brazier's glow and listened to tales of Kyushu's mighty warriors. Back then there were people who remembered actually seeing squat, bullet-shaped Saigo Takamori and his

- ROBOTIC ARMS that can stop on a yen weld bodies of the Mark II hardtop, made only for domestic sale, at Toyota's new plant in Fukuoka Prefecture.

Along with Japan's industrial marvels are sorrows left by ignorance and shortsightedness. During the 1930s a chemical plant began dumping lethal methylmercury into Minamata Bay. The eating of contaminated fish led to deaths and birth defects. At Meisui-en Hospital, built expressly for the victims, Kazumichi Hannaga, 37, indulges his passion for photography.

rebel army, banners aflutter, when it gathered on the banks of the Kikuchi River for its last ill-fated charge on Kumamoto Castle, then a national army stronghold.

Nowadays, the old folks watch game shows on TV. What good is long life, asks Yoshihiro, if it ends in loneliness and boredom?

Yoshihiro offered to show me Kikusui's nursing home, down the hill from his farm. This was despite an unfortunate incident that had marred his last visit there. An amateur entomologist, Yoshihiro was collecting fireflies from bushes near the home's entrance when he was mistaken by lady residents for a *nosoki*, or Peeping Tom. The night had erupted in shouts and finger-pointing.

"Are you sure it was a mistake?" asked his younger brother Tomosuke, my hitchhiking partner, who had guided me to Kikusui.

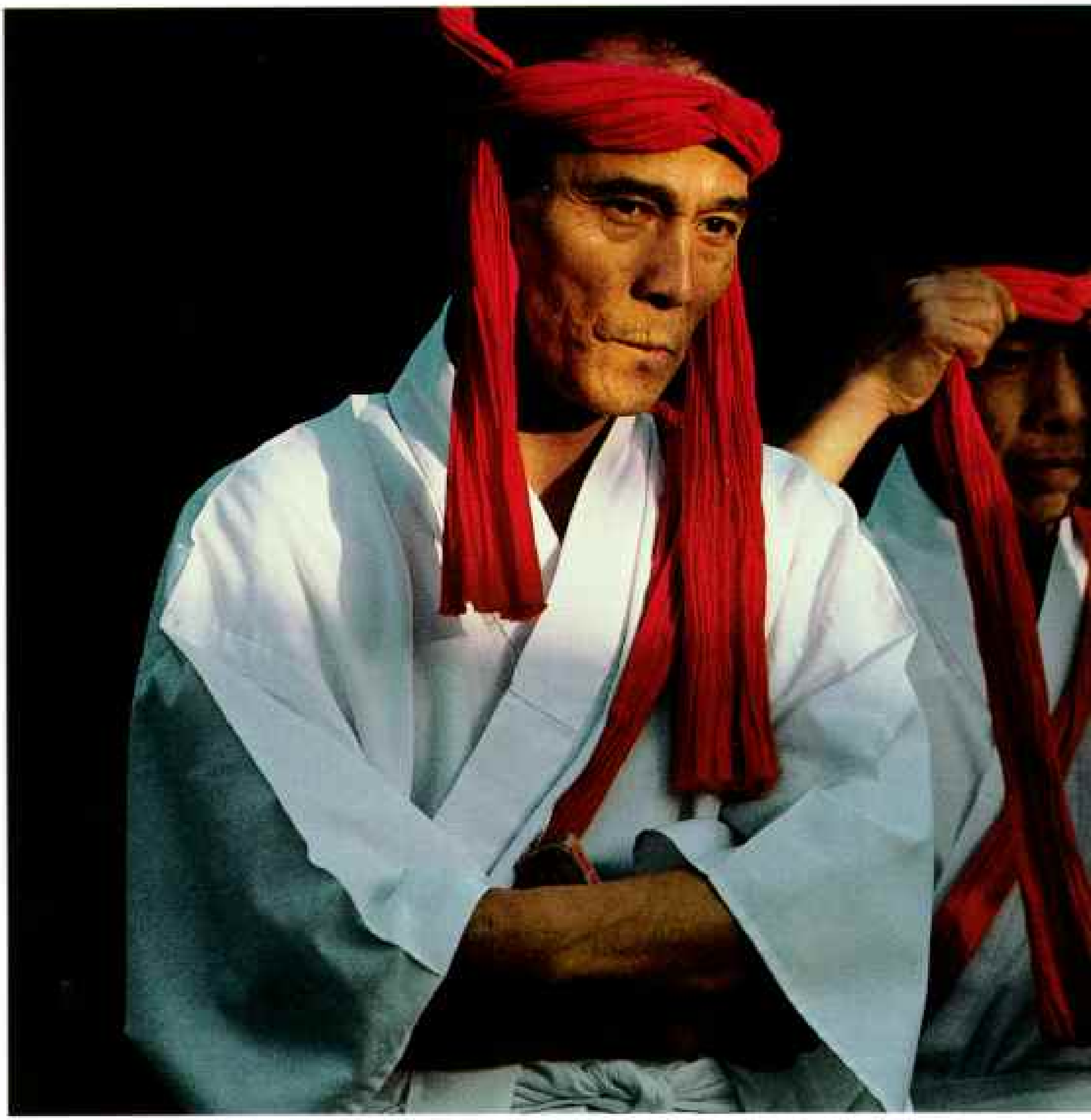
Yoshihiro guffawed. "Who in his right mind would want to peep a rest home?"

In spite of the mix-up, director Kunio Ikeda greeted us warmly, showing us the premises, which resembled a tasteful country inn. He then introduced us to Kayo Sakamoto, who, at 103, was its oldest resident.

"So that's what an American looks like," she said, delightedly, when I ducked my head to walk through the door. "You know, I've never seen one of those before."

I knew from Mr. Ikeda that the waiting list for this popular home was a long one but was amazed to learn that Mrs. Sakamoto had been there just six months. Before that, she had spent her days weeding the vegetable patch on her son's farm. "I used to carry 60 kilos [132 pounds] of rice on my back! I drink sake every night," she added vigorously. "Then I sing the karaoke!"

I shook her hand for good luck, as she instructed, and then caught sight of Yoshihiro, who was gazing out the window at his adjacent fields, scratching his head and smiling. He appeared to have changed his views on



boredom and old age. "If I were to donate that field to you," he said to Mr. Ikeda, "do you suppose I might get accepted here . . . you know, when the time comes?"

The director smiled. Perhaps he was remembering the night of the fireflies. "Thank you for coming," he said.

Not everybody has benefited from Kyushu's economic revolution, as Tomosuke and I discovered two days later when we found ourselves in a shiny brown sedan hurtling south along Kyushu's flat, semitropical Pacific coast. On leaving Kumamoto, we had crossed the great green hump of volcanic Mount Aso, hitching rides through the mountains to the city of Nobeoka, where, after a long wait, Mitsunori Awata retrieved us from a strip of burning asphalt.

"Come on," yelled Tomosuke, rushing forward excitedly, after Mitsunori had nearly caused a multicar pileup by slamming on his brakes in the middle of rush-hour traffic. Tomosuke, who had written entertainingly about kayaking treks in Alaska, Mongolia, and other exotic locales, had become something of a cult hero for a younger generation of adventure-starved Japanese. That had led to the inevitable TV endorsements, and now—lucky for us—he had been recognized by a member of his driving public.

● IN ROBES OF SACRED WHITE, dancers await their cue for a reenactment of the myths of creation in Takachiho. Shintoism, the nation's indigenous religion, holds that the Japanese people sprang from Kyushu, where gods who walked the earth were made mortal.

"This is the guy in those instant-noodle commercials!" Mitsunori shouted to his young woman companion, as we roared off. She peeked at Tomosuke over her dark glasses. Unimpressed, she cranked up the rock music on the car stereo and lit a cigarette as we rolled down a long, arrow-straight highway lined with fast-food restaurants, enormous gas stations, and ragged palm trees that helped explain why the Japanese refer to this area as the Florida of Japan.

It might look like paradise, said Mitsunori, a loquacious, round-faced 34-year-old, but folks like him were caught in a bind. The area's biggest employer, Asahi Chemical, had cut its payroll. New factories had been built, but, in the same ironic twist bedeviling much of the industrialized world, Mitsunori and his friends discovered that an economy that prospers on technology doesn't necessarily create many new jobs.

"Robots do the real work around here now," he said.

Mitsunori himself worked as a *daiko*—a taxi driver who patrols bars and nightclubs late at night, picking up inebriated patrons who pay many times the regular fare to get themselves home. But he insisted on taking Tomosuke and me—free of charge—all the way to our remote destination: the sprawling Seagaia resort in Miyazaki.

WHEN WE REACHED the hotel's long, circular drive, with its platoon of bowing lobby attendants, I asked Mitsunori and his companion in to lunch, to repay their kindness. But he declined. This wasn't their world, he said. "We don't feel comfortable here."

I could understand how he felt when Tomosuke and I found ourselves inside the resort's Ocean Dome complex, which billed itself as the world's largest indoor water-recreation facility. We walked the broad, man-made beach, where a machine would generate perfect eight-foot tube waves for surfing, and stared openmouthed at the painted underside of the huge canopy, where white clouds scudded across a sky of artificial blue.

Our guide, a genial public-relations man, said the project would create some 2,300 service jobs to cater to the 2.5 million yearly visitors the dome was expected to draw after it opened in the summer of 1993.

Those jobs won't pay as much as manufacturing jobs, of course. But Miyazaki lags behind the rest of the country, and even the burger-flipping, pool-cleaning types of jobs are preferable to no jobs at all.

The PR man caught me staring at the plastic coconut palms sprouting from a stone grotto

● MASSAGED INTO INEFFABLE BLISS, a hotel patron in Kagoshima finds solace in a bath sanctified by a shrine to a god of water and rain. Finding time to relax is not easy under Japan's burdensome

work ethic. A nationwide campaign to reduce the hours spent on the job and in school propels a rush to build theme parks, golf courses, and indoor ski slopes for a thriving leisure industry.

● MOUNT FUJI OF A MAN called Konishiki, 580 pounds of him, clowns around before catching a ferry for a sumo exhibition in tiny Arikawa. As football is to Texas, sumo is to Kyushu, a traditional breeding ground for practitioners of the wildly popular national sport.

that workmen were painting brown. "Only the coconuts are real," he said proudly. The air temperature, I was informed, was a constant 86°F, the water 82°. I thought of Mr. Hirasawa and his turtles.

"The Japanese will love this," said Tomosuke with a cool eye. Although it is less than half a mile to the real ocean, today's parents consider the surf too risky for their children. The nation has become captive to its mania for careful programming, he believes. "We now prefer things that are safe and predictable, and leave nothing to chance."

FINALLY WE REACHED Kagoshima, Tomosuke's adopted hometown, and I began to wonder if he hadn't gone a little soft himself. His residence was elegant—with the exception of his pet duck, Akio, who inhabited the tub room, making human hygiene impossible. The flat bespoke a lifestyle more commonly associated with California dreaming than the *usagi goya*, or rabbit hutches, that Tomosuke had occupied all the years I had known him.

Still, Kyushu's renegade spirit was much in evidence. Behind us rose conical Shiroyama, the city's hilltop monument to Saigo Takamori, where, in 1877, the old warrior had slit his belly in ritual suicide rather than surrender to Tokyo's hated minions. From the balcony I could see the blue sweep of the bay, where a fleet of eight-man shells from Kagoshima University raced over the cresting waves, shouting as they went, while in the background volcanic Sakurajima glowered and belched.

Thanks to the latest corruption scandal to rock the country's ruling Liberal Democratic Party, Japan's usually staid political world was itself churning with new fire. In only a few weeks angry voters would unceremoniously put an end to 38 years of LDP rule and open the premiership to Morihiro Hosokawa, an energetic, reform-minded politician from one of Kyushu's oldest samurai families.

Viewed from Kyushu, the direction of events already seemed clear enough. "The big gap that's separated the people from the professional politicians is narrowing," said Koji Nakamura, a respected local journalist, while I sat sipping tea with him at his office.

Ordinary citizens were finally demanding a say in the issues that affected their lives: Why they were obliged to pay some of the industrialized world's highest prices for groceries, for example, or to live in some of its tawdriest housing.

Deregulating and decentralizing, Japan might finally succeed in prying open its clam-like economy—to the benefit of both Japanese consumers and chronically irritated

trading partners, including the United States.

The makeover might take years, Koji warned. But when it comes—if it comes—it would move from the outside in—from places like free-and-easy Kagoshima, not bureaucratically infarcted Tokyo. Ever since World War II the authorities have thought only of making the country rich, but the fabled Japanese patience was wearing thin with that old formula.

"People want a new sense of identity," said Koji, "based on the quality of life and the place they call home." For an example of the new pluralism, Koji volunteered, suppressing a grin, "Look at Mr. Noda here."

I looked. Somehow, I had never thought of Tomosuke, who was dressed in an ancient T-shirt bulging with the unmistakable contours of middle age, as a symbolic figure. Still, I had to admit that he did represent a sort of quirky triumph of personal predilection over the forces of organization and control, and I made the mistake of saying so.

Tomosuke smiled smugly. After all, it had only taken me 20 years to figure out what he and every other Kyushuan had always taken as gospel: Given their due, there was no telling where the people of the south, with their fire and fight, might eventually lead themselves—and the rest of Japan as well. □

A rowdy crowd of macaws spatters their brilliance on a clay riverbank in a Peruvian rain forest. Why they congregate daily to eat clay by the footful is still a question. Study of these smart, long-lived birds brings the promise of knowledge that may help protect them for—and from—their admirers.

Winged Rainbows Macaws

By CHARLES A. MUNN

Photographs by FRANS LANTING

ARA MACAO

In one flash a four-month-old fledgling scarlet macaw learns to fly on wings that span almost three feet. Native to the Americas, macaws have been coveted by collectors since Spanish and Portuguese explorers took specimens back to Europe in the early 1500s.

WHEN the morning sun clears the Amazon tree line in southeastern Peru and strikes a gray-pink clay bank on the upper Tambopata River, one of the world's most dazzling wildlife gatherings is nearing its riotous peak.

The steep bank has become a pulsing, 130-foot-high palette of red, blue, yellow, and green as more than a thousand parrots squabble over choice perches to grab a beakful of clay, a vital but mysterious part of their diet. More than a dozen parrot species will visit the clay lick throughout the day, but this midmorning crush belongs to the giants of the parrot world, the macaws.

Hidden in a blind a hundred feet away, I watch the congregation. Flying in on wings of royal blue with a hint of green, the husky red-and-green macaw is the largest, weighing three pounds and measuring more than three feet from head to tail. The slightly slimmer scarlet macaw unfurls darker blue wings with brilliant yellow shoulders. The blue-and-yellow macaw flashes feathers more turquoise and gold. All three shake tails as long as their bodies and boast probably the most powerful bites in the bird world.

Macaws seem to mate for life, so most arrive at the lick in pairs. Some are shepherding offspring. The juveniles are perfectly capable of biting off their own clay, but they're spoiled. Bleating relentlessly at their parents, they usually get their way, and the adults regurgitate clay into their mouths, pampering them as they have since the day they hatched.

Only a third of the macaws can get on the lick at a time. About every half minute the rotation changes, and those shrieking for their turn from surrounding trees and vines surge forward. The air reels with color.

Now one macaw sees an eagle soaring above and screams an alarm that catapults the birds into flight. Ten adults peel off from the flock and circle just above the predator, which can attack only by diving. They

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CHARLES A. MUNN is a senior research zoologist with the Wildlife Conservation Society. The work of wildlife photographer FRANS LANTING has appeared frequently in NATIONAL GEOGRAPHIC as well as in the Society's recent book *Forgotten Eden*.

TWINING CHANNELS of the Tambopata River bring water from the Peruvian Andes to rain forest at the edge of the Amazon basin. Mostly untouched by the development that has scarred neighboring areas, 50,000 square miles here shelter an especially diverse group of plants and animals, including eight species of macaws.

assault it with their loudest cries, and the eagle quickly flies away. I came to appreciate the close-range power of that ultimate macaw shriek early on in my ten years of studying these extraordinary birds. A trumpet blown straight into your ear would not feel worse.

THE FIRST MACAW clay lick I ever saw was 150 miles northwest of the Tambopata lick, in Manu National Park, where I was researching small forest birds. Other biologists and I assumed that it was the only macaw lick in the world. That's how little was known in 1984 when I began the first study of macaws in the wild for the New York Zoological Society, now called NYZS/The Wildlife Conservation Society.

Today we have counted 18 major licks in southeastern Peru and heard reliable reports from the region's native people of 15 others. There are likely dozens more on riverbanks in the inaccessible reaches of this forest—arguably the most biologically diverse and intact rain forest in the Amazon, and in the world.

Sixteen species of macaws inhabit tropical forests from central Mexico to northern Argentina, distinguished among the world's 340 parrot species by their long tails and huge beaks. Eight are considered large; the others weigh a pound or less. Nine are endangered or threatened, and Spix's macaw of Brazil may soon be extinct in the wild. Macaws' intelligence ranks them among birds as chimpanzees rank among apes.

Eight species of macaws remain abundant in southeastern Peru. But when I began to study the region's three largest—the red-and-green, the scarlet, and the blue-and-yellow—the birds and their forest were facing some of the pressures that have imperiled macaw species elsewhere.

Fortunately, export of rain forest birds (outlawed by Peru in 1973) had not been a problem in this wilderness east of the Andes—it was simply too remote. But the 400 Machiguenga Indians in Manu National Park would occasionally shoot macaws for their tough, stringy meat if a day's hunt for spider monkeys and tapir had failed. Also gold miners were pushing into tributaries of the Tambopata River. And that region's virgin stands of timber were luring commercial harvesters.

As I began to fill in the blanks of macaw biology—what is their diet? why do they eat clay? how often do they reproduce? what is their family structure?—the sheer joy of watching these birds gave me an idea.

If the Machiguenga and others could make money showing wild macaws to tourists, macaw conservation—and the conservation of their Amazon habitat—would be profitable.

Now a fledgling ecotourism industry is under way, and appreciation of the value of macaws contributed to Peru's recent proposal to create a 1.8-million-acre national park in the Tambopata-Candamo Reserved Zone. Macaws—elegant, rambunctious, always personable—are becoming Peru's rain forest ambassadors.

ON THE MAP Manu National Park lies less than a hundred miles north of the ancient Inca capital of Cuzco. With 3.7 million acres, the Connecticut-size park probably holds more species of plants and animals than any other protected region on earth: an Amazon realm of jaguars, giant otters, ocelots, red howler monkeys, emperor tamarin monkeys, black caimans, brilliantly colored tree frogs, hundred-pound catfish, and a thousand known kinds of birds.

The human population averages around 500: two villages and scattered clans of Machiguenga Indians and about 40 Peruvians, Americans, and Europeans working with me or the Cocha Cashu Biological Station, operated by biologist John Terborgh of North Carolina's Duke University. There are also several tiny clans of Mashco-Piro and Yaminahua Indians, who are rarely seen; they leave everyone else in peace and wish the same for themselves.

The macaw lick where my

ARA CHLOROPTERA

work began is 12 winding miles from the Cocha Cashu station up the 200-yard-wide Manu River. Near the lick we cleared ground for the Machiguenga Ccollpa Biological Station.

A thousand-square-foot raised wooden platform with a palm-thatch roof serves as kitchen, dining room, and work area. There are seldom more than a dozen scientists and assistants in camp at any one time. We sleep on the ground in tents with window mesh fine enough to keep out the tiniest insects. We stock the station each May, at the end of the rainy season, by loading food and gear onto a lumber truck in Cuzco and crossing the two eastern ranges of the Andes on a single-lane dirt road.

More than five hours out, the road peaks at the top of the second range, and the green sea of the Amazon basin swells to the horizon below. A seven-hour descent from cloud forest to lowland forest brings us to the eight-family village of Atalaya on the Alto Madre de Dios River. The next morning we move our supplies into 55-foot cargo canoes and push into trackless rain forest. After five hours we meet the Manu River and veer northwest for three hours. The next day six hours of slow motoring brings us to camp. We sleep well that night and awake at dawn to the cries of macaws.

GAUDY, RAUCOUS BIRDS would seem to be easy subjects to track. But when macaws fly into the dense forest canopy to search for food, they become invisible and almost silent.

To learn what they were eating, my assistants and I spent the first two seasons of the study

A GALLERY of portraits enables author Charles Munn and his wife, Mariana, to identify individual red-and-greens that visit a nearby clay lick on the Manu River (above). "Lines of face feathers are as unique as fingerprints," Charles explains. With this knowledge of the local macaw community, the Munns can build a picture of each bird's habits and interactions throughout the four decades of its life.

walking the forest and listening for the subtle sounds of debris falling onto the thin layer of leaf litter, a sure sign that parrots or monkeys were feeding in the canopy 120 to 180 feet above.

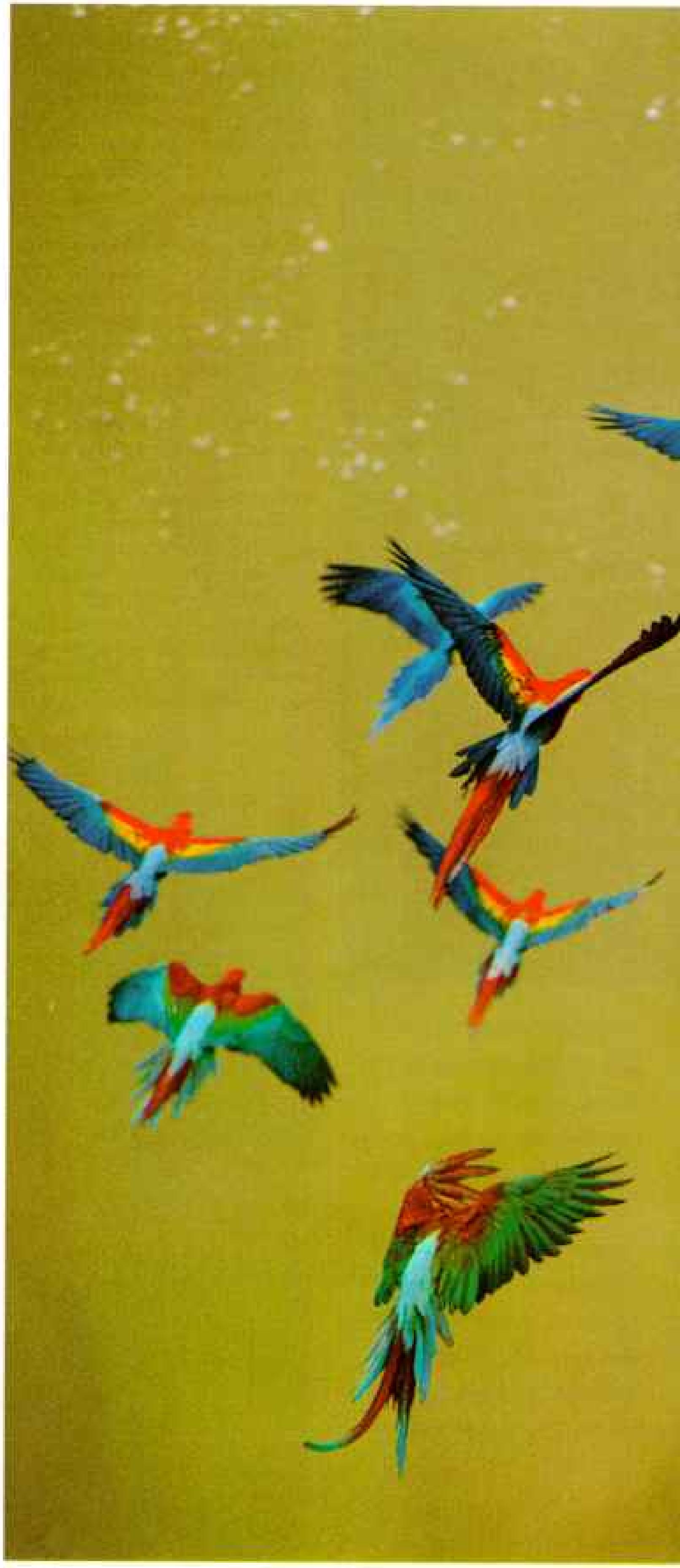
If the falling seeds or fruit had scoop-shaped beak marks, we knew we had found parrots, and we hoped they would be large macaws. If we waited in silence, the birds would often reveal themselves by squawking quietly—communicating, we now know, with family members. Then we could locate them with high-powered telescopes and observe their feeding behavior.

We discovered that macaws break through the pulp of fruits to get directly to the seeds, which they crack and eat. They also eat the pulp of some fruits and occasionally flowers and leaves. But their main goal is seeds, making macaws unlike most birds in the tropical forest.

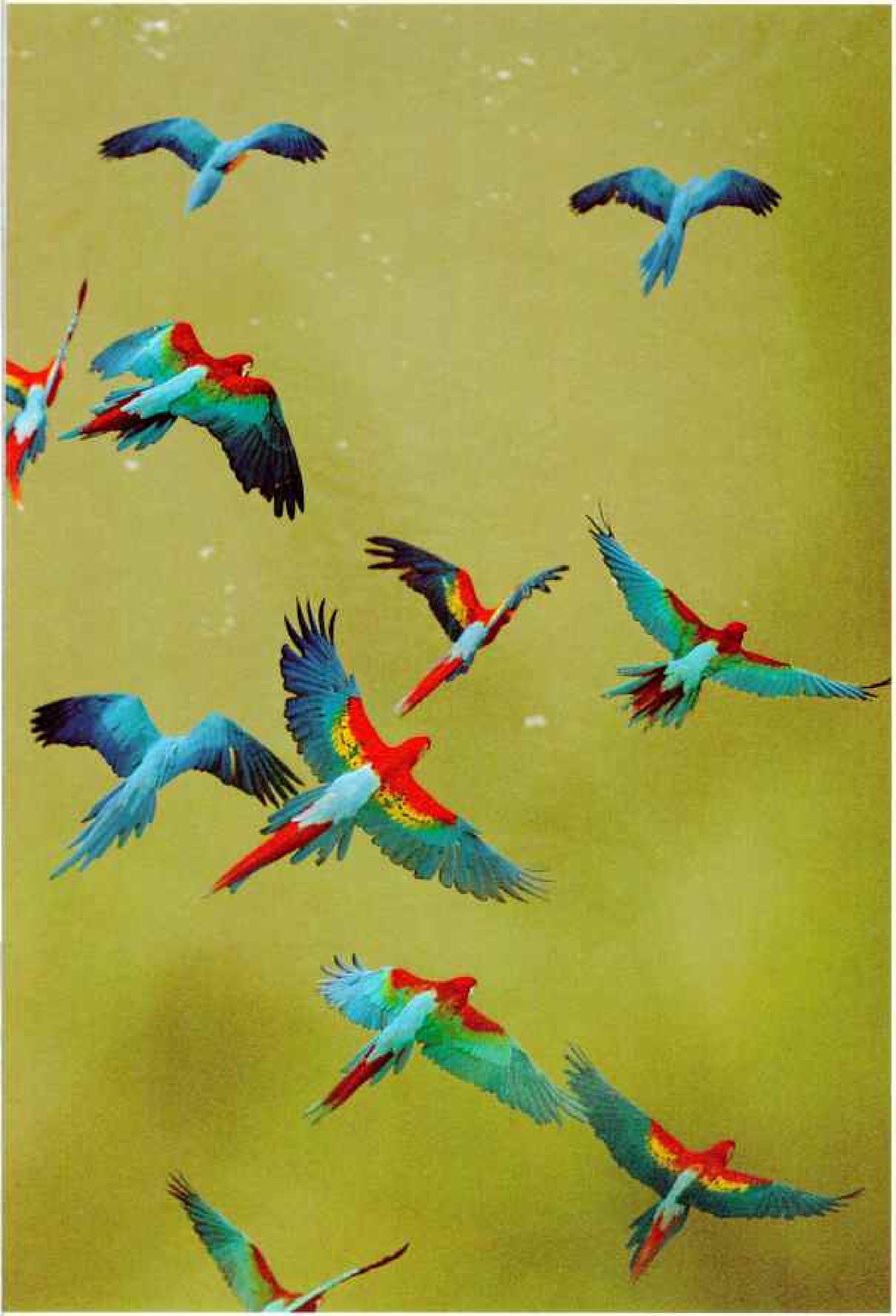
In feeding, a macaw displays mammal-like dexterity. Each muscular leg powers a foot of four clawed toes, two facing forward, two backward. The bird can hang upside down or reach sideways effortlessly, anchored by one foot to pick fruit with the other. Its hooked beak can act as a third foot for climbing.

Once the bird has lifted a fruit to its beak, it cannot see it, but its thick tongue judges the shape and works with the skills of a thumb to rotate the fruit and position its seed for cracking.

No seed appears to be a match for that beak. We find



IN A FIREWORKS BURST, macaws lift off from a clay lick on the Tambopata River. Such spectacles are a major attraction for a growing ecotourism industry, which generates jobs without harming the birds or destroying their habitat.



macaws eating in mahoganies, kapoks, coral bean trees, and rubber trees—among a list of 60 or so favorites. But I think they experiment with everything. It's part of their curious nature to bite and test. How hard is it? Does it taste good? If I eat one or two, will it hurt me? And in a forest of maybe 2,000 species of flowering or fruiting trees, plants, and vines, they may come upon something they haven't seen before, that blooms only every few years.

But if macaws seem to have no lack of food, why are they also eating riverbank clay?

We found that the clay is high in salts and minerals the birds may not get from their primarily vegetarian diet. Even more intriguing, as we analyzed the commonly eaten seeds, we discovered that many held toxic chemical compounds—tannins and alkaloids. I tried chewing the seeds myself. Some were sweet at first taste, then my mouth began to tingle, burn, and swell.

It is likely that macaws take almost daily doses of clay to detoxify themselves. Clay binds to the toxins and speeds them through the body. Indians in the high Andes eat clay to counter the effects of bitter wild potatoes.

Another clue is the seasonal fluctuation of visits to clay licks. Most years macaws eat less clay during May and June, at the start of the dry season, when many plants are flowering. By late July the licks are active again, and the macaw crowds peak in August and September, the driest time of the year. We suspect that as food sources dwindle, macaws may have to fall back on more toxic seeds.

To pinpoint the biochemical function of clay eating, James Gilardi of the University of California at Davis is now analyzing dried foods from Manu for toxic compounds. In lab experiments he is also feeding these foods to Amazon parrots—more manageable macaw relatives that also eat clay in the wild.

ARA ARARAUNA

WITH A WICKED BITE and a tongue as agile as a thumb, a blue-and-yellow will open a nutritious seed with ease after tearing away the fruit. Of the myriad fruits and flowers available to macaws (opposite), many contain toxic seeds that fend off predators. The birds show no ill effects; they may gain protection—along with basic minerals—from the clay they eat.

MACAWS NEST in cozy tree cavities a hundred feet or more off the ground. Two questions loomed as I set out to investigate macaw reproduction. How would I get up there, and how would the birds react once I did?

Climbing straight up most rain forest trees is not a good option. Their trunks are highways for stinging insects and are tangled with vines and bromeliads. I took my lead from the technique of cavers, who need to get up and down fragile cave walls without touching them—then improvised.

I start with a giant slingshot, launching a weight on a long thin line over a branch near the nest. Then I tie a climbing rope to the unweighted end and pull the weighted end by hand until the rope is hanging over the branch. With one end anchored to the base of a thick tree, I attach a harness to the other, sit in it, and hoist myself using special clamps.

As I approached my first nest, where a red-and-green macaw chick was about to fledge, I had a feeling that the adults would not attack me outright. But I honestly had to wonder: If they objected to my presence, would they use their considerable intelligence to size up the situation and bite through the rope?

In fact they did neither; instead they sat on a close branch and screamed. The fledgling screamed. I wanted to scream as I stuffed toilet paper into my

SPROUTING its first gaudy feathers at five weeks, a red-and-green rides out a nestling study weigh-in. Although this chick, like most, hatched in a hollow tree trunk, some now thrive in nests of textured PVC pipe. A researcher guides one such nest to the top of a tree, where he will strap it in place. Augmenting nest sites in this way has increased successful breeding.

ears and made a mental note that industrial earplugs would be part of my next climb.

My colleagues and I have now made thousands of ascents to chart life in 140 macaw nests. The screaming occurs only on the initial visit. On follow-up trips the birds simply watch as we dangle before the nest hole to count eggs, weigh hatchlings, and follow their progress. They remember us.

IT WAS STILL LEGAL in the late 1980s to import wild tropical birds into most of the U. S. Opponents of this policy were gathering scientific evidence to back their conviction that wild bird populations could not quickly replace those taken. What my colleagues and I learned among the macaws contributed to the U. S. import ban that became effective last year.

Our data suggest that in a sample of a hundred mated pairs, only 10 to 20 pairs try to reproduce in a given year and that only 6 to 14 fledglings will come of these efforts.

Since males and females look alike, we can distinguish between the sexes only during breeding and nesting. They usually mate in December, and the female lays two eggs. While she incubates them for four weeks, her partner brings her food he has swallowed and stored in a throat pouch. He regurgitates it into her mouth, just as both parents will do later for their young.

If the eggs are not chilled by rainwater or eaten by long-beaked toucans or by weasels called tayras, they hatch in January, one to five days apart. The oldest nestling enjoys the major competitive advantage of being fed first at every meal. Its sibling seldom survives. Usually the parents push a dead chick out of the nest. But my colleague Daniel Blanco Zamalloa of the University of Cuzco found one red-and-green buried in the nest floor.

When a macaw is ready to fledge at three to four months, it is as large as its parents—but it still has a lot to learn. Maneuvering its body out of the nest hole is the first challenge if the hole is quite narrow. Sometimes the parents cut back the nestling's rations to force it to make the effort.

That was the case at the red-and-green macaw nest I first climbed to. When the nestling finally squeezed out, it flew awkwardly to a nearby tree, its doting parents flying just behind, squawking what probably

was advice and encouragement. Then the youngster flew a wobbly course through the forest mid-story and crash-landed in soft leafy branches. Several days passed before it was flying confidently with its parents at a stately 20 miles an hour.

MACAWS PLAY and interact with each other in ways that most other birds don't. A pair of mated adults will preen each other and their offspring for hours, removing lice and ticks and naturally dispersing body oil on one another's feathers. They don't usually socialize with macaws outside their nuclear family, but they talk to each other constantly.

In a trio or quartet of macaws we can identify the young by their eye color. Their irises are dark, becoming yellowish-white with age. But their behavior is a giveaway too; even when they can care for themselves, they often pretend to be babies.

Macaws usually leave their parents and start looking for a mate at age two or three. Finding a place to lay eggs is a far more difficult matter. I learned, to my surprise, that a contributing factor in the macaws' low reproduction rate is an acute housing shortage.

A square mile of virgin rain forest in Amazonian Peru contains as few as one or two nest sites that are deep, clean, and dry enough for large macaws.

A HUNDRED DIZZYING FEET high, Eduardo Nycander von Massenbach examines a blue-and-yellow for parasites. Twice a week he checks on the progress of dozens of chicks, weighing and measuring them before returning them to their nests.

The blue-and-yellows look for dead palms in the river floodplains. Red-and-greens seek hardwoods on higher ground. Versatile scarlets use both. The competition is intense.

Once red-and-greens lay claim to a nest hole, they guard it year-round. We came upon an attempted takeover one day and watched fighting birds tumbling in a blur of red feathers. Beak-to-beak and talon-to-talon, they separated just above the ground.

A couple of blue-and-yellows saw their chance to grab a nest occupied by a single parent and two young nestlings and began a harassment campaign. The solo adult, perhaps widowed by an eagle attack, finally had to leave its young unprotected in order to get food. The marauding pair grabbed the larger nestling and dropped it 50 feet to the ground, killing it. The parent returned to defend the survivor, which then fledged prematurely a few days later. Now the victors moved in, but the parent stayed near to feed its fledgling, which took shelter in bushes. After several days the interlopers left to nest in a palm right next door, and parent and fledgling flew off to another nest site.

RED-FACED FROM ANXIETY, blue-and-yellows (left) guard a nest site from another pair scouting for a place to breed. Once the rains sweep in the season of abundance, a female usually lays two eggs, which she incubates for a month. Macaws are thought to mate for life; both sexes feed their offspring. In close quarters (above) one regurgitates food into the mouth of a hungry chick.

AN ARCHITECT from Lima, Eduardo Nycander von Massenbach never imagined he would turn his talents to designing homes for macaws—and climb 150 feet up trees to install and monitor them. But working as my assistant in 1987, he says, "brought me to a crossroads in my life."

Nycander is now also a field biologist and the director of the Wildlife Conservation Society's macaw project at the Tambopata Research Center. Much of the work is financed by a Lima brewery, Cervecería San Juan, and Rainforest Expeditions, a company Nycander created with macaw biologist Kurt Holle Fernández to introduce tourists to wild macaws. The center, 600 yards from the spectacular Tambopata River clay lick, is much like our camp in Manu.

Expanding macaw nesting opportunities is one aim of the center. Nycander and his field director, José Moscoso Garcés, experimented with several materials for birdhouses (wood was devoured by termites within two years; metal risked overheating) before settling on PVC pipe. They burn the outside, then scrub it with a steel brush to give it the same color and texture as the tree trunks.

In 1992 they hoisted six PVC nests, 14 inches in diameter, eight feet tall, and strapped them to the trees. All but one, for reasons we're unsure of, attracted macaws, all scarlets.

Last year the center launched another mission: to balance the chances of survival for that second macaw nestling. Nycander and his team took 18 weaker siblings from nests (natural and artificial). They fed them formula by hand, slept with them in the nursery at night, and lived with colorful chaos. "The birds are very loving," Nycander reports. "They control their bills to just nibble softly on our ears."

Wild macaws took a social interest in the foster birds as they began to fly. Now 18 macaws that probably would have died in infancy have joined the clay-lick throngs. They return to camp for daily visits.

The overriding good news from our housing and day-care experiments in Peru is that we

have two proven ways to try to boost the most endangered macaw populations. Wildlife Conservation Society biologists are already setting up the nests in Bolivia and Brazil.

THE IDEA that macaws could be raised by humans and still successfully interact with wild flocks came from the practices of the Machiguenga Indians, who would cut down trees to take nestlings as pets. They were also using bows and arrows to shoot adult macaws for food when I arrived in Manu. I at first thought that the birds would be too skittish to study. With time the Machiguenga and I began to learn from each other, and now they have become allies in macaw conservation.

They agreed to stop hunting and capturing macaws, to help us locate nests and licks, and to teach us what the birds eat in different seasons. The Wildlife Conservation Society in turn provides shortwave radios, money for boats, medicine, and education, and advice on running the Machiguenga's tourist bungalows, which sit on Cocha Salvador, the finest lake in the Manu region.

Fifty miles southeast, the macaw clay lick at Blanquillo, on the Madre de Dios River, is not officially in a national park. But it is treated as such by four Quechua-speaking Peruvians who, as wilderness homesteaders, legally claimed 5,000 acres around the lick in 1989. They had come to Manu a few years earlier to work with me. To try their hand at conservation tourism, they filed a land claim and built the rustic 20-bed Manu Parrot Inn.

The partners survived the slump in Peruvian tourism—now beginning to rise as peace returns to the country—by serving meals to boats of Quechua-speaking gold miners from Cuzco, who pass by daily to pan rivers downstream. They taught the miners about the lick and showed videos, provided by the Wildlife Conservation Society, of macaws and other wildlife in the Manu area. Soon the miners' commute was sounding like a nature tour, with the boat drivers and passengers calling out names of passing flora and fauna. "No throwing trash or bothering animals here," the drivers announce as they dock the boats at Blanquillo. "This is a park!"

As I had hoped, ecotourism is helping macaw conservation pay for itself and at the same time raising awareness of the birds. The national park in Tambopata has been planned with a farsighted balance of Peru's conservation and economic needs. Beyond the northern edge of the park, commercial zones for small-scale streambed gold mining and Brazil-nut harvesting will provide income without destroying the forest cover. The country will also profit from tourists drawn to the rich wildlife in a 1.8-million-acre park that will protect the world's largest known macaw clay lick.

NEW BREAKTHROUGHS in macaw research should be happening this year. Accurate tracking of macaws in a rain forest is impossible from the ground. Radio collars won't work; macaws nonchalantly destroy them as they preen one another. We have been able to follow their paths to and from the clay licks only from observation posts in the tallest trees on the highest ridges, swaying in harnesses with our eyes pressed to telescopes. Now we will actually be able to fly with the birds, in an ultralight aircraft equipped with pontoons.

AS CURIOUS AS TODDLERS, young red-and-greens chew apart headphones at the Tambopata Research Center. Since macaws often fatally underfeed the younger of their two chicks, researchers rescued 18 weaker siblings to raise by hand. Besieged at feeding time, Alvaro del Campo flinches from a nip. "They have different personalities, and some are very difficult," he says. The birds now fly free in the forest, reinforcing the local population.

AS IF FOR PROTECTION, a juvenile scarlet takes a friend under its wing. If human efforts to protect them and their rain forest home are successful, they may yet live out their years free and safe.

We have speculated that the birds using any one lick are coming from no more than five miles away. In the ultralight we can follow them to the forest where they forage and nest. This will also let us calculate an area's population density.

When clay-lick attendance falls in May and June, we will be able to learn if the macaws are still feeding in their home forest or if they are traveling to a rich source of nontoxic food in another area. Many blue-and-yellow macaws leave the Tambopata lick area between April and July, returning in August. Where are they going? And are they protected there? Now we can follow them.

Another long-term project may be the analysis of photographs of the faces of red-and-green macaws taken at the Manu lick. The red-and-green, I discovered, has a unique pattern of feather lines on each side of its face. (So does the blue-and-yellow, but not the scarlet.) This facial fingerprint makes it possible to watch the behavior of individual birds over many years. Macaws seem to mate for life, but perhaps they also divorce and remarry. We could also learn more about their life span.

Macaws in captivity live for 50, 60, occasionally 70 years. In the wild, large macaws that survive their first year have few natural predators and probably die between the ages of 30 and 45 from a combination of eagle attacks, parasites, disease, and old age.

Few birds live so long or learn so much throughout their lives. It pleases me to know that years after I have retired from its rain forest, that first red-and-green nestling I met face-to-face will probably still be flying—protected and free. □

Golden-rumped Elephant Shrew **Genus:** *Rhynchocyon* **Species:** *chrysopygus* **Adult size:** *Average 29 cm; tail, 24 cm* **Adult weight:** *540 g* **Habitat:** *Coastal forest and scrub in Kenya* **Surviving number:** *Unknown*

Photographed by Galen Rathbun

WILDLIFE AS CANON SEES IT

A carpet of dry leaf litter rustles and crunches beneath the long legs of a golden-rumped elephant shrew as it busily turns over leaves and twigs in search of insects. Every few days the elephant shrew selects a new sleeping nest from about ten domed leaf chambers which it has constructed throughout its territory. Deforestation and development are threatening the survival of the golden-rumped elephant shrew. To save endangered species, it is vital to protect their habitats and understand the role of each species within the earth's ecosystem. As a global corporation committed to social and environmental concerns, we hope to foster a greater awareness of our common obligation to ensure that the earth's life-sustaining ecology survives intact for future generations.

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Czechoslovakia: the Velvet Divorce

The establishment of Czechoslovakia was less a marriage of convenience than a shotgun marriage. Rather than a divorce, its dissolution, described in the September 1993 issue, may be called an annulment, implying a correction of something that shouldn't have happened. I challenge one Czech's claim that 85 percent of Czechs and Slovaks alike were against the breakup. Slovaks cried out for independence and decided to dissociate democratically. They have had no desire to be lorded over by Czechs any more than by Hungarians, Germans, or Soviets.

CYRIL E. SAGAN
Volant, Pennsylvania

Thomas Abercrombie should be praised for his objective and well-documented report. However, recent events may call for some revision. On June 13, 1993, a popular politician, Jiří Hájek, founded a civic movement promoting reunification. Hájek has since died, but the movement, which has no status as a political party, is growing.

One also notices that Czech aristocrats, once the largest landowners, and churches, especially the Roman Catholic Church, are reclaiming land. Yet many argue that without up-to-date methods neither group is qualified to work the land.

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Eastern Kentucky University
Richmond, Kentucky

Czechs and Slovaks could have lived peacefully together, but tension, even hatred, has often been fueled by outside agitators, primarily Germans.

While Bohemia and Moravia were occupied by the Nazis, the people were brutally tyrannized. For example, the entire male population of Lidice was exterminated, women were sent to concentration camps, and children were placed with German families to be raised as Germans. Many crimes were committed by the Sudeten Germans, made fanatical by Hitler. The Nazis established an "independent" vassal state of Slovakia, from which they broadcast hate propaganda against the Czechs. The lasting poison of the Nazi era is largely responsible for the impossibility of the two nations being governed as one.

JAROSLAV KLUGAR
Lansdale, Pennsylvania

In 1945 some 240,000 Sudeten Germans died while fleeing Czechoslovakia, where they had lived for centuries. The rest were later forcibly evicted from home and country. They were subjected to ethnic cleansing to the extent that my grandmother's 1944 grave and marker were, by 1948, appropriated for a Czech body.

MARIA REYES
Columbia, South Carolina

Czechoslovakia is the country not only of Hašek's *Good Soldier Schweik* but also of the great philosopher of democracy T. G. Masaryk. Surviving under the communists favored the Schweik aspect of our character—shiftless, dishonest, obsequious, chauvinistic, and nationalistic. Today we are seeing the consequences. We can hope, though, that life in freedom will bring forth the spirit of Masaryk—honesty, tolerance, self-respect, and respect for others.

ERAZIM KOHÁK
Prague, Czech Republic

Britain's Hedgerows

You relate the beauty and the animal diversity found in hedgerows. More significant is the fact that they greatly reduce water and wind erosion. Even on a slope as mild as 2 percent, six-foot-high soil accumulations have been found on the uphill side of English hedgerows. Thus they provide a cost-effective method to curb soil erosion.

Hedgerows, often referred to as windbreaks in the U. S., actually increase crop yields because they block moisture-absorbing wind. Hedgerows can provide firewood and a valuable crop of fruits or nuts, and they absorb a lot more carbon dioxide than an equal area planted with crops.

HANS W. MORSBACH
The Hedgerow Foundation
Chicago, Illinois

The loss of Britain's hedgerows is analogous to the loss of windbreaks and woody field borders on U. S. farms. The key to preservation here lies not so much in government incentives as in education. Research at the University of Nebraska, Lincoln, has shown that preserving windbreaks boosts crop yields more than enough to make up for the land taken. Field borders also provide habitat for beneficial insects. Innovative U. S. farmers are manipulating the species mix in windbreaks to attract specific predators of the pests that plague their crops, allowing the reduction or elimination of pesticides.

CRAIG CRAMER
The New Farm
Emmaus, Pennsylvania

Not all hedgerow scholars accept as infallible Hooper's hypothesis for dating hedges. Hooper's method assumes that hedges were planted as one

species and that later invasions, accumulating over time, increased the number of species. But hedgerow planting was not consistent. Thomas Hill, writing in the 1570s, advocated planting as the Romans did: Seeds of thorny briars, gooseberries, barberries, etc., were mixed with meal, spread into a hemp rope, and dried. The rope was buried along the boundary to be hedged. It is by no means certain that Hooper's method is as scientific or accurate as your article implied—though it could be a useful guide.

DIANA WELLS
Washington Crossing, Pennsylvania

My wife and I planted a hedge in the spring of 1953 with a single species, *Rosa multiflora*. Recently the director of the University of Michigan Matthaei Botanical Gardens identified 13 species of plants in the hedge. It gives me a real feeling of accomplishment to consider that we have grown a 1,300-year-old hedge in a mere 40 years and four months.

CLAN CRAWFORD, JR.
Ann Arbor, Michigan

New Sensors Eye the Rain Forest

Your article is an impressive description of the level of sophistication that science is providing in understanding the impact of deforestation. However the question remains, what can we do about it? Floresta, a nonprofit organization, is focusing on the small subsistence farmer. Developed in the Dominican Republic, the program of training and low-interest loans enables slash-and-burn farmers to switch to fast-growing wood and fruit trees as cash crops.

During a four-year growing period, a revolving fund provides income to supply basic needs and helps him or her (we have several women farmers) raise alternative crops such as oregano and vine-growing fruits. Once harvest begins, income can increase tenfold from $300 to over $3,000 a year. The stumps of harvested eucalyptus trees resprout for continual harvest in ensuing years. Soil erosion and depletion are almost eliminated.

ROBERT L. AINSWORTH
Executive Director, Floresta
San Diego, California

Having traveled through much of Belize, I know the Belizeans want to keep their forests healthy, but they need hard currency. As one travels the coast south from Dangriga to Punta Gorda, it becomes apparent that the entire lowlands from the Maya Mountains to the Caribbean are under direct attack from citrus growers pushing back the forest to enlarge their plantations.

ALAN GERECKE
Fruitland, Missouri

Pecos River

I nearly cried with homesickness when I read your story on the Pecos River. I followed my husband to Colorado earlier this year, and though watching the light play across the face of the Front Range every morning is great, I get tired of people telling me how much better the scenery is than in West Texas.

As an oil company engineer for the past 12 years, I traveled grasslands of that area, watched the sun set behind the Davis Mountains, looked for the mesquite blooms that herald spring, followed the flight of the sandhill crane, and ate chicken-fried steak in every town on or off the map. The people define a land, and nowhere are they more resilient, tough, and friendly than in the beautiful, harsh Chihuahuan Desert.

NAOMI B. ORBECK
Littleton, Colorado

As a kayak enthusiast I have traveled the Pecos many times—from south of Girvin all the way to Iraan, when it has rained enough. At no time during my trips have I seen any sort of pollution, spilling of oil, or waste by-products littering the banks of the Pecos. There are many operating oil wells and gas plants along the river, and their well and battery locations are spotless. If oil leaks develop along any pipeline, they are immediately taken care of. As for the people out "yonder," you will always receive a smile, help if needed, and someone to talk to over a cup of coffee or a tall glass of iced tea.

L. B. LONG
Big Lake, Texas

Wandering With India's Rabari

I admire Robyn Davidson's courage and persistence as she experienced the hardship of the Rabari people by being part of their lives. In them she was able to glimpse the beauty, affection, and kindness that all human beings possess. The Rabari are luckier than millions of people in India who have very little to eat, no shelter, and minimal help from the government.

MANJIT BRAR
Vancouver, Washington

The photographs of Dilip Mehta crystallize what Robyn Davidson experienced.

H. L. BARRETT, JR.
Alexandria, Virginia

Being a Gypsy and having lived the first 15 years of my life traveling, I felt a kinship with the Rabari and could well understand and envision the ways of their hard-earned life. Even were I not, Davidson laid it out well, telling us of the things that were misery for her but simply a fact of everyday life for the Rabari. One was drawn into the scene by her writing. Ms. Davidson has a new fan.

LEO W. COVER
Beaumont, Texas

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Geographica

Colonial America's First Science Center

Roanoke Island near North Carolina's Outer Banks is synonymous with the Lost Colony and Virginia Dare, the first English child born in the New World. Her fate, and that of 116 fellow colonists who vanished between 1587 and 1590, remains unknown—a mystery that has overshadowed the intriguing role an earlier English settlement on Roanoke played in U. S. history.

In 1585 Roanoke became England's first foothold in the New World. To prevent Spanish expansion north from Florida, Sir Walter Raleigh sent a detachment to build a fort on the island. Most of the 108 men were soldiers. But to assess the region's commercial potential (a previous expedition had reported that Roanoke Indians wore copper ornaments), Raleigh also sent two scientists—Thomas Hariot, a surveyor, mathematician, astronomer, and oceanographer, and Joachim Gans, a metallurgist.

Now Ivor Noël Hume, the retired senior archaeologist of Colonial Williamsburg, has discovered where Hariot and Gans built their dirt-floor laboratory, the first science center in colonial America. The find was "the most exciting in a lifetime of discoveries," he says. "What Hariot and Gans learned justified England's investment in the New World."

Noël Hume and his late wife, Audrey, decided to dig at the Fort Raleigh National Historic Site after reevaluating finds from earlier excavations. Bricks, burned on one end and ground down on one side, had been thought to have been used for sharpening tools. Noël Hume speculated that they had formed the round mouth of a furnace. Artifacts previously unearthed near the bricks included sherds of ointment pots and clay crucibles and chunks of copper. "Nothing related to domestic life," he recalled. Another clue was one brass apothecary weight (bottom, at front), matched here with a set from the era.

Noël Hume's excavation—funded by the National Geographic Society and organized by the Virginia Company Foundation—uncovered over a hundred new artifacts: fragments of crucibles (center right), flasks, and laboratory glassware; a chunk of antimony for processing silver and other ores (center left); and a burned bowl possibly used in distilling. Pieces of charcoal likely were fuel used by Gans to assay minerals in the furnace. Seeds and nuts may have been part of Hariot's pharmaceutical studies.

Relations with the Indians soured after the soldiers attacked a village, and the English returned home in 1586. Hariot's accounts provided Europeans with the first detailed look at North America's southeast coast and inspired future colonists. Among them: the men and women who the following year settled what would be remembered as the Lost Colony.

IVOR NOËL HUME, AT LEFT, AND FELLOW ARCHAEOLOGISTS

ANTIMONY (ABOVE); CLAY CRUCIBLE FOUND IN ENGLAND AND SIMILAR FRAGMENT FOUND AT FORT RALEIGH

NESTED BRASS APOTHECARY WEIGHTS. PHOTOGRAPHS BY IRA BLOCK

National Geographic, January 1994

Geographica

A Close-up Visit to a Passing Asteroid

Clementine 1, an experimental spacecraft scheduled to be launched this month, aims to visit an asteroid zipping through earth's neighborhood. The cigar-shaped asteroid was discovered in 1951 during the National Geographic Society-Palomar Observatory Sky Survey and named Geographos to honor the Society's role in mapping the skies. Clementine 1 will pass within 60 miles of it in August, when the asteroid will be eight million miles from earth.

Studying the images Clementine's cameras transmit, NASA scientists hope to measure the asteroid, thought to be two and a half miles long and a half mile wide; to determine its composition; and to learn if it broke off from a larger body or formed by itself. If all goes well, a second Clementine will call on two other asteroids and perhaps a comet in 1996.

Mission completed, Clementine 1 will sail into deep space. There, like the heroine of the folk song, it will be lost and gone forever.

Clementine spacecraft

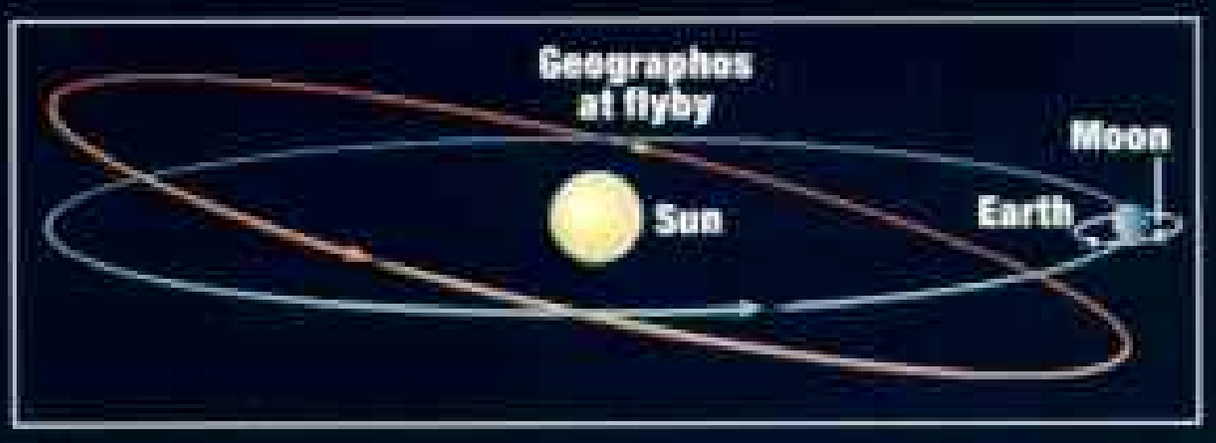

ILLUSTRATION BY BILL PITZER

STEVE WINTER

Flooding Damaged Record of Region's Past

As last summer's floodwaters rose to record levels in the Midwest (page 42), so did the fears of those who care for the region's historical and archaeological sites.

In the Illinois River Valley, where humans have lived since at least 7500 B.C., 5 to 10 percent of the archaeological record was lost or damaged, according to Cindy Sutton of the Kampsville Archeological Center. Water flooded open pits at two digs and washed away other potential sites; excavating sand for sandbags destroyed still others.

To protect the Kampsville center, 50 miles north of St. Louis, volunteers and staff members built and tended a sandbag wall for 28 days—in vain. "We held that line until 24 hours before the final crest in early August," says Sutton. "Then the wall gave way." Most artifacts, including millions collected from the Koster site nearby, had been moved, but five feet of water poured into the center's museum.

Crushed under a shade port, a classic homebuilt Glasair (left) was one of seven St. Louis Aviation Museum planes swamped. Water rose to 15 feet at Fort de Chartres, a partly rebuilt 18th-century French fort "a musket shot from the Mississippi" in Illinois. In Kansas City, Missouri, exhibits of old saddles, chaps, and boots were damaged at the American Royal Museum.

But plywood-and-sandbag barriers along with nonstop pumping saved an 1839 warehouse museum on the restored riverfront of Jefferson City, Missouri. The levee held at Nauvoo, Illinois, sparing Nauvoo House, designed as a hotel in 1841 by Joseph Smith for his Mormon followers. The prehistoric Indian site at Cahokia Mounds in Illinois also escaped unscathed.

And the flood revealed a "new" geologic site when Coralville Lake in Iowa overflowed a concrete spillway, baring fossils beneath the soil downstream. Thousands of people have visited, many to make rubbings (below) of creatures that lived 375 million years ago in the Devonian period—another time the Midwest was underwater. —BORIS WEINTRAUB

LINDA KAHLENBERG

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GEORGE F. MOBLEY, NGS

Wild About Bears: Giant Carnivores of Kodiak

First comes a spring salad of grasses, roots, and tender cow parsnips. Then an appetizer, some deliciously rotten whale or seal carcasses. As spring ripens to summer, time to go fishing (above) for the main course: stream-fresh, roe-packed salmon.

With berries for dessert in the late summer and fall, Kodiak brown bears, subject of a new National Geographic Special, prosper and grow large on their verdant island off the southern coast of Alaska.

"Island of the Giant Bears" visits the storm-swept, fog-draped Kodiak National Wildlife Refuge, which supports the densest concentration of brown bears in the world—one animal per 1.5 square miles. Some 2,700 bears roam the hundred-mile-long island, accounting for nearly 10 percent of Alaska's brown bear population.

Kodiak brown bears dwarf even their feared cousin, the grizzly. A male Kodiak can rear up ten feet and, at 1,500 pounds, roll along at

JILL SHINEFIELD

speeds as high as 35 miles an hour.

In 1971 the Alaska Native Claims Settlement Act gave large portions of prime bear habitat to the Alutiiq people, who have hunted and fished on the island for 7,000 years. They now face a dilemma: To be economically self-sufficient, they may have to develop their land, but that would destroy the bears.

Kodiak native Sven Haakanson, Jr. (above), like many other islanders, hopes to sell the land back to the government. "That way," says the 26-year-old doctoral student at Harvard, "we preserve the refuge for the bears and with them our cultural heritage."

"Island of the Giant Bears," Special on PBS, January 12, 8 p.m. ET; available as a home video in March.

Spinning a Tale of Versatile Weavers

Silk is the lifeline of spiders. The softest strands swaddle spiderlings in their egg sac, protected on the outside by the toughest. Mating signals are tapped out over lines of silk. And silk often ensnares the day's meals.

Masters of adaptation, spiders have evolved diverse uses for their silken thread—as tool, weapon, bridge, trap. "Webs of Intrigue" travels down the spiders' Silk Road, coming face-to-face with, for example, the giant *Nephila* spider, ten inches across, whose enormous web can entangle small birds.

"Webs of Intrigue" is a January selection of the National Geographic Video Club.

Earth Almanac

Retired Airliner Hosts Marine Jet-setters

A Boeing 727 ended its career with a splash last September when it was intentionally sunk 80 feet deep three miles off Miami, Florida. Dade County had already deep-sixed 36 ships and two oil rigs to serve as artificial reefs. For something new, they called Stephen O'Neal, a Miami diver, pilot, and aircraft salvager. How about a jet? they asked.

"At first I thought they were insane," O'Neal says, "but eventually I purchased the plane and it all came together." Already divers are watching barracuda and jacks swimming through the stripped fuselage, which should become a mature coral reef in about 30 years.

The mothballed 727, for which O'Neal paid an undisclosed price, had flown 4.6 million passengers more than 16 million miles. To prepare, transport, and sink it cost $130,000. A barge carried the plane offshore; then a crane lowered it to its final touchdown. Divers used ten anchors to secure the jet, christened by O'Neal.

A final cargo rode down with the 28-year-old airliner—126 science projects from eight area schools. Some experiments, each housed in a milk crate, will test whether materials like metal, tile, or wood can create good underwater habitat; other crates will test corrosion resistance. Student divers will monitor the results.

TRYON (UM STOLLENWERK) BY LUCILLE MCCOOK, MISSOURI BOTANICAL GARDEN (BELOW); AMOS NACHOUM

Bringing Back a Clover to Its Missouri Roots

"Buffalo clover . . . nearly knee-high . . . afforded a rich pasture." In 1788 an image of the fertile frontier near Marietta, Ohio, was penned by historian S. P. Hildreth. The native plant that he saw in such abundance, the running buffalo clover, once flourished from the eastern Great Plains to West Virginia. Now it is an endangered species. But reintroduction efforts are under way in Missouri, thanks in part to a botanist who discovered the clover—unseen in his state since 1907—growing in his backyard.

"In 1989 I had a load of topsoil delivered at home, and soon afterward I was astounded to find running buffalo clover growing in it," says George Yatskievych of the Missouri Department of Conservation. He and his colleagues tracked down the source of the topsoil, but they could find no other specimens. So George's six homegrown clovers were cultivated.

All told, some 700 seedlings have been planted in 25 sites. Last summer's floodwaters claimed two of the clover plots.

The plant sends out long runners—explaining the first part of its name—and buffalo fed on it, dispersing the seeds. Botanists are uncertain why it declined, but the buffalo's decimation in the eastern Great Plains and large-scale loss of habitat are likely causes.

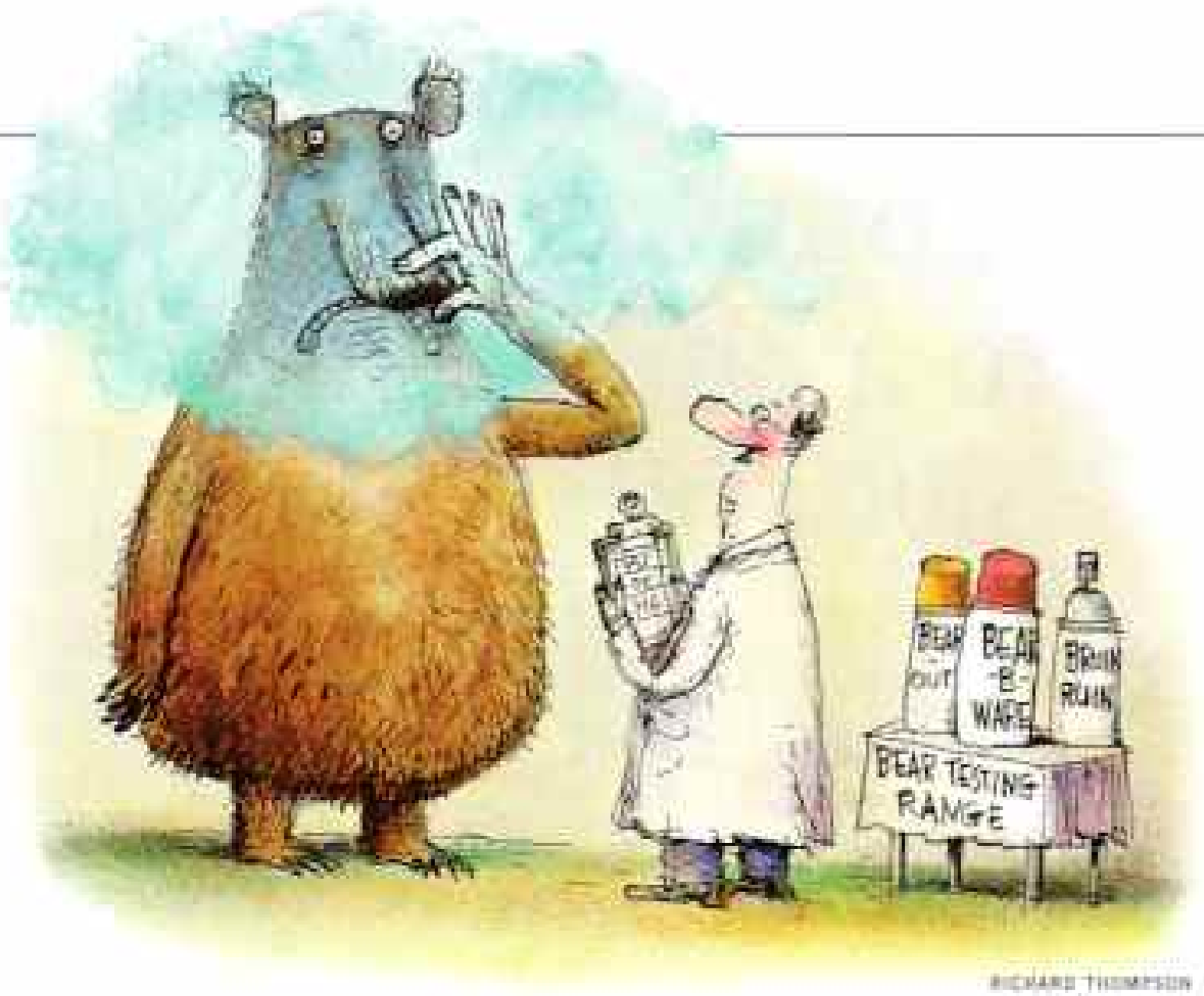
National Geographic, January 1994

Cocaine Witches' Brew Poisons the Environment

Some 3,020 people a year die in the U. S. after using cocaine. But the drug has another sinister side. In the rain forests of Peru, Colombia, and Bolivia hundreds of illegal coca farms are contaminating rivers and streams with millions of gallons of toxic chemicals.

Processing coca leaves is a foul, cumbersome process. First the leaves soak in a solution of sulfuric acid. Next a worker strains the leaves from the liquid (below), which will be mixed with lime, kerosene, ammonia, and other chemicals to make cocaine base. The base is refined with acetone, ether, and hydrochloric acid, resulting in cocaine hydrochloride—the drug itself.

About 308 tons of cocaine were seized worldwide by officials in 1992, according to the U. S. Drug Enforcement Administration. To make that much—a mere fraction of the total—required 28 million gallons of kerosene, 1.1 million gallons of solvents, 295,000 gallons of sulfuric acid, 18,500 gallons of hydrochloric acid, and 3,700 gallons of ammonia. Much of the total amount is dumped into river systems, destroying aquatic life and polluting irrigation and drinking water.



RICHARD THOMPSON

Bear-spray Decree Backfires on EPA

A face full of pepper spray deters angry bears, many Alaskans believe. They won't set foot in bear country without packing an aerosol can of fiery red pepper extract, sold under several brand names. Last year the Environmental Protection Agency (EPA) riled Alaskans by trying to whisk the sprays off store shelves. The agency had decided the sprays were pesticides—for very large pests—and had not been tested. Ironically the sprays *can* be sold for use against human attackers. After protests, EPA agreed to wait while manufacturers test the repellents.

Are they effective? "Sometimes, but not in rain and wind," says Vic Barnes, a biologist who works with nearly 3,000 bears in Kodiak National Wildlife Refuge. "And their range is about 20 feet. If it doesn't work, you have no second option."

Ferocious Pip-squeak: the Grasshopper Mouse

Like the proverbial mouse that roared, a grasshopper mouse takes a break from pursuing prey and shatters the desert night by cutting loose with shrieks and chirps to defend territory or attract mates.

The prey's the thing that defines this tough little mouse. It's the only North American rodent that dines primarily on live prey, including spiders and insects. But that's just the small game. This predator bites a scorpion's business end to immobilize it, then goes for the head. It eats other mice and can penetrate a horned lizard's armor. To foil beetles that shoot poison from their abdomens, the mouse just jams their backsides into the ground. And in territorial disputes against each other, they square off in wrestling matches.

—JOHN L. ELLIOT

JOSÉ AZEL, AURORA

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National Geographic, January 1994

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On Assignment

"I never thought I'd do something this frightening to get pictures," says freelance FRANS LANTING, 80 feet high in a palm swamp in Peru. While he was there, a friend and colleague, filmmaker Dieter Plage, died after a 150-foot fall in Sumatra's rain forest.

Frans's cramped platform put him at eye level with a nest of blue-and-yellow macaws, and weeks of ten-hour days paid off (page 137).

Getting there meant preparations akin to planning a mountain climb. A ton of steel scaffolding was flown from Lima over the Andes to Puerto Maldonado and carried upriver by cargo canoe. His crew lugged the sections over forest trails, then reassembled them in towers at far-flung nests, fruiting trees, and clay licks.

"It was the most complicated assignment logistically," recalls Frans, who has photographed from Botswana to Borneo. "But it was rewarding to see things that few people witness. It goes to the heart of why I do this work: To turn wild creatures into ambassadors for whole ecosystems."

FRANS LANTING

DOUG WILSON

Searching for bright spots during last summer's Mississippi flood, freelance photographer JIM RICHARDSON found a whole armful. The orphaned fawn was stranded by rising waters near Meyer, Illinois. Jim, on river patrol with a state conservation officer, spotted the exhausted deer lying in the levee grass. He quickly helped transport the animal to safety on high ground.

Jim had finished shooting Mississippi photographs for our special water issue (November 1993) when the Midwest's torrential rains made the river national news. Returning to cover the flood, he soon found himself sandbagging levees with the people he'd come to photograph. Says Jim, whose work includes stories on the Colorado River, the Ogallala aquifer, and the Great Salt Lake, "I always bring my hip boots on assignment."

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