SPECIAL DOUBLE SUPPLEMENT: THE UNIVERSE

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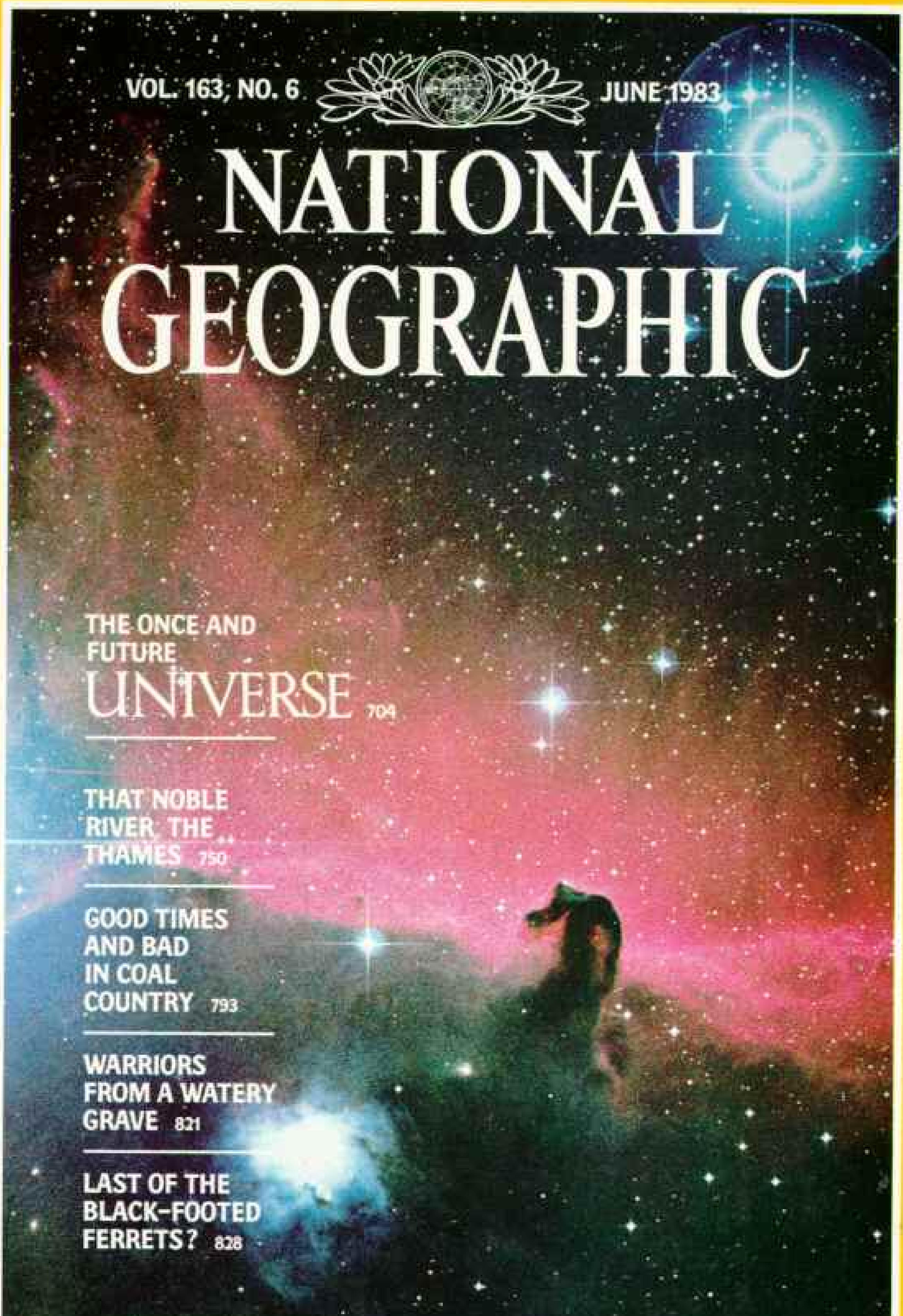
NATIONAL GEOGRAPHIC



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WE'VE ALL been hammered now and then by the tired aphorism "Figures don't lie." Ridiculous! They are used and distorted equally by the most devious and the most guileless, the selfish and the selfless, to buttress their arguments. Because columns of numbers, graphs, and charts are usually accepted as accurate and authoritative, they increasingly decorate every sort of article and bureaucratic report.

Frankly I am suspicious, distrustful, and even resentful of this growing dependence on surveys, charts, and graphs. I'm quick to quibble over discrepancies, especially if they challenge my own preconceptions or concern my taxes.

Recently two books crossed my desk. The first estimated that one entire species of life becomes extinct on earth each day. The other cited estimates that one to two species of plants, alone, leave us each day. A Smithsonian news report noted a warning that between now and the end of the century species will disappear at the rate of one per *hour*.

These sources are reliable, authoritative, and well-meaning. Normally, such widely divergent numbers would stir me to a flurry of quibbling, but unlike taxes this subject is too important to permit figures to obscure the problem. To become mired in numbers or argue the pace of extinction and do nothing would be like standing in the path of an onrushing train, debating its time of arrival.

So far as we know, man is the only species capable of speeding or slowing our planet's rush to extinction. We're proving the former each day. Are we able or willing to prove the latter? Further, there is no law—natural or man-made—that exempts *us* from the ever growing endangered-species list.

Regardless of whose figures you like, we face a gloomy scenario. One tiny bright spot is found in our article on the black-footed ferret in this issue. Given up for lost by many, it seems to have crept back from the brink of extinction.

But we must not take too much comfort in this—whether the rate is one a day, one an hour, or one a second, we are witnessing a massive, accelerating, and terrifying loss of species that are irreplaceable. And too often they're gone before we have even found them, much less understood why they were here in the first place.

Wilbur E. Garrett
EDITOR

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COVER: *Against a bright field of ionized gas, the dark, cool Horsehead Nebula rears in the constellation Orion. Photograph by David Malin © Royal Observatory, Edinburgh.*

THE ONCE

U N I V

"AH, BUT A MAN'S REACH should exceed his grasp," wrote the poet Robert Browning. "Or what's a heaven for?" Even ancient man strove, with such technologies as the megaliths of Stonehenge, ***above,*** to comprehend the heavens. When Galileo turned his telescope skyward, he ushered in the age of reason and the notion that, by using mathematics, mankind could indeed divine nature.

Recently our earth-based telescopes and spacecraft have revealed a panoply of astronomical objects, behaving in ways heretofore thought impossible, pulsing with undreamed-of energies. In charting some of the billions of galaxies, like our own Milky Way, we have been stunned by the immensity of the universe. (See ***The Universe,*** a special double supplement to this issue.) Radio telescopes such as the Very Large Array, ***above right,*** let us study objects so distant that their light

By RICK GORE NATIONAL GEOGRAPHIC SENIOR WRITER

AND FUTURE

E R S E

has been traveling toward us for more than ten billion years.

We have reached beyond Einstein and pioneered physics that traces the universe back almost to its very instant of origin. Our universe, astrophysicists have concluded, was born in an explosion of space, called the big bang, perhaps 15 billion years ago.

Astonishingly, scientists now calculate that everything in this vast universe grew out of a region many billions of times smaller than a single proton, one of the atom's basic particles.

The evolving logic of the cosmos defies our imagination. Still, man continues to reach—back in time to unravel the secret of creation, forward to discern the ultimate fate of this our universe billions of years hence. Do we stand—as some think—on the brink of grasping the infinite? Does man's reach now truly exceed his grasp?

Photographs by JAMES A. SUGAR

The effort to understand the universe is one of the very few things that lifts human life a little above the level of farce, and gives it some of the grace of tragedy. —STEVEN WEINBERG, "THE FIRST THREE MINUTES"

ON THE EVENING of January 27, 1982, Minoru Honda, the most famous of Japan's many comet hunters, had a feeling that something unusual had happened in the constellation Aquila. Honda, 69, drove up to his "mountain inn," a fastidiously kept hut atop Black Rock Mountain, not far from the Inland Sea city of Kurashiki. He brushed a dusting of snow off the hut's sliding roof and opened it, exposing his eight cameras and wide-view telescope.

Then, as he does some 200 nights a year, he began to photograph the sky. Aquila would not rise until just before dawn. This would be his first look at that constellation this winter. For several months it had been too close to the rising sun to observe.

Honda became well known in Japan for discovering comets shortly after World War II, when the country was in ruins. Inspired by his achievements in those desperate years, many Japanese turned to the sky. Today the country has perhaps the world's most dedicated corps of amateur sky-watchers.

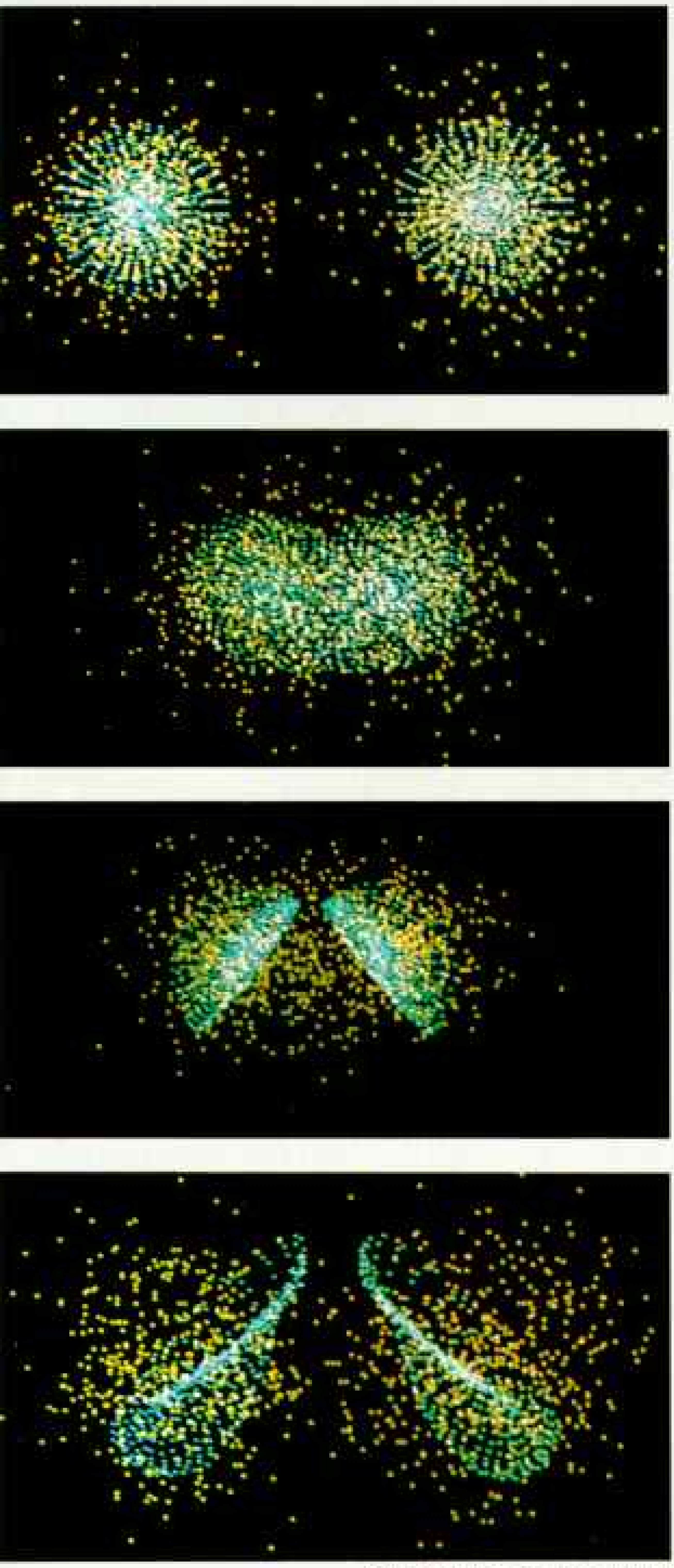
"I'm not a professional," he insists. "I just think stars are beautiful. And if someone asks me what happened in the sky last night, I want to be able to answer."

Honda took two time exposures of Aquila that night. The next morning on the negative he saw an unfamiliar black smudge. It looked like a new star, one that would be barely visible to the naked eye, but quite bright compared to most of the hundred billion or so other stars in our galaxy, the Milky Way.

Honda quickly realized that this new star was actually a tremendous nuclear explosion called a nova. To ancient astronomers novae, which appear suddenly and gradually fade away, were omens of important events. Recently astronomers have concluded that novae release as much energy in just one year as our sun does in a million. They occur on the surface of a bizarre type of star called a degenerate dwarf.

I first encountered the dwarf, known now as Nova Aquilae 1982, five months after Minoru Honda, while I visited the European station for the International Ultraviolet Explorer (IUE) satellite at Villafranca near Madrid. I was beginning an exploration myself—of the exhilarating *(Continued on page 718)*

Steel eyelids shut at dawn *as the optical telescopes of Kitt Peak National Observatory are secured for the day. These and other superb instruments push our knowledge outward into that ultimate laboratory and profound experiment—the universe itself.*



BRUCE SMITH, NASA AMES RESEARCH CENTER

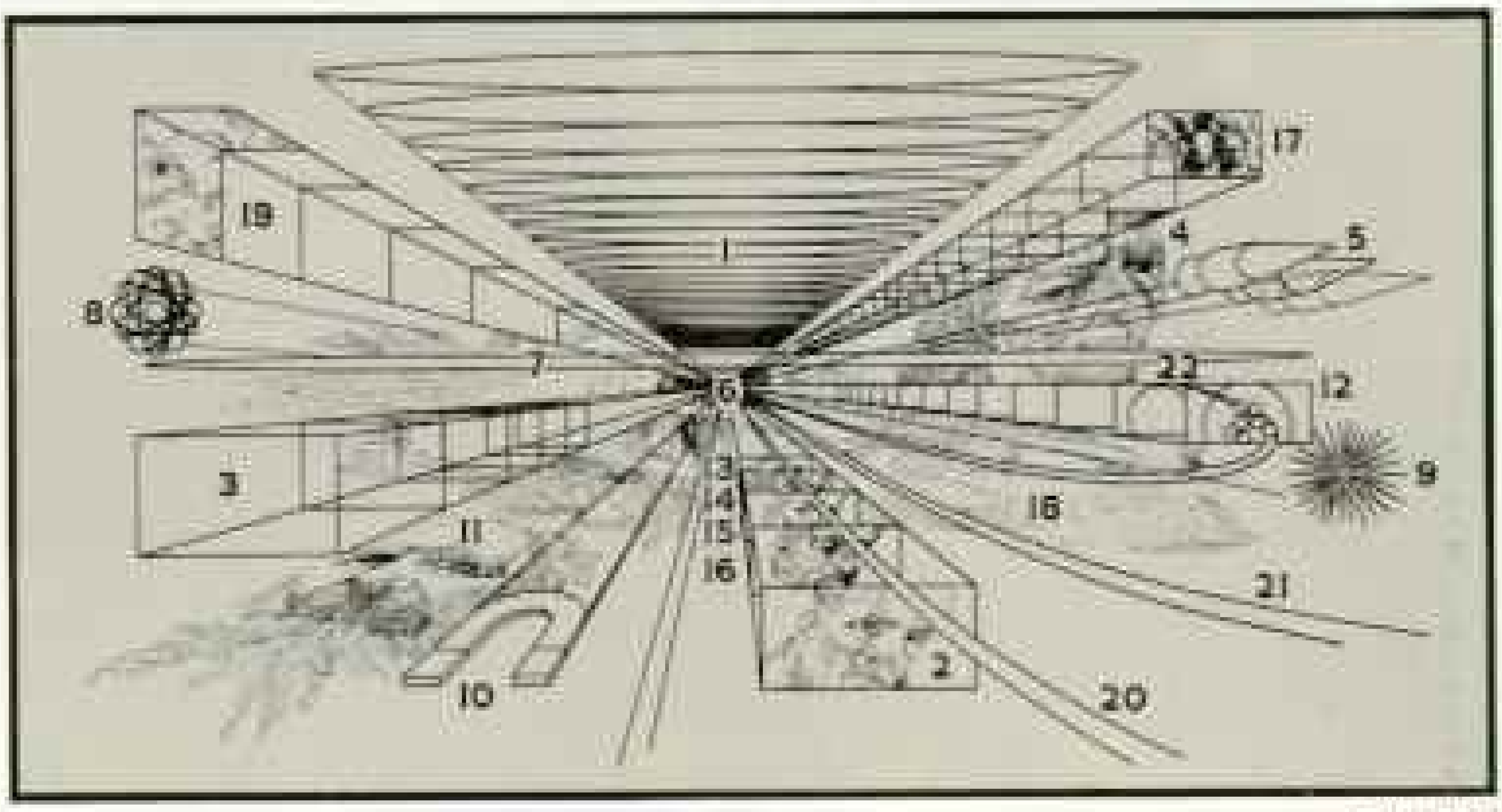
The age of the universe is one of astronomy's great debates. Estimates range between 8 and 20 billion years. Although no consensus exists, the age of 15 billion years used in this article is consistent with most theories, give or take 2 billion years.

Lazy spiral *in the southern sky, the galaxy NGC 2997 (**above**) is shaped much like our own Milky Way. To study how galaxies might behave upon colliding, Bruce Smith and Dick Miller at NASA used a computer to simulate and graphically represent them.*

National Geographic, June 1983

Two disk galaxies approach each other edge on (**left,** *from top). Blue dots represent visible stars; yellow dots represent invisible mass in halos around galaxies. Few stars collide as the galaxies pass through each other, but gravity deforms galactic structures. A real encounter might last about 200 million years. Astronomers in such galaxies would recognize the state of collision by a jumbled field of stars and nebulae, a condition that would confound their view of the universe.*

THE BIG BANG AND AFTER



TWO CENTRAL observations: On a large scale, every part of the expanding universe (**1**) is receding from every other part, a fact first recognized in the 1920s by Edwin Hubble (**2**). A corollary is that all the parts were once much closer—in fact, packed into an ultradense, ultrasmall clump. The second observation, first made in 1964, is that a telltale radiation (**3**) at three degrees above absolute zero on the Kelvin scale (3K) pervades all space in every direction; it is interpreted as the fading glow of the ultrahot expansion that brought into being space and time, matter and energy. Conclusion: our observable universe began at a finite time in the past in a hot explosion—the big bang.

Physicists believe that just after that time, perhaps 15 billion years ago, the four basic forces of nature—gravity, electromagnetism, the strong atomic force, and the weak atomic force—were unified. Isaac Newton (**4**) first explained the operation of gravity (**5**), now thought to have separated from the other forces just before Planck time (**6**), 10^{-43} second—a tenth of a thousandth of a millionth of a billionth of a trillionth of a trillionth of a second after the big bang.

Some physicists think a sudden inflation (**7**) followed. As the universe continued to expand and cool, the other basic forces separated. The strong force (**8**) operates across the nuclei of atoms to bind protons and neutrons. The weak force (**9**) produces certain kinds of radioactive decay. Electromagnetism (**10**) was described in 1864 by James Clerk Maxwell (**11**). Electricity and magnetism are aspects of the same force. It binds atoms into molecules and, by means of massless particles called photons, transmits radiation across the spectrum at wavelengths from gamma and X rays through ultraviolet, visible light, infrared, and radio waves.

To assess the universe is to inquire into the atom, now known to be a complex structure of particles composed of subparticles such as quarks orbited by a cloud of electrons (**12**). No earthly atom smasher can ever duplicate the energy available at the big bang. Yet in the structure and behavior of the very smallest things lies the explanation of all matter.

Astronomy was simpler once. To Ptolemy (**13**) the earth stood at the center of the universe. Copernicus (**14**) displaced it with the sun. Galileo (**15**), aiming a telescope skyward, first saw Jupiter's moons. Kepler (**16**) discovered the planets' elliptic orbits.

Astronomy is experiencing a golden age, in part because its tools permit exploration of such objects as galaxies (**17**) all across the electromagnetic spectrum and to immense distances. Yet abstract mathematics, especially the theories of Albert Einstein, underlie much of it, as Einstein's image underlies this painting (**18**). To wit: Nothing exceeds the speed of light; matter is a form of energy; gravity warps space and time.

The universe has much to reveal. Did galaxies first form, then clump together, or did great sheets of matter (**19**) fragment into clusters? How will it all end? If the energy of the big bang can overcome or equal the force of all gravity (**20**, **21**), the universe will expand forever. If gravity dominates, matter will collapse, the big bang becoming the big crunch (**22**).

Paintings by BARRON STOREY


Epochs of the early universe
THE STRONG FORCE
the inflationary universe
evolving ways of seeing the universe
GRAVITY
NEWTON
evolution of the atomic model
10^{-43} sec
Planck time
PTOLEMY
COPERNICUS
GALILEO
KEPLER
HUBBLE
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The microwave background 3K
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Ω>1
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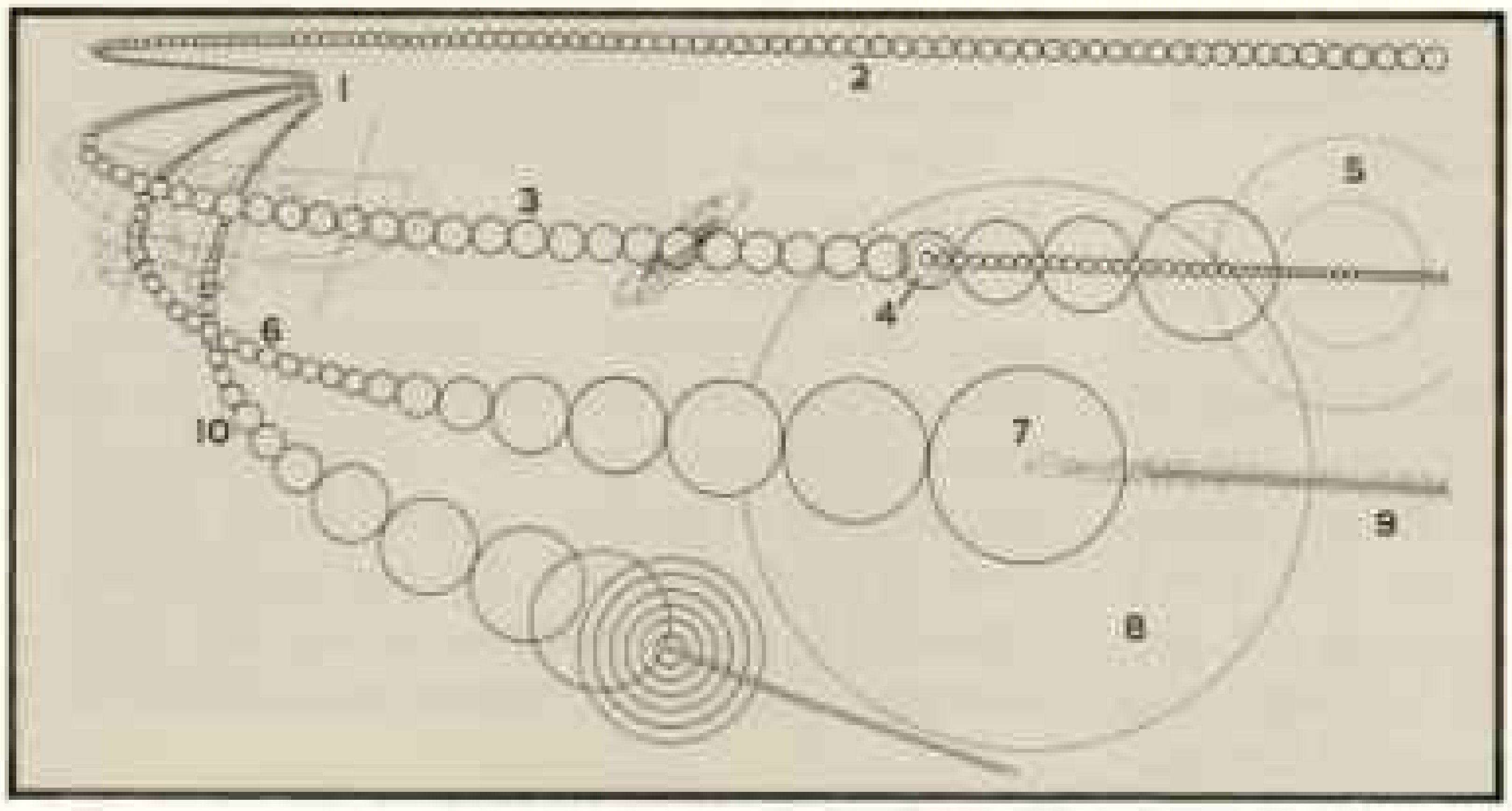
The Big Bang. Barron Storey. 83


Origin of star in giant cloud of gas and dust
Brown dwarf, one tenth solar mass
One solar mass
White dwarf
Ten solar masses
Neutron star
Thirty to fifty solar masses
Black hole
The evolution of stars
B. Storey '83



SAM VELTON

THE BIRTH AND DEATH OF STARS

OUR planet and all its continents, seas, and living things rose from the deaths of nearby stars. While hydrogen and helium were created by the big bang, the more complex forms of matter, from planets to purling brooks to stargazers, are composed of heavier elements created from the debris scattered through space by dying stars. The arms of a spiral galaxy such as ours are rich in stellar debris, cooled clouds of gas and dust (1), the birthplaces of new generations of stars.

When a gas cloud along a galaxy's spiral arm is compressed, it will collapse under its own gravity and ignite as a star if the clump has sufficient mass; if less than one-tenth the mass of our sun, it may become a "brown dwarf" (**2**). Jupiter is such an object, too small to "turn on" by nuclear fusion but still shedding heat from its collapse. Brown dwarfs cannot be seen at great distances but may well account for a large part of a galaxy's mass.

Our sun, or any star of about the same mass (**3**), has a typical history. It begins as a cloud of gas and dust, or nebula. When enough matter falls to the center, the central mass ignites and becomes a star, which may go through a "jet phase." Stellar winds blow gas and dust away from the star and, in the case of our sun, leave planets in the clear. The star burns hydrogen, converting it to helium. (The sun, at 4.6 billion years old, is about halfway through this process.) Then, as hydrogen becomes exhausted, the core shrinks and heats ever more rapidly, while the outer layers expand and the star becomes a red giant. The core, now almost pure helium, is surrounded by a shell of fusing hydrogen (**4**). More contraction, more heating: The helium core starts to fuse and ignites, liberating energy, and actually pulsates for thousands of years. Finally the helium core collapses and fuses into carbon, a stable state. The outer layers drift away (**5**). The now naked core, a slowly cooling white dwarf, is left "like a diamond in the sky"— which, being carbon, it may well become.

A star of ten solar masses (**6**) has similar beginnings but a more rapid, fiery, and creative end. Its core fuses past helium and carbon, all the way to iron. Iron absorbs energy rather than releasing it. In less than a second, gravity overwhelms the core, crushing it to a superdense nucleus that rebounds outward throwing off shock waves (**7**). These blast through the gases of the star's outer envelope, superheating them and creating heavy elements in an explosion—a supernova—burning brighter than a billion suns (**8**). The core then becomes a star composed of neutrons. Like a cosmic ice skater drawing in its arms, the star's gravitational collapse accelerates its spin. This concentrates its magnetic field perhaps 100 million times. As the field encounters charged particles, they will be swept along and emit radiation. Called a pulsar (**9**), the star now beams radio or other waves from its magnetic poles like a hyperactive lighthouse.

A star of 30 to 50 solar masses (**10**) may have a still shorter life. When its fuel is exhausted, nothing can support the core against its own gravity. It must collapse into itself and become a black hole and, in a sense, exit the universe.

All picture text by DAVID JEFFERY
NATIONAL GEOGRAPHIC SENIOR STAFF

(Continued from page 706) progress being made in explaining the origin, current state, and ultimate fate of the universe.

Today our universe is so vast that we measure it by the light-year—the nearly ten trillion kilometers that photons, the basic units of light, travel in a year. It began perhaps 15 billion years ago with the big bang, the explosion of an incredibly tiny, intensely energized speck of space. As this hot speck expanded and cooled, matter froze out, primarily as the basic elements hydrogen and helium. These elements condensed into galaxies of the celestial furnaces we call stars.

Much of the progress in understanding this universe has come with instruments like the IUE satellite, a joint United States-European telescope, and one of many that have been probing regions of radiation beyond the limited horizons of visible light.

The human eye cannot see the vast bulk of radiation surging through space. For example, extremely hot objects, such as young novae, emit most of their energy in ultraviolet, X-ray, or gamma-ray wavelengths. Cold, dark objects often radiate strikingly in the infrared. Paradoxically, radio waves, the least energized form of radiation, pulse forth from intensely violent events.

New insights provided by these wavelengths have radically revised our traditional view of the universe as relatively serene and static. Especially in the past decade the new instruments have revealed it to be an arena of furious fireworks, of galaxies hurling out jets of matter, and of shock waves from exploding stars buffeting and heating interstellar gas to millions of degrees. The universe, it appears, thrives on explosions.

WHEN HE TRAVELED from London's University College to the Villafranca IUE station in Spain last June, Anthony Lynas-Gray was anticipating eight hours to himself on the IUE satellite. But earlier that night in Australia, astronomer Don Morton had observed Nova Aquilae in visible wavelengths during breaks in the cloudy skies. The nova was by now the object of an international investigation, and Lynas-Gray was told that the IUE was being commandeered to follow up the Australian observations with a nearly simultaneous ultraviolet look at the nova.

Losing telescope time is part of life to astronomers. Usually weather is the culprit. Competition for telescope time is fierce, and a young astronomer's career can be crippled if he is rained out too often. Rescheduling can take months or sometimes years.

But Lynas-Gray took this change enthusiastically. When I met him in the control room at Villafranca, the IUE was beaming an image of a star field down to a TV monitor. Lynas-Gray was helping technicians aim the satellite's telescope at the fading nova. Even though the nova was by then extremely faint, IUE's ultraviolet eyes could break down its radiation, as a prism does with visible light, into a spectrum filled with valuable data about the gas blowing off the surface of that degenerate dwarf.

The IUE data would take months to analyze. But I learned enough about novae that night to set my course.

True, there are far more energetic phenomena out there. A supernova, the nearly total annihilation of a dying star, releases a million times more energy. And quasars, mysterious powerhouses billions of light-years from earth, shine with the brightness of hundreds of galaxies. Novae, in fact, have been a bit of an astronomical backwater.

Nevertheless, the latest technology in astronomy now was being turned on Nova Aquilae. Moreover, novae offer basic insights into the fires that power our explosive universe. Like Minoru Honda, I found Nova Aquilae irresistible.

"I do have a fancy for novae," said Honda over tea. In the early 1970s Honda had shifted his attention from comets to novae. "These explosions took place thousands of years ago far away. Finally that light reaches earth. I am sometimes lucky enough to encounter it. I find that quite exciting."

Honda has discovered nine novae. Astronomers estimate that each year some 30 degenerate dwarfs—also called white dwarfs—go nova in our galaxy. Yet almost all are hidden by interstellar dust. So thickly does dust pervade the Milky Way that for every photon of visible light that reaches earth from our galactic center, some 30,000 light-years away, another trillion are obscured. We are lucky to learn about three or four novae a year, and without the hundreds of amateurs like Honda who patrol the sky,

*"**I love to see stars in the sky.** That's all there is to it." Not quite, for when amateur Minoru Honda of Japan (**left**) processed film he had taken on the freezing night of January 27, 1982, he saw something literally new—a nova. That spot of light (**right,** arrow) proved to be a thermonuclear explosion in the constellation Aquila, and Honda's discovery sent professionals all over the world to their instruments. Professional astronomers rely on the scouting of such amateurs, since research telescopes spend a large measure of their time looking at known objects.*

MINORU HONDA

NASA

***In a C-141 jet** modified by NASA, scientists can soar above atmospheric water vapor that absorbs infrared radiation. Here Allan Meyer perches in the opening port with a 36-inch telescope (**upper right**). At 41,000 feet nearly all of earth's water vapor lies below, and the infrared telescope, also capable of seeing in optical wavelengths, can clearly observe distant quasars or much closer objects, such as the rings of Uranus that it discovered.*

*These observations are true eye-openers. For example, in optical wavelengths the Swan Nebula appears as a white blob surrounded by stars. When enhanced infrared images are added (**above**), new detail adds understanding of its structure.*

*The telescope can stay locked on an object billions of light-years distant, balanced and aimed by gyroscopes and a digital tracking system. Not so the crew. Flights are cold, noisy, and sometimes bumpy. Allan Meyer helps keep the telescope aligned (**right**) as Cornell astronomer James Houck rubs fatigue from his eyes during a seven-hour flight, December 7, 1982.*

From the log—"8:31:3 This is the worsed turbulence Ive ever seen. . . . 9:53:31 Two people got sick. I told some little anecdotes about sick people which were not well received. . . . 13:18:8 Good flight, heading for home."


GERARD P. KUIPER
AIRBORNE
OBSERVATORY

even those would most likely be missed.

What is a nova? And how does a star become a degenerate dwarf in the first place? Sumner Starrfield, an astronomer at Arizona State University, has spent much of his career dealing with those questions.

"A nova starts out with two stars, each about the size of our sun, very close together," Starrfield told me. Such binary stars are extremely common—probably more so than solitary suns like ours.

One of these two stars consumes all its hydrogen. If the star's mass is comparable to our sun's, it flares for 200 million years or so into a huge fireball called a red giant. When it then exhausts its helium, it contracts into a dwarf about the diameter of earth.

During this contraction, gravity squeezes the dying star so tightly that its gas then behaves in ways that physicists consider degenerate: Its structure now resembles that of a metal, and when heated, it can no longer expand rapidly enough to relieve the pressure. The surface of these degenerate stars becomes ten million times denser than the surface of the sun. Under this enormous pressure the star's core, now largely converted to carbon, can compact into a crystal. The interior could actually be one big diamond.

As the degenerate dwarf and its companion orbit each other, the dwarf's strong gravity pulls gas from the other star. This swirling gas forms what astrophysicists call an accretion disk, which feeds onto the surface of the dwarf, wrapping it in an ever growing mantle.

An accretion disk has recently become an important astronomical concept. Just as water swirls around the drain of a bathtub, gas drawn toward a compact, high-gravity object such as a degenerate dwarf spirals through a rotating disk analogous to Saturn's rings.

If Isaac Newton could have dropped his apple into, say, a quasar's accretion disk, that apple would have gained, as it swirled ever faster inward, energy equivalent to that in a five-megaton thermonuclear warhead. That is 400 times more potent than the atom bomb dropped on Hiroshima.

Gas swirling around a degenerate dwarf is accelerated to 5,000 kilometers per second. As this gas strikes the dwarf's thickening mantle, the impact heats the degenerate gas enormously. Temperatures in the mantle rise to the ten million degrees needed to ignite nuclear fusion, the same process that fires our sun. But since it is degenerate, the mantle cannot shed the heat by expanding.

"Basically a new sun is temporarily created around the ember of a dead one," said another nova expert, Bob Williams of the University of Arizona. A nuclear smolder begins to spread. When it hits a flash point, a holocaust engulfs the dwarf.

That explosive phase is what Minoru Honda saw as Nova Aquilae. Several weeks after Honda's discovery, on top of one of earth's great volcanoes—Mauna Kea on the island of Hawaii—two British astronomers, Andy Longmore and Peredur Williams, also took a fancy to Nova Aquilae.

MAUNA KEA rises 4,200 meters (14,000 feet) out of the Pacific Ocean. The six telescopes on its summit sit above nearly half the earth's atmosphere and most of its water vapor. Moreover, in mid-ocean there are no landmasses to create the atmospheric turbulence that distorts star images in most telescopes. In short, Mauna Kea is an astronomer's dream.

Being there can actually seem like a dream. At the summit oxygen deprivation makes the newcomer feel drugged. To my surprise, the stars did not seem as bright as at sea level. With less oxygen the retina does not function as well. "It's the only place I've ever fainted," said astronomer Tom Geballe of UKIRT, the United Kingdom Infrared Telescope. "Many people can't function for a while. But it can be euphoric."

Mauna Kea can also be a monstrous mountain. "This is *not* Hawaii," said UKIRT astronomer Kevin Krisciunas. "In July we can have snow, sleet, hail, and freezing fogs. In winter the wind can blow more than a hundred miles an hour. You practically have to crawl along the ground. Astronomers have been stranded for days."

Mauna Kea's height and climate make it the most noted mountain in the world for infrared astronomy. Infrared wavelengths are longer than visible light waves but shorter than radio waves. Infrared radiation is essentially heat. Everything above absolute zero—even cold dust—radiates in infrared.

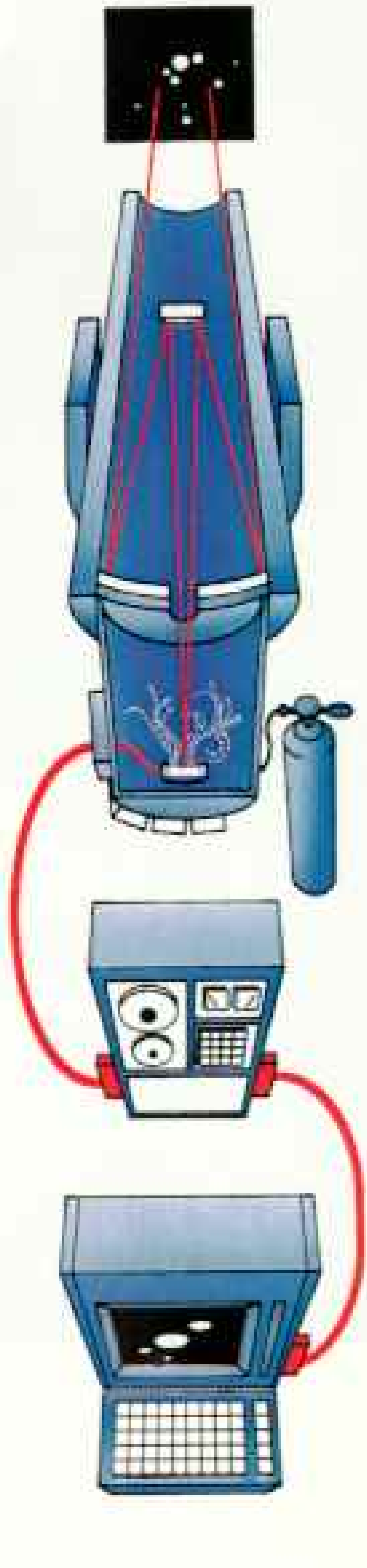
Infrared waves can pass right through interstellar dust, letting astronomers see deep into our galaxy.

Infrared poses one major problem, however. "Earth's atmosphere is warm," explained Geballe. "Its molecules emit a lot of infrared. So do telescopes. Trying to do infrared from earth is like doing visual astronomy in daylight. We need special techniques to eliminate background radiation. Obviously, cold, high, dry sites are best."

Hence the British, whose cloudy climate typically frustrates astronomers, built UKIRT atop Mauna Kea, alongside an American infrared facility and a joint Canadian, French, and Hawaiian optical instrument. UKIRT's 3.8-meter mirror makes it the world's largest telescope devoted to infrared astronomy.

The question about Nova Aquilae that intrigued UKIRT astronomers Longmore and Williams was whether the nova had begun emitting much infrared. That would mean, they believed, that the shell of gas blown off by the nova had cooled enough to form dust grains. Dust absorbs ultraviolet and visible light and re-emits it in infrared. Nova Aquilae, however, had a surprise in store.

DAVID AUSTEN (ABOVE); DIAGRAM BY SAM HALTOM



To wring the last bit of data from arriving radiation is the ideal of astronomers. The best film and even the eye are inefficient sensors.

*A new class of electronic chips called charge-coupled devices (CCDs) can detect nearly every photon of visible light that reaches them. Photons entering a telescope (**diagram, right**) are funneled onto a supercooled CCD chip. Photons liberate electrons in the chip, where they are stored until read out by a computer. The computer processes the chip's data, which can be displayed on a video screen. CCDs work with all sizes of telescopes, enabling smaller telescopes to do the task of larger ones and for the largest, such as the 200-inch Hale at Palomar Mountain, improving performance tenfold.*

*Another device, designed for working in the infrared, is an indium antimonide detector. In a demonstration (**above**) at the Anglo-Australian Observatory in Australia's Warrumbungle mountains, the spectrum of a tungsten lamp is aimed toward the detector. Its opening admits infrared photons beaming just beyond visible light.*

Technician John Sullivan releases −200°C liquid nitrogen to cool the detector and keep it from recording its own radiant heat.

***In the moonscape** of lava cones atop Hawaii's Mauna Kea volcano, the U. S., United Kingdom, Canada, and France have raised a cluster of observatories. Nearly three miles in altitude, they stand above almost half the earth's atmosphere and 90 percent of its water vapor, excellent for ground-based*

infrared telescopes. The island location is free from atmospheric turbulence induced by landmasses, as well as light pollution from cities. Logistic support can be shared. A real problem for astronomers, however, is that too few such telescopes are available for the research that needs to be done.

"Even the first time we looked at it, we saw excess dust grains," said Longmore. "The gas blown off by the nova couldn't have cooled that fast. That means some of that dust was there already. Hot gas must have been coming off the star for perhaps thousands of years before it went nova."

Why is this star dust so interesting? Primarily because it is the stuff of new stars. Matter evolves during the lives of stars and emerges largely through their nova, supernova, and red-giant stages. The big bang, remember, created almost exclusively the simplest elements, hydrogen and helium.

More complex elements are forged only in the fiery death throes of stars. Some of the air we breathe, for instance, may have been released by a nova or a red giant. So were many carbon and silicon atoms. Supernovae have created most of the heavier elements.

As Sumner Starrfield put it, "The very materials out of which our bodies are made were cooked up in a violent process somewhere in the universe."

While Longmore and Williams were watching Nova Aquilae's shell expand in the infrared, halfway around the world at Westerbork in the Netherlands an array of radio telescopes was also listening in on the nova.

THICK CLOUDS off the North Sea heralded an autumn storm as I walked along a three-kilometer lineup of radio antennas at Westerbork with astronomer Thijs van der Hulst. These 14 gray disk-shaped antennas measured 25 meters each in diameter. They looked like big ears tuned in to the heavens.

Neither daylight nor the dismal weather was deterring the Westerbork radio astronomers. Radio waves are measured in centimeters or even meters—not in angstroms like X-ray, ultraviolet, and optical wavelengths. They are thus no more hindered by galactic dust or the North Sea's raindrops than ripples are stopped by mud suspended in a puddle. Like infrared, radio waves also let us probe distant, dusty reaches of the universe.

Moreover, when electrons move rapidly through magnetic fields, as they do in particle accelerators on earth and violent processes in space, they release radio waves. Oddly enough, so do the tiny molecules of some very important cosmic chemicals. So radio emissions can let astronomers both map hot eruptions and analyze the chemistry of cold interstellar clouds.

For many months the ears of Westerbork had been monitoring the expansion of Nova Aquilae. Its radio data were sent, along with the spectra from Hawaii, Australia, and Madrid, to London's University College. There, astronomer Mike Seaton was leading a team that was working out a detailed portrait of the fires of Nova Aquilae. Those fires, he concluded, were exceptionally violent. They may have blasted out matter at speeds more typical of a supernova.

WE WITNESS supernovae in our galaxy perhaps once every 300 years, when one flares up to become nearly the brightest star in the sky. The star of Bethlehem, for instance, was once thought to have been a supernova. The last appeared in 1604. We are due for another.

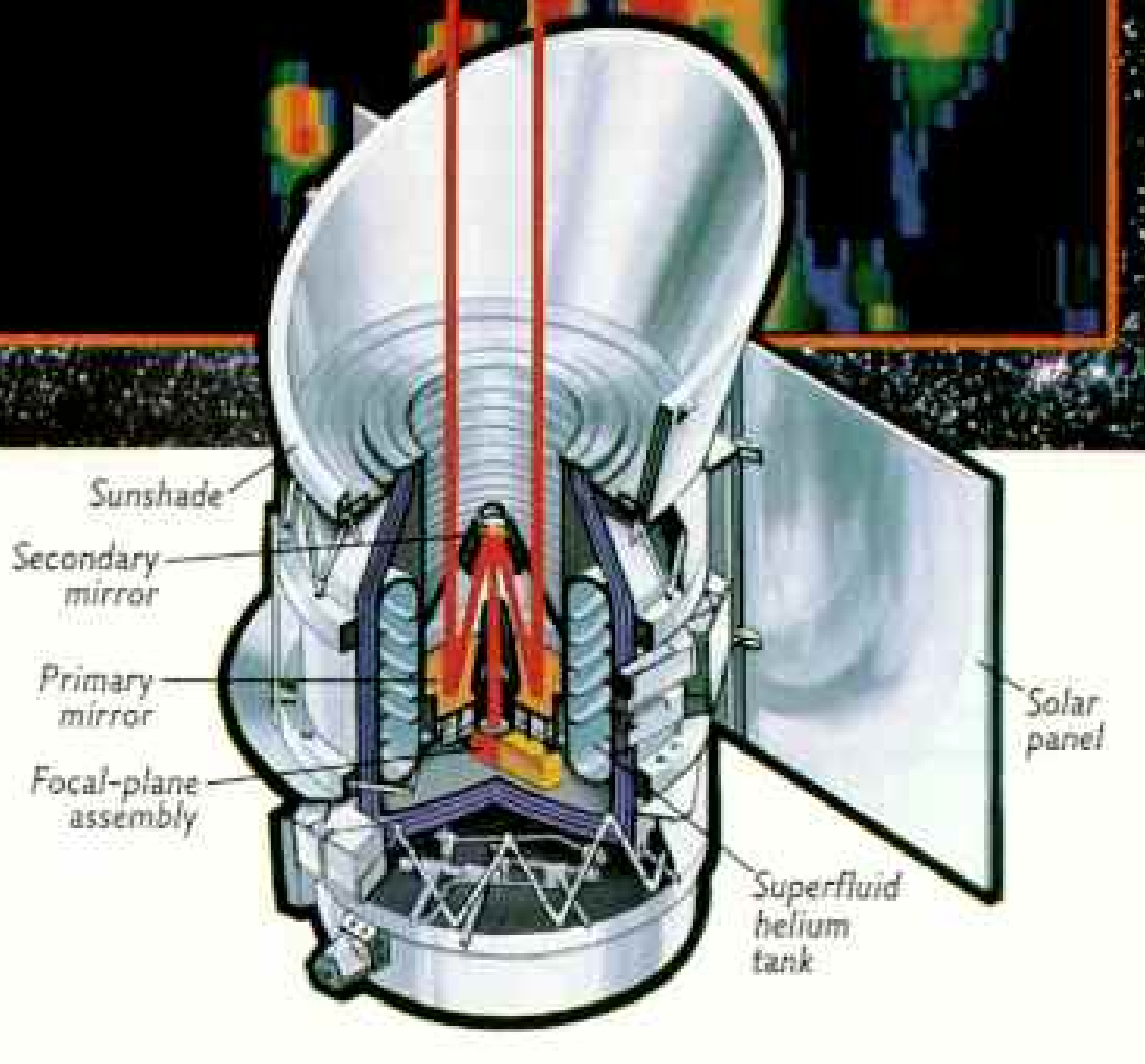
Supernovae come in two types. Type I may begin as degenerate dwarfs. In fact, on these dwarfs nova eruptions may merely be precursors of a grand finale.

"Novae are just blisters on a degenerate dwarf's skin," joked Craig Wheeler of the University of Texas. "We supernova people turn our noses up at novae."

Indeed, the grand scale of supernovae has special allure. "I'm interested in supernovae because I want to know what makes a star blow up—as well as which ones do it," said Wheeler. "But a colleague of mine simply likes anything that goes bang. Supernovae do make one hell of an explosion."

Supernovae occur so rarely in the Milky Way that astronomers have to study those that go off in other galaxies. In March of 1981 a Soviet astronomer detected the brightest Type I supernova seen in ten years—in a galaxy some 50 million light-years away. This explosion, christened SN 1981b, has triggered more than two years of analysis by a team headed by Wheeler.

What can blow apart a degenerate dwarf? Like Nova Aquilae, Wheeler theorizes, SN 1981b could have been part of a binary system, with mass from a companion flowing onto its surface, heating the star and causing it to flare as a nova every 10,000 years.



ICY PROBE INTO DARK SECRETS

*JOINT VENTURE of the U. S., U.K., and the Netherlands, the Infrared Astronomical Satellite (IRAS) was launched January 25, 1983, into near-polar orbit and began its career operating beyond expectations. Designed to make an all-sky infrared survey, its first images were revealing. Scanning past the Large Magellanic Cloud, closest galaxy to ours, it detected active star-forming regions. Computer processed, these images confirmed the Tarantula Nebula (***above,*** at left, in rectangle) as a nursery where a cluster of stars from less than one to perhaps 100 solar masses is forming, white representing the hottest areas, blue the coolest. A smaller, similar region is to the right. The infrared images are aligned with a photograph of the same region, showing corresponding features in visible light.*

Indeed, as IRAS team member Michael Rowan-Robinson points out, the satellite will provide a "snapshot of places in the universe where dramatic star formation is going on."

With its sensors chilled to 2K by superfluid helium and shielded by a sunshade, IRAS is especially sensitive to objects from 10K to 1,000K, the cooler range of celestial bodies. While it can look out to distant galaxies and quasars, it can also see solar-system objects from planets to asteroids. And if, as some astronomers propose, the solar system is home to a tenth planet, Planet X, IRAS may be able to see it and resolve a long-standing debate about its existence.

VISIBLE-LIGHT IMAGE FROM CERRO TOLOLO INTER-AMERICAN OBSERVATORY, © AURA, INC. INFRARED SCAN FROM NASA JET PROPULSION LABORATORY. PAINTING BY NATIONAL GEOGRAPHIC ARTIST WILLIAM H. BOND

These explosions still could not get rid of all the accreting mass; so temperatures and pressures within SN 1981b would rise.

At some point, suggests Wheeler, things just got too hot inside SN 1981b. Its whole core ignited. In a few seconds the explosion ripped through to the earth-size star's surface, blasting the bulk of the star away in a gaseous ball of elements. This cloud raced outward so rapidly that, had it been earth, our planet's debris would have reached Pluto in only a few days. That journey, by contrast, would take the Voyager spacecraft more than a dozen years.

Type II supernovae explode no less violently. However, they signal the death of a giant star, not a dwarf. These giants, with masses of 8 to more than 30 times our sun's, are the primary cosmic alchemists. Like all stars, they make energy by fusing simple atoms such as hydrogen or helium into more complex elements, such as carbon and oxygen. Such fusion releases energy through the same process as does a hydrogen bomb.

This chemical cooking proceeds until the star's core is completely converted to iron. Iron is the ultimate stellar ash. Its atoms are so stable that they actually consume rather than release energy when they fuse. Thus the star runs out of fuel and collapses. The energy released by that collapse, however, bounces the infalling matter back into space as a tumultuous, glowing shock wave much like SN 1981b's. The extreme heat released in this explosion also forges the heavier elements, such as uranium.

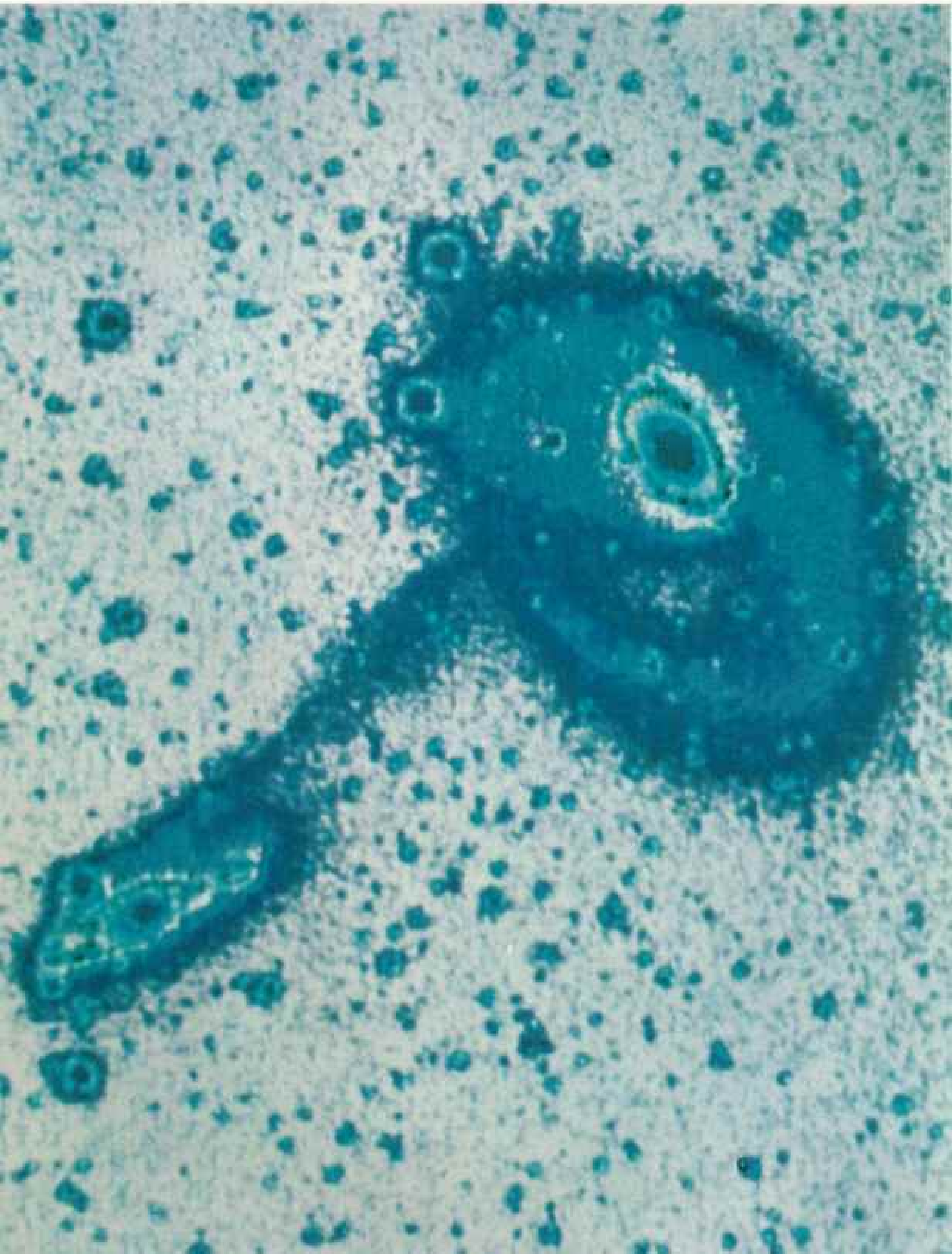
A supernova typically leaves behind a corpse—a spinning neutron star. These little stars are made of neutrons, atomic particles that can survive the crushing gravity of a supernova collapse. So densely are these neutrons packed together that a thimbleful of a neutron star would weigh more than all the cars on earth.

Such tiny stellar embers, whose diameters are each about the length of Manhattan, concentrate the magnetic fields of their parent stars. These intensified fields cause highly charged particles to stream, like the beam of a searchlight, from the magnetic poles of most young neutron stars. These mini-stars rotate rapidly, and, if the beams point toward earth, astronomers can detect rapid pulses of radio energy as the beams flash repeatedly past us. Astronomers call these stars pulsars. Until November of 1982 the fastest known spinning pulsar was the fresh corpse of a supernova that created the chaotic, brilliant Crab Nebula in the constellation Taurus in A.D. 1054. That neutron star is still so charged up from its collapse that it rotates 30 times a second.

BART J. BOK, UNIVERSITY OF ARIZONA

***A star is born** but remains invisible within a small globule of dark gas and dust (**left**). What is visible, as discovered by Richard Schwartz of the University of Missouri at St. Louis, are bright knots called Herbig-Haro objects, here connected by a glowing filament. The less than million-year-old star is still organizing itself, and in the process it ejects gouts of matter. As this matter encounters other material, a shock front is created, and the motion of ionized gas behind the front is converted to radiation.*

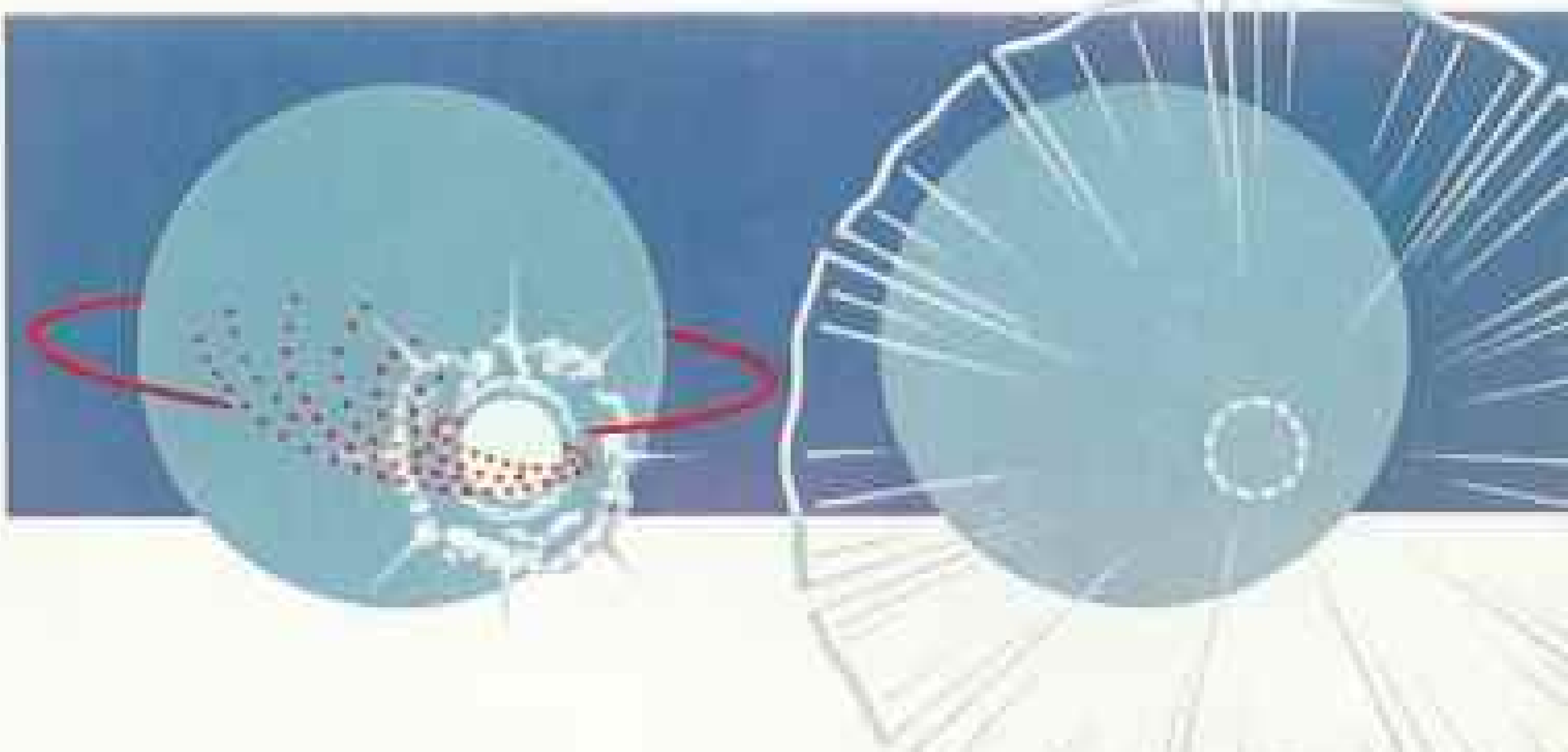
*On a much grander scale (**right**), galaxies called "the toadstool" are linked by a bridge of hydrogen where great hordes of stars are probably forming.*



BINARY STARS: ODD COUPLES

A MINORITY OF ONE, our sun has no companion star. But the majority of stars appear in company. Our nearest stellar neighbor, Alpha Centauri, is a three-star system, while Castor, in the constellation Gemini, must be counted as a trio of double, or binary, stars orbiting a common center.

When binary stars are close enough to interact with each other, they produce some of the most explosive, peculiar, and baffling events yet observed.



NOVA AQUILAE

If a dense white dwarf orbits a normal star, the intense gravity of the dwarf will draw matter away from the companion. This matter swirls through an accretion disk onto the dwarf's surface, building up pressure. Since the dwarf cannot shed heat by expansion, the excess is blasted away by periodic nuclear explosions.

TYPE I SUPERNOVA

A white dwarf may erupt as a nova many times. Finally, however, the buildup of internal pressure becomes too great, and the dwarf cannot shed heat except by exploding entirely. Unlike a Type II supernova—the catastrophic collapse of a giant star that leaves behind a neutron star—this explosion may leave no remnant star.

IN 1979 Donald Backer, a research astronomer at the University of California at Berkeley, submitted a paper to a prestigious astrophysical journal proposing that an obscure object listed in a 20-year-old survey of galactic radio-wave sources might be a superfast pulsar. The paper was rejected as unconvincing and poorly written. He put this object, cataloged as 4C21.53, on his back burner.

Backer returned to 4C21.53 last year while at the 305-meter-diameter radio telescope at Arecibo in Puerto Rico. He and his colleagues confirmed, after rechecking their instruments for every conceivable glitch, that 4C21.53 was in fact a pulsar rotating 642 times a second—20 times faster than the Crab pulsar.

"I was simply stunned," said Backer. So was the rest of the pulsar world.

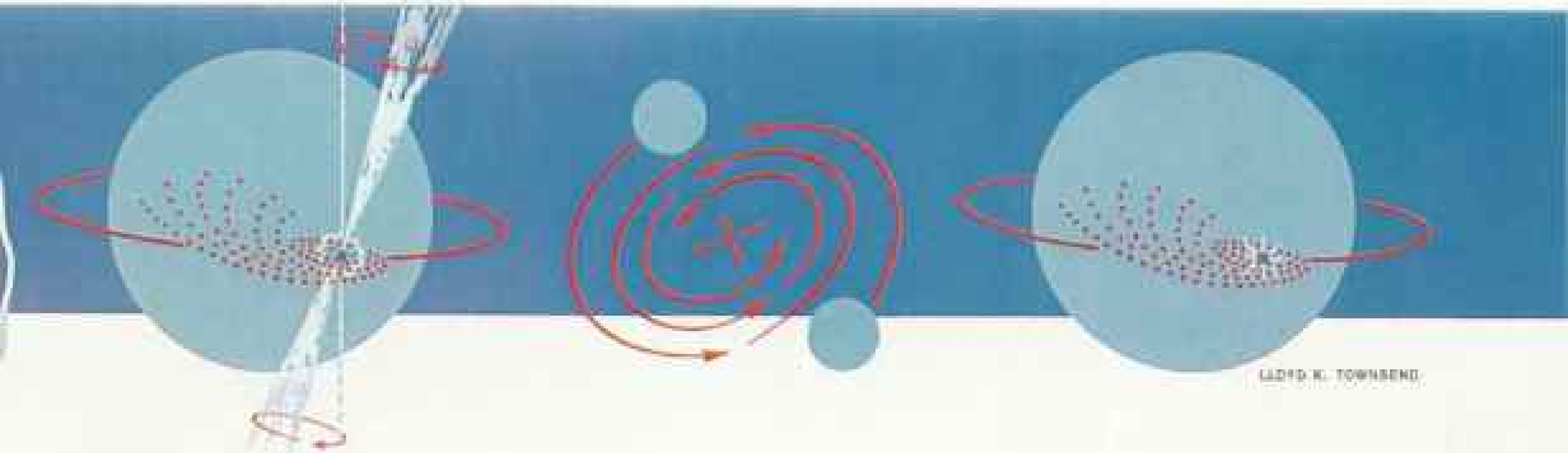
Two theories for making such superfast pulsars have been proposed. One, the pulsar was born with an extremely weak magnetic field—the force whose drag normally causes pulsars gradually to slow down. Alternatively, the superspinning object's magnetic field decayed. Then a companion star began throwing mass onto 4C21.53, kicking it up to high speeds. Later the companion star itself vanished in a supernova explosion, leaving this naked neutron star to spin alone at heretofore impossible speeds.

Neutron stars whirling around companion stars are responsible for a variety of explosions in our galaxy. Most radiate storms of X rays. More than any other wavelength, X rays have revealed the ubiquitous violence of the universe.

As penetrating as X rays are, they are absorbed by earth's atmosphere. Early satellite telescopes could not focus X rays well. But in 1978 the Einstein Observatory, which could make sharp X-ray images, was launched. Before it died in 1981, Einstein analyzed a dizzying assortment of violent binary systems: X-ray pulsars and X-ray bursters, including a rapid burster.

"We are like the 18th-century botanists in the jungle finding all those new flowers," said MIT astronomer Eric Feigelson, a member of the Einstein team. "We are still classifying things."

If we had Einstein's X-ray vision we would see our quiet sky pulse and flash.



SS 433

Even in a strange universe, this was impossible—a star that seemed to be both coming and going at a quarter of the speed of light. What SS 433 may be is a neutron star engulfed in matter from a companion and firing off blobs of matter and jets of radiation in rotating beams that make it look like a relativistic yo-yo.

BINARY PULSAR

Two ultradense stars, one a pulsar, the other a mysterious object so far unseen, have been found circling about each other in tight orbits. Their gravity pulls them ever closer, and in time they will merge. Their combined mass will then be insupportable, and they will disappear into a black hole of their own making.

X-RAY BURSTER

Material from a companion accumulates on a neutron star and is blown away—in hours or days on common bursters, in seconds or minutes on rapid bursters. It may be that hydrogen fuses and builds up helium on the star's surface. Under pressure, the helium ignites, and, in fusing to iron, liberates a burst of X rays.

Some fires would appear for a few moments and disappear for the rest of our lifetimes. Others would sputter continuously at us. The entire sky would glow with the soft radiance of an unexplained dilute fog of ions, or charged particles, as hot as 500 million degrees. We would also see bright 50-million-degree supernova remnants plowing past interstellar islands of ultracold gas.

If we could extend our vision to see the still more energetic gamma rays, we would perhaps once a week notice astonishing bursts, popping off like flashbulbs. On March 5, 1979, a particularly awesome split-second gamma-ray burst was recorded. It may have come from the closest galaxy to us, the Large Magellanic Cloud. If so, in that brief instant, calculates Kevin Hurley of France's Centre d'Etude Spatiale des Rayonnements, the burster released as much energy as one hundred billion stars. Even if the burst had occurred in our own galaxy, as most bursters appear to, its energy would have been less, but still amazing.

Astronomers cannot explain these outrageous outbursts. All they can say is that the bursts seem to be coming from an object about the size of a neutron star. Speculation abounds. Some scientists have suggested that the bursts occur when accreting gas from a companion star somehow causes a degenerate dwarf to collapse into a neutron star without a supernova explosion. Others have proposed that asteroids or comets striking a neutron star cause the bursts. Neutron-star quakes might also generate gamma-ray energies.

Recently, however, 26-year-old Bradley Schaefer may just have seen the normally invisible gamma-ray beast.

As a boy in Denver, Schaefer constructed his own telescopes and stayed up nights stargazing. Later, when he enrolled at MIT, he became infatuated with nearby Harvard's plate collection, an archive of 400,000 photographic plates, each recording some tiny part of the night sky and taken since 1885 at observatories around the world. "The Harvard plates are a time machine," said Schaefer. "You can go back and sneak a look at what any star was like 10, 50, nearly 100 years ago. Very few people realize what you can do with these plates."

What Schaefer did with them was to

search nights and weekends through some 5,000 old plates of the region of sky where a strong gamma-ray burster had been detected on November 19, 1978. He was scanning six exposures taken minutes apart in South Africa in 1928. He noticed a bright new star on the fourth plate. On the fifth and sixth plates the star had vanished. Was the new star an optical flash given off by the same object that had flared in gamma rays 50 years later? If that is the case, gamma-ray bursters recur. That would rule out many theories. Nevertheless, the nature of the gamma-ray beast will probably take years and new instruments to identify.

PERHAPS the most famous neutron-star flasher in our galaxy is an enigmatic object called SS 433. It is yet another binary system—probably a neutron star being fed by a huge companion.

"It simply looks absurd," said University of Washington astronomer Bruce Margon. "Sometimes SS 433's spectra make it appear to be moving away from us at 50,000 kilometers a second. At that rate it would have zoomed out of the Milky Way long ago. But at other times, SS 433 seems to be coming toward us at just as preposterous a speed."

Two jets of gas shoot out in opposite directions from the accretion disk that feeds the neutron star. "These jets each extend some ten billion kilometers—or twice the diameter of our solar system. That kind of blasting can't last long. Otherwise those jets would exhaust the entire mass of the companion in less than a million years."

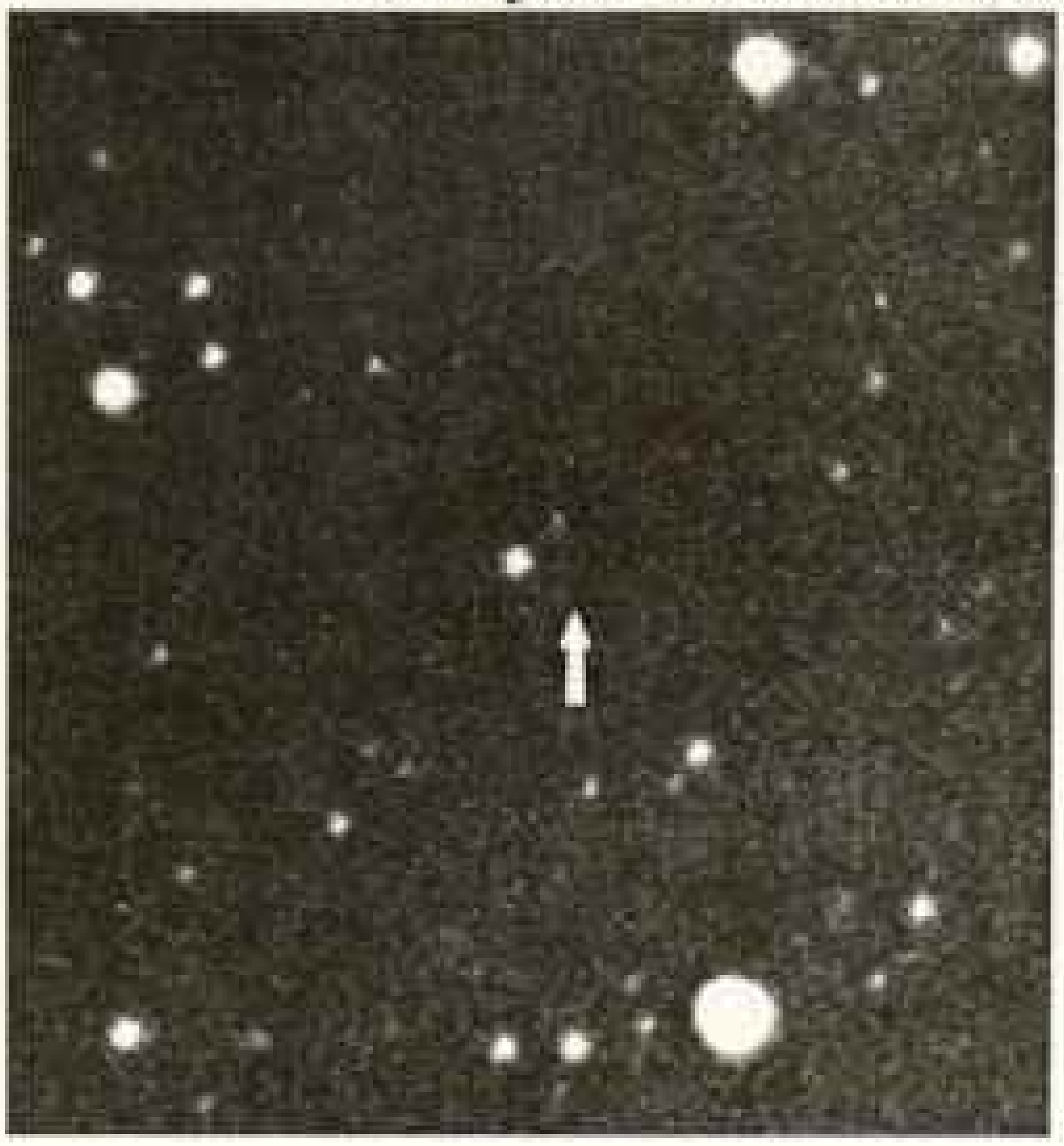
If we could fly past SS 433, we would see that it is really not soaring to and fro. The jets just make it look that way. They rotate. Sometimes one points toward us, sometimes the other. Thus the star seems to be both coming and going.

On an arid plain in New Mexico, 27 big movable white metal sentinels, lined up in the shape of a Y, have been watching almost

*With a detective's tenacity, MIT graduate student Bradley Schaefer (**left**) searched old sky plates in Harvard College Observatory's archives, seeking visual evidence for one of astronomy's great mysteries, a gamma-ray burster. But he couldn't be sure of spotting anything.*

*After weeks of digging, he hit pay dirt: a plate from South Africa recording no unusual object (**below left**) and then, on another taken less than an hour later (**below right**), a flash of light where the burster should be—indication that it does flash and emit radiation in visible light as well as gamma rays.*

10:31 p.m. 17 November 1928



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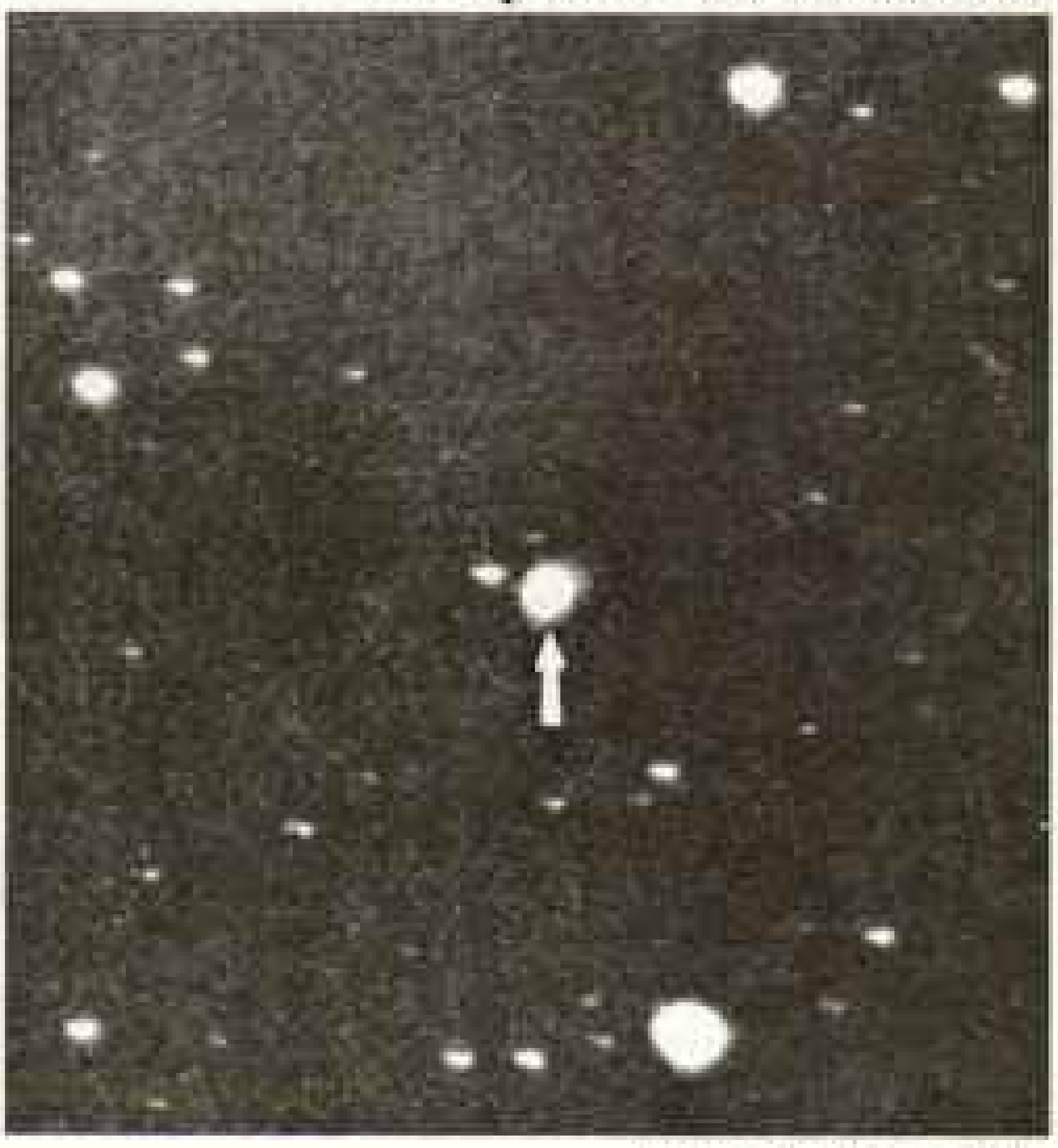


HARVARD COLLEGE OBSERVATORY

every move SS 433's jets make. Individually, these sentinels are dish-shaped radio-telescope antennas. Together they compose the new pride of radio astronomy, the Very Large Array, or VLA (page 738). "It's a giant radio camera," explained astronomer Bruce Balick of the University of Washington. "It's the most difficult way man has ever devised to take a picture."

I prefer to think of each antenna in the VLA as a rod in the retina of an eye. The VLA's rods, however, detect radio waves. When VLA's brain—its computers—combines the signals each antenna senses, it can create sharp images or radio maps.

The 27 antennas can fan out far enough across the desert to make the array equivalent to a radio eye the size of metropolitan Washington, D. C. This huge eye has the resolution to dissect distant galaxies. Since SS 433 is much closer—only 13,000 light-years away—the VLA can zero in on the fine structure of its jets.

The VLA devotes so much time to SS 433's jets largely because they may be miniature versions of monstrous jets spewing forth from highly disturbed galaxies all across the universe. Some of these "active galaxies" throw out their jets at more than 99.5 percent the speed of light.

To study these cosmic blowtorches, radio astronomers have developed a still more remarkable technique called Very Long Baseline Interferometry, or VLBI. They can synchronize many hours of data recorded simultaneously at radio telescopes all over the world to within an exquisitely tiny fraction of a second, and in effect combine the telescopes into a radio eye the size of the earth. A satellite telescope, which would expand the radio eye to 40,000 kilometers across, may be added to the network in the 1990s.

Already computers can make VLBI images that reveal 1,000 times the detail of the VLA. VLBI can measure the width of a human hair from 80 kilometers away.

VLBI has revealed that those huge jets seen in distant galaxies emerge from their central cores. Anthony Readhead, a VLBI pioneer at Caltech, showed me a computer movie of an active galaxy spitting out a blob of matter as part of a jet. The blob alone measured five light-years—or 47 trillion kilometers—across.

That galaxy was a special one. It contained the first confirmed quasar.

For years after their discovery in the early 1960s quasars mystified astronomers. The extremely distant objects seemed mere points of light, racing away from us at remarkable speeds, but radiating a thousand times more light than an entire galaxy.

To appreciate the energy quasars release, consider a big nuclear power plant producing 1,000 megawatts of electricity. Multiply those 1,000 megawatts by a billion trillion. Then multiply again by ten billion. That is roughly a quasar's power.

Only recently have most astronomers concluded that quasars are in fact the cores of very disturbed galaxies. Susan Wyckoff and Peter Wehinger of Arizona State University have found a "fuzz" around some 45 quasars. And Todd Boroson of Mt. Wilson and Las Campanas Observatories has detected starlight emanating from that fuzz. Today we have charted some 1,500 quasars—roughly one for every piece of sky the size of the bucket of the Big Dipper.

Some astronomers argue that quasars are much closer, and hence much younger, than they appear. But most now believe that quasars turned on in a great burst when the universe was one-fourth its current age.

The quasars have been speeding away ever since, on the same thrust of expansion initiated by the big bang. Since their light is just now reaching us, their enormous fires have probably long been quenched.

What caused the quasars to flare? The answer may also explain what upsets today's less active galaxies enough to produce jets. The engine probably resides in these galaxies' cores, which we cannot yet see well enough to probe. However, many astrophysicists already speculate on what they will detect within the cores of quasars. First, they would expect to find a whirling, superhot accretion disk, where particles of incoming gas are accelerated to nearly the speed of light. The heart of this glowing disk, from which the jets and blobs emerge, would span a diameter perhaps three times the distance between earth and Pluto.

Embedded in that disk would lurk the ultimate cosmic bête noire—a huge spinning black hole.

THOUGH their existence is nearly impossible to confirm, black holes theoretically occur when matter collapses into an exquisitely compact state. Its gravity grows strong enough to trap everything, including light, within the horizon of its gravitational field. The earth, for instance, would become a black hole, if it could somehow be squeezed to the size of a marble.

This extreme gravity plays queer tricks with space and time. According to Albert Einstein, time is a dimension just like up and down. At this moment I am at a particular point in both time and space. The future and past exist—somewhere else.

If I could fall into a black hole—and magically look back over my shoulder—I could watch the entire future of the universe pass by. However, to someone standing outside the black hole, unaffected by this gravity, it would take an eternity for me to cross the black hole's border, or event horizon.

Incredible? Not to a mathematician. Mathematics describes with ease cosmic concepts that the human mind intuitively rejects. Infinity, for instance, no more troubles a mathematician than does a black hole.

Black holes come in at least three sizes.

"A fraction of a second after the big bang," explained Caltech black-hole expert Kip Thorne, "overdense regions of the universe could have collapsed into multitudes of mini-black holes as the rest of the universe kept expanding. Each could have measured less than the diameter of the nucleus of an atom, yet weighed a billion tons."

A loophole in the laws of physics, discovered in 1974 by Stephen Hawking of Cambridge University, probably enabled most mini-black holes to evaporate long ago in catastrophic explosions. Some may still be around. Perhaps once a month one may explode randomly in space.

Medium-size black holes result from the collapse of giant stars too massive to stop at the neutron star stage. They just disappear into their dark prisons. Also, a neutron star in a binary system might become a medium-size black hole if enough mass from its companion accumulates on it to push it over a critical edge.

In addition, a pulsar has been discovered orbiting another compact object, separated by a distance comparable to the sun's diameter. "That's like two soccer balls ten miles apart," said Joseph Taylor of Princeton University, "exerting a profound influence on each other." Gravity is irresistibly drawing the two stars closer. "When they meet in 300 million years," says Taylor, "they will merge into a black hole."

The monster black holes that may be at the centers of galaxies probably formed as the galaxies were getting organized. Whirlpools of matter would have gravitated inward to the collapsing core. Michael Penston of Britain's Royal Greenwich Observatory believes his team has actually weighed a galactic black hole by using IUE to measure the speed of gas orbiting it. "The black hole in NGC 4151," he says, "has the mass of 100 million suns." The diameter of such a black hole would stretch three-fourths of the way from earth to Jupiter.

"I ALWAYS WANTED to know what a black hole would look like," said University of British Columbia physicist William Unruh. He was about to show me a computer movie he made to fulfill that fantasy. "You can't see a black hole. Just its effects. I imagined myself in a spaceship in orbit around a 10,000-solar-mass black hole, looking at the constellation Orion."

The movie began from a point in that orbit with an unobscured view of Orion. Soon something that looked like a dark amoeba with a twirling crown of stars moved across the screen. The stars were not real. Rather, the gravity near the black hole's horizon had made a profound mirage, bending the light from every star in the sky like a lens and focusing it into second images of those stars, creating a halo around the hole.

As the spacecraft went behind the black hole, Orion turned into a pinwheel. I could watch the three stars in the hunter's belt being pulled apart and hurled into the black hole's crown of stars. As the spacecraft came out from behind the amoeba, Orion quickly reassembled.

Even though this star twirling was an illusion, Unruh's movie was compelling testimony to the gravitational strength of black holes. Black holes literally can tear stars apart. Stars could well be what feed the black holes in active galaxies. Like Newton's apple in an accretion disk, pieces of stars would liberate enormous energies and create colossal fireworks on their swirling descent into extinction.

"Fifteen years ago black holes were on the fringe of respectability," said Anthony Readhead. "Now we must take them seriously. No other mechanism can explain the energies released by active galaxies. Nuclear explosions won't do. Throwing stars into black holes is perhaps a 50 times more efficient way to generate energy."

Quasars may simply have been a stage most galaxies went through as their black holes formed and swept up stars and gas within their gravitational reach. In those early days the universe had expanded only to a fourth its current size. Galaxies were close enough to collide frequently, cannibalizing each other. So the quasar epoch may also reflect the prevalence of food back then.

The age of quasars has ended. "Apparently, most galaxies have used up the fuel near their cores," said Roger Blandford of Caltech. "But they are left with their central black holes, quietly waiting for more food."

Occasionally there may still be acts of cannibalism. A strange dark band streaks the agitated center of the nearby galaxy Centaurus A. "That band," said University of Washington's Bruce Balick, "suggests that Cen A has ripped apart a galaxy perhaps as large as the Milky Way. Some of its remnants now appear to be streaming in to feed Cen A's monster."

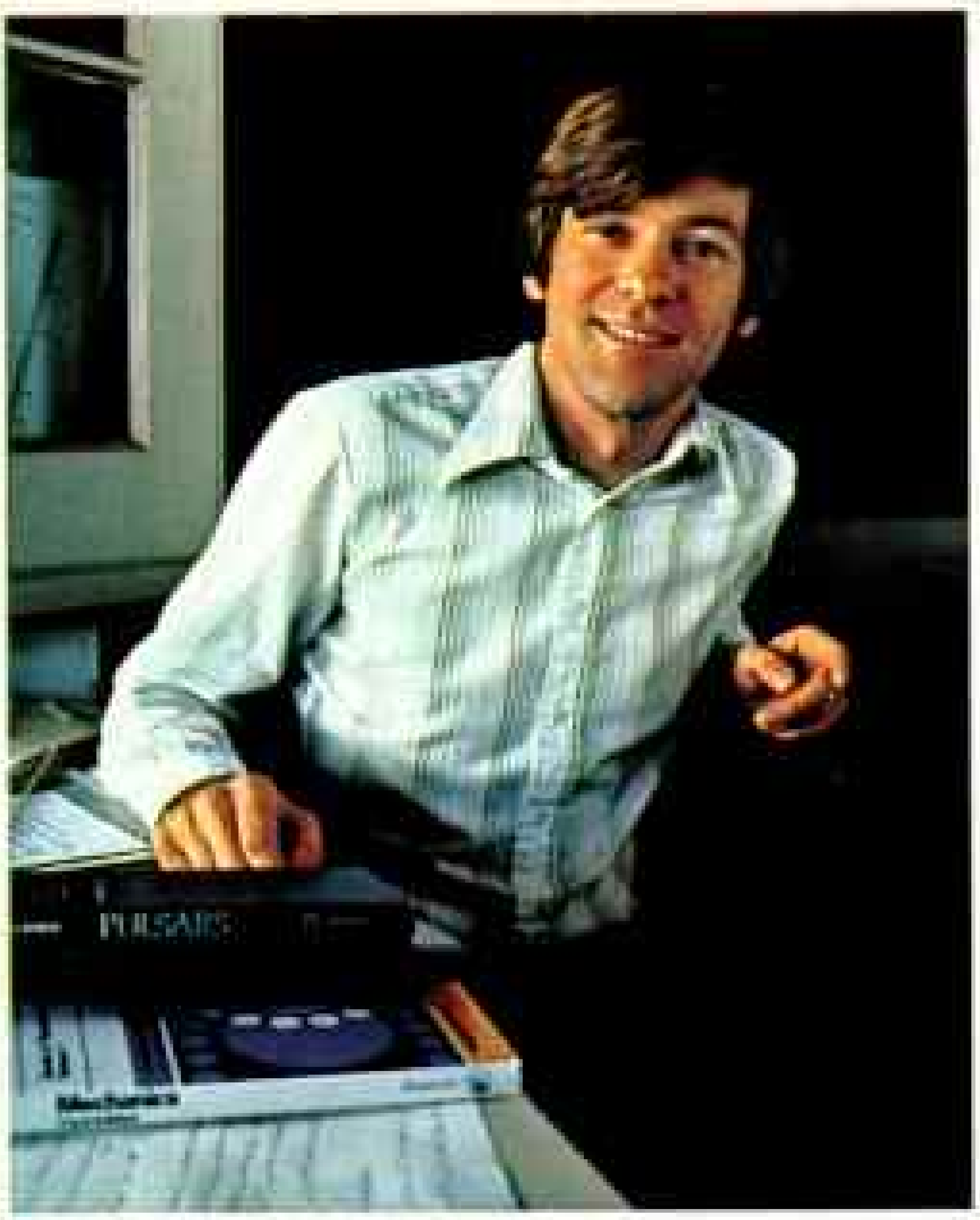
Does the Milky Way have a slumbering monster of its own?

"Radio astronomers have found a curious energetic dot in our galactic center," said Balick. "It could well be a black hole."

We might even have been active ourselves recently. "There's an expanding ring of gas clouds around our galactic center," said Dennis Downes at the French Institut de Radio Astronomie Millimétrique. "What's causing it? Was there a big explosion?"

BLACK HOLES: STOPPING TIME, POWERING GALAXIES

DAVID MONTGOMERY (ABOVE)



*EXCEEDINGLY ODD but perhaps relatively common, black holes may be scattered across the universe in a variety of sizes. Cambridge University theorist Stephen Hawking (**below,** at right, with student Chris Hull) has calculated that conditions in the early universe might have produced black holes about as large as a proton, yet heavy as a mountain. He has also calculated that black holes emit quantum radiation named "Hawking radiation," that they will eventually evaporate, and that some of the mini-variety probably already have.*

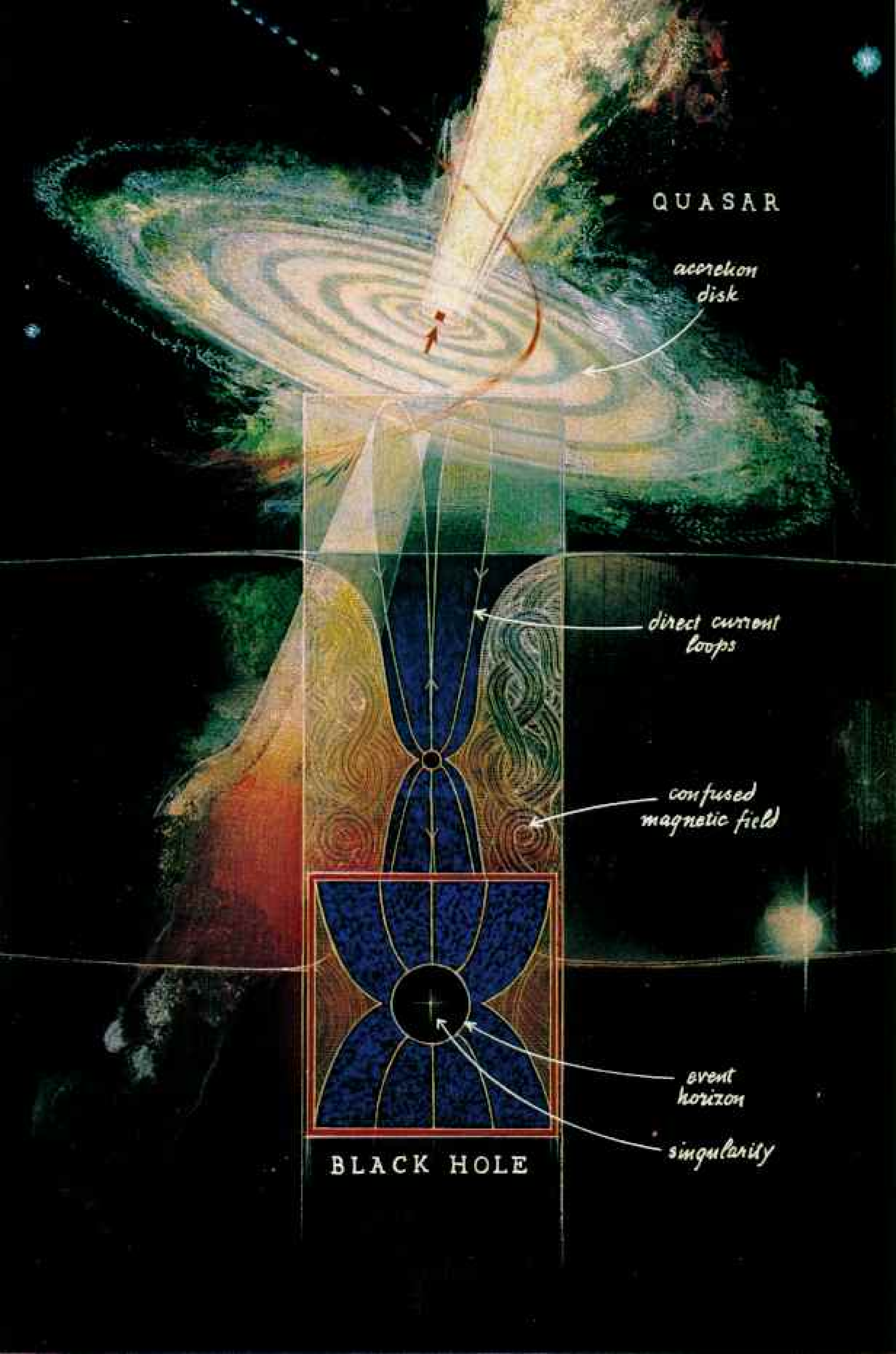
Gravity, in Einstein's formulation, causes space and time to curve. When enough mass is concentrated, as in a large collapsing star, that curvature becomes extreme enough to prevent light from escaping—a black hole has formed.

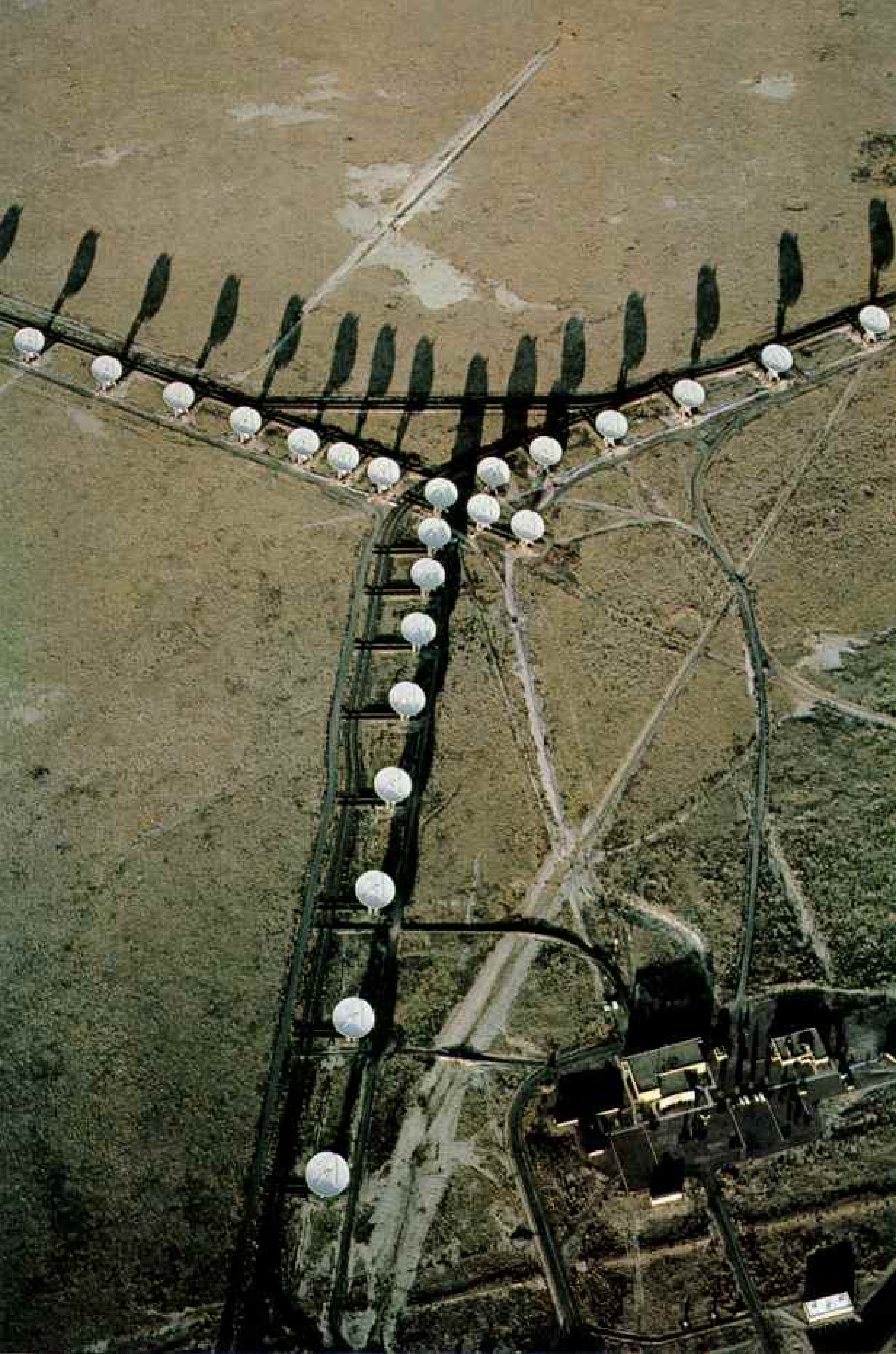
*A rotating black hole of 100 million solar masses with a diameter equal to Mars' orbit could be a powerful engine; here one drives the quasar at the heart of a young galaxy (**right**). Roger Blandford of California Institute of Technology (**below left**) has made significant contributions to understanding how this mechanism might work. A star falling into the range of this black hole would be ripped apart by gravity and spiral in as part of an accretion disk that emits jets of radiation and particles moving at nearly the speed of light. At closer range in cross section, the black hole is seen drawing in the gas and confused magnetic field of the accretion disk. Then, like a dynamo, it converts the energy of its spin into loops of direct current.*

A still closer view enlarges the black hole's event horizon. Any object such as a spaceship that was somehow able to cross this boundary would have its matter torn apart and obliterated as it fell into what astrophysicists call "the singularity," a point of perhaps infinite density.

What is the final fate of matter that enters a black hole? As Roger Blandford says, "If I knew the answer to that question, I would be very famous."

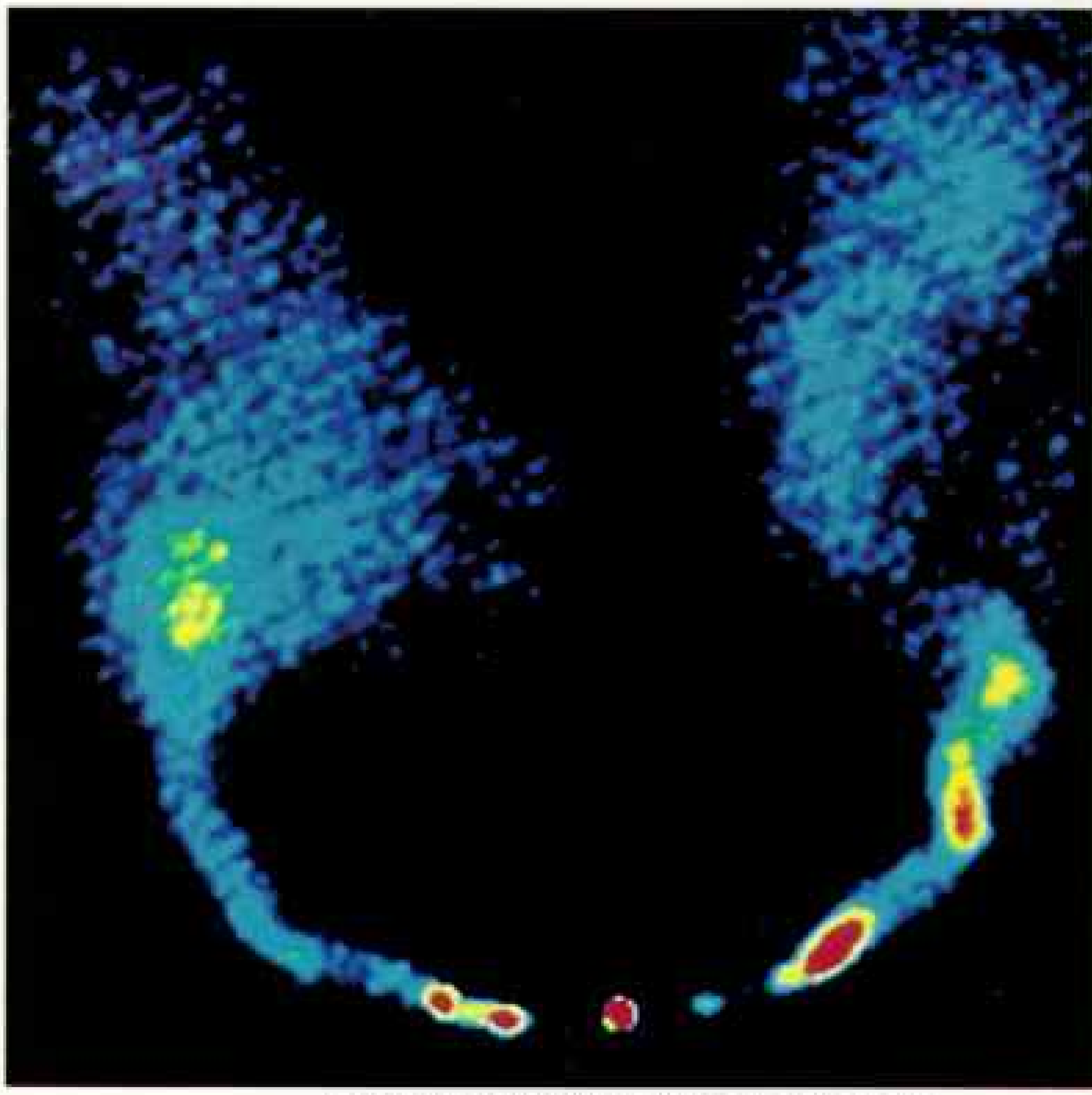
Since not even light can escape a black hole, one can never be seen directly. Yet if one lies between a distant star and a cosmic observer, the hole will act as a lens. As light rays from the star pass near the black hole, they will be bent by its intense gravity. The bending will create a mirage, and the observer will think he is seeing two stars. Actually, he is seeing what is not there—and not seeing what is. Warped though it may be, the universe is not without a sense of humor.


QUASAR
accretion disk
direct current loops
confused magnetic field
event horizon
singularity
BLACK HOLE



Sensitive enough *to detect a one-watt citizens-band-radio transmission from Pluto, the Very Large Array radio telescope in New Mexico* **(left)** *acts like a giant zoom lens, making use of the earth's rotation to sweep a circle every eight hours. When its mobile antennas are clustered for a wide-angle view as here, VLA can examine radiation in dust clouds. With antennas extended as far as 21 kilometers apart, it can zoom in on distant objects such as the galaxy NGC 1265* **(right)**.

This galaxy has an energetic source—perhaps a black hole—at its center and is beaming electrons at nearly the speed of light. The distance across the beams is 70,000 light-years, and they are being bent by collision with intergalactic matter.



NATIONAL RADIO ASTRONOMY OBSERVATORY; F. N. OWEN, C. P. O'DEA

In Australia, where both the galactic center and our two closest galaxies, the Large and Small Magellanic Clouds, pass directly overhead, Mount Stromlo Observatory astronomer Michael Dopita told me there is evidence that less than 100 million years ago a third Magellanic Cloud might have been ripped apart by the Milky Way.

Astronomers are finding many young stars above our galaxy's spiral disk, where there is no longer enough gas to form stars. How did they get there? Also, a gaseous cloud, called the Magellanic Stream, wafts like a tail out of the Milky Way. The stream may be the remnant of a close encounter, suggests Mount Stromlo's Alex Rodgers.

Some astronomers doubt that there is a black hole in our galactic center. "However, we certainly see a burst of star formation in there," says University of Arizona's George Rieke. We are just learning that the births of stars may be as explosive as their deaths.

Most stars form in groups in cocoons of gas and dust, called Giant Molecular Clouds. From Mauna Kea, infrared astronomers Eric Becklin and Gareth Wynn-Williams of the University of Hawaii have been monitoring our closest GMC, in the constellation Orion, watching the violent birth of several young stars. "These not only pull gas in as they condense," said Wynn-Williams, "they also blow material away ferociously."

Big blobs of cosmic shrapnel, some emitting as much energy per second as our sun, blast out from young stars. Perhaps the stars are just igniting, launching a shock wave that hurls out these gaseous cannonballs. Such interstellar bullets may be pieces of matter too small to form planets, suggests Dennis Downes. Similar pieces that stay near the star may become comets.

Moreover, astronomers now see jets streaming from many star-forming cocoons. Perhaps even stars go through a jet stage.

As University of Arizona's Charles Lada put it: "Maybe when the sun was born, the solar system looked like a little quasar."

"Stars, they come and go. They come fast or slow," sings vocalist Barbara Cook in a Washington, D. C., cabaret. "They go . . . in a blaze and all you see is glory. But most have seen it all."

BEGINNINGS: THE FIRST MOMENTS

10^{-43} SECOND 10^{32} K *Physics starts here; theory cannot account for conditions before this time. Gravity has just broken free from the single unified force presumed to exist at the big bang. Our universe is 10^{-33} centimeter in diameter; it is inconceivably hot, but cooling as it expands.*

10^{-35} SECOND 10^{28} K *The "inflationary epoch" begins. The observable universe has grown to 10^{-24} cm and is cooling, but it can remain briefly in its previous state, much as water remains liquid below 0°C before crystallizing to ice. In this state a condition like negative gravity develops and inflates the universe exponentially. Toward the end of this split-second epoch, the universe reheats as the strong and electroweak forces begin to take on separate identities. Energy begins to congeal into particles of matter such as quarks and electrons and their mirror images called antimatter. Antimatter is identical to matter but with an opposite charge. A negative electron is, for example, paired with a positively charged twin called a positron. The universe has inflated to the size of a softball.*

10^{-32} SECOND 10^{27} K *The inflationary epoch ends, having made the universe smooth and almost homogeneous. Matter, antimatter, and radiation are a bubbling opaque stew.*

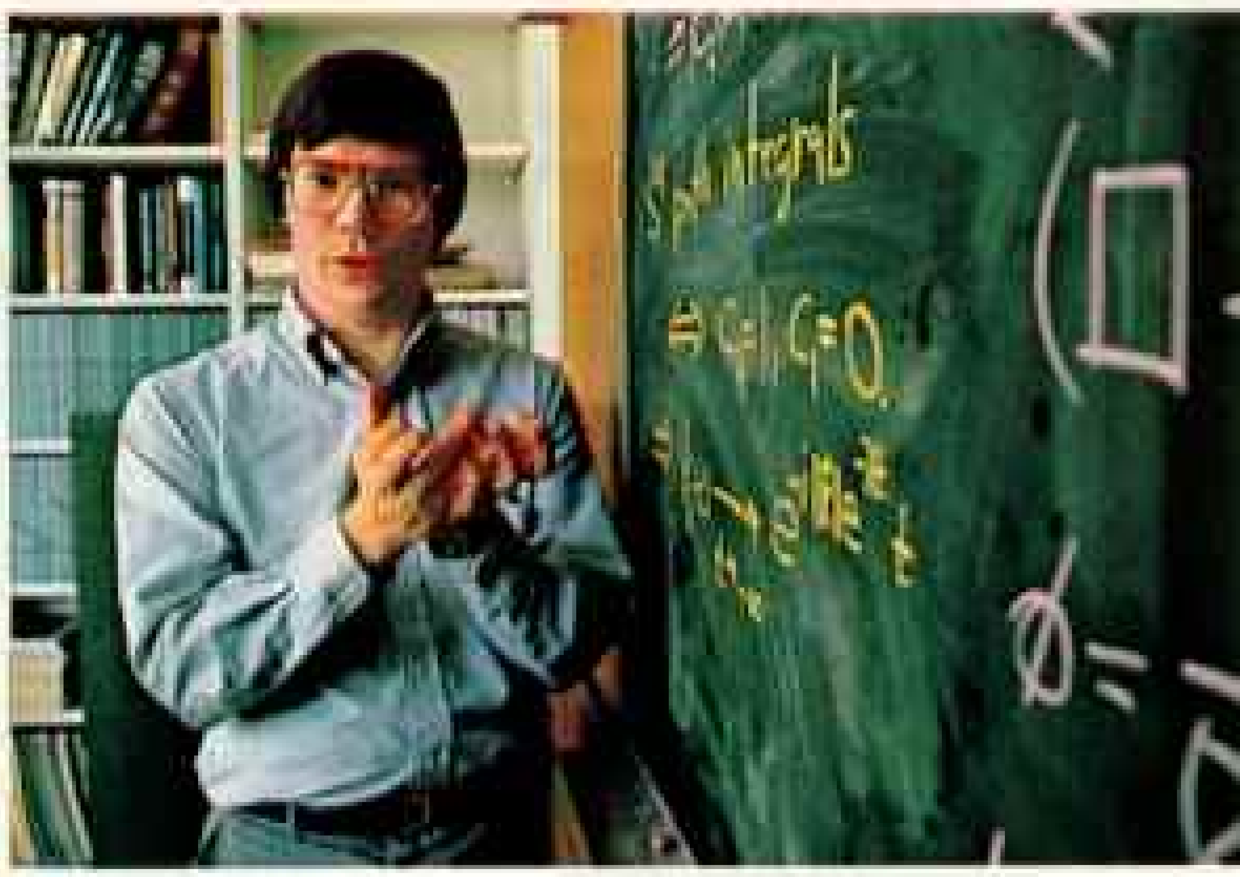
10^{-6} SECOND 10^{13} K *The universe has grown to about the size of our solar system. At this lower temperature, quarks bind into protons and neutrons. Matter and antimatter annihilate each other. Fortunately, there is slightly more matter, and this excess comprises the matter in the universe today.*

3 MINUTES 10^{9} K *Protons and neutrons fuse into atomic nuclei; electrons are still too energetic to be bound in atoms.*

10^{5} YEARS 3000 K *Electrons join with nuclei to make atoms. Radiation separates from matter, and light can now travel through space.*

10^{9} YEARS 15 K *Quasars form, and the observable universe is on course to assume its familiar appearance, bright points of light in a dark sky.*

KELVIN TEMPERATURES (K) BEGIN AT ABSOLUTE ZERO. ZERO K EQUALS −273°C, OR −460°F.



***Squeeze and heat** all the matter in the cosmos to the nth degree, and physicists have derived a standard model of the universe just after the big bang. But this model unrefined is flawed—for, run forward in time, it predicts creation of supermassive particles that would force the universe to collapse on itself at the tender age of 30,000 years. To address such problems, MIT theorist Alan Guth **(above)** and others conceive an "inflationary universe" that, in a sudden surge of expansion, suppresses creation of massive particles and smoothes out lumps of excess density.*

*Thereafter, when the universe is between a few minutes and a million years old, it evolves into a mass of particles, computer simulated **(below)** by S. Djorgovski, University of California at Berkeley. Lines enclose regions of equal density where seedlike cores grow to the scales of galaxies or clusters of galaxies.*

I have just returned from the Texas Symposium on Relativistic Astrophysics, and the simplicity of Janis Ian's lyrics soothes a brain badly muddled by the complexities of cosmology—the story of how it all began.

Invoking the insights of Einstein and an inscrutable command of mathematics, theoretical physicists have worked out a history of the universe all the way back to a mere 10^{-43} second after the big bang. That fraction of a second would be expressed by a decimal point followed by 42 zeros and a one—.0000000000000000000000000000000000000000001.

What existed before 10^{-43} second? Remember, the latest theories propose that at that moment our universe—all the cosmos that we can observe—was condensed into a region much smaller than an atom. Matter, as we know it, did not exist yet. The universe was pure, pent-up, exquisitely hot energy.

"The very fabric of space and time was being fashioned then," said British physicist John Barrow of the University of Sussex.

If we could time travel back to this moment, suggests David Schramm of the University of Chicago, we might encounter "a foam of mini-black holes popping off and reforming." Our universe may have been just a minute part of this foam. At some point at least one region of the foam—our universe—began expanding rapidly, somewhat like bread dough rising explosively fast. The big bang had begun.

In our universe today there are four basic forces—gravity; electromagnetism; the strong force, which glues together the particles within the nucleus of an atom; and the weak force, which causes atomic nuclei to decay radioactively. Physicists have recently predicted that at ultrahigh energies electromagnetism and the strong and weak forces are unified into a single force.

Most suspect that at the extreme temperatures prevailing in our tiny universe before 10^{-43} second, gravity also belonged to that single dominant force. Since physicists do not understand gravity well enough yet to describe this ultimate unification, they cannot break beyond the 10^{-43} barrier.

What caused the big bang? That question also still transcends our knowledge of physics. However, a provocative new theory called the "inflationary universe" takes us back to that brink of our origin.

"THE INFLATIONARY universe attempts to build the universe from *almost* nothing," says the theory's originator, Alan Guth of MIT. "In fact," he says, "the universe may be the ultimate free lunch."

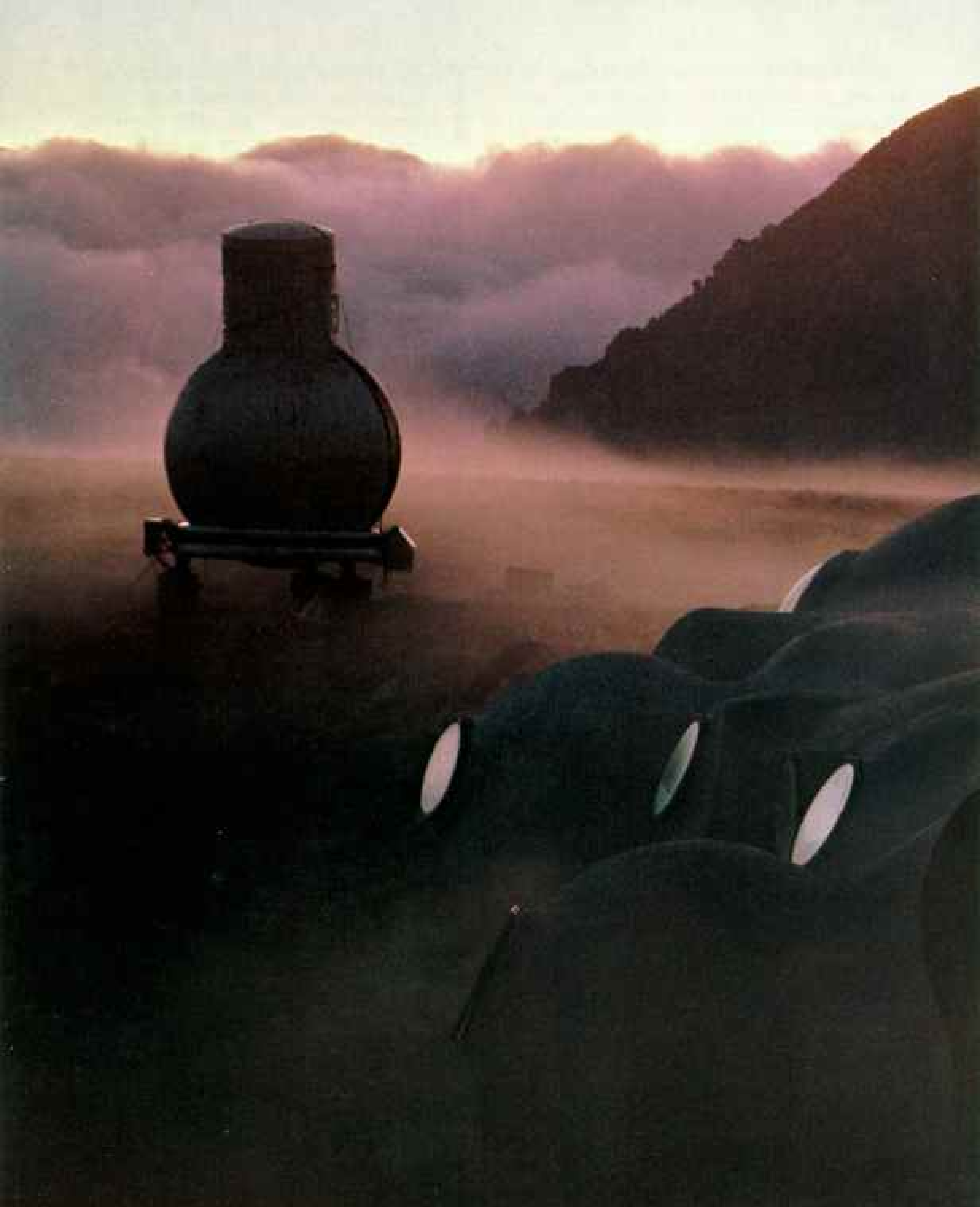
The awesomely brief inflationary epoch, described by Guth and others, begins at 10^{-35} second and lasts until 10^{-32}. By 10^{-35} gravity had emerged as a separate force as the space foam had expanded and cooled and the strong force also began to assume an independent identity. This transition, as the single unifying force lost its previously perfect symmetry, caused a condition something like the opposite of gravitational attraction to permeate some regions of the foam briefly. Space ballooned out. The region that would become our universe drastically inflated—to the size of an orange. Then, much as steam condensing into water releases a surge of heat, the emergence of the strong force unleashed an intense reheating of our bubble of a universe.

Within those inflationary moments, essentially all the matter and energy in our universe today was created. Quarks, the tiny building blocks of protons and neutrons, were produced by the intense heat, as was a family of particles that includes electrons.

Did other universes form? Perhaps. Will we ever know for sure? Physicists cannot agree. Some contend all universes would be like raisins in rising dough: Since the dough continues to expand, even expanding raisins would never meet. Other scientists say that the expansion between raisins will slow down and that as time goes by the growing universes will eventually converge.

A young universe could have been so dense it would have collapsed back on itself, like a rocket without enough thrust to escape earth's gravity. Or, matter might have been spread too diffusely to clump into stars and galaxies. A burst of inflation would have smoothed out the matter in the young universe to just the right density.

"To get a universe that has expanded as long as ours has without either collapsing or having its matter coast away would have required extraordinary fine-tuning," University of Chicago physicist Michael Turner told me. He calculated that the odds of achieving that kind of precise expansion



Pods wrapped in Alpine fog *are part of an observatory run by CERGA, a French agency for the study of geophysics and astronomy. Light shines from the windows of spherical offices and support buildings. The structure shaped like a light bulb is one of two telescopes in operation out of perhaps 12 to be built*

on bases that cost a fraction of traditional domes. The telescopes will be aligned by computer to tolerances as small as a wavelength of light and will function as one giant eye. The system will have enough resolving power so that if placed in orbit, as some future system might be, it could spot a dime on the moon.

without an early homogenizing inflation would be the same as throwing an imaginary microscopic dart across the universe to the most distant quasar and hitting a bull's-eye one millimeter in diameter.

This finely tuned course was set by 10^{-32} second after the big bang. Much later—when it was a millionth of a second old—the universe had cooled sufficiently for quarks to clump into protons and neutrons. At about one second a ghostly particle called a neutrino broke free. It was these neutrinos, many scientists now suspect, that went on to play a vital role a few hundred thousand years later.

Prime space atlas, *the National Geographic-Palomar Observatory Sky Survey has guided astronomers since the 1950s. Survey director Wallace L. W. Sargent stands by the 48-inch Schmidt telescope. The instrument's optics and film emulsions are being upgraded for a new survey to be supported by the Society, the Alfred P. Sloan Foundation, and Eastman Kodak—one that will look twice as deep into space.*

Three minutes after the big bang the temperature of the expanding universe had dropped to one billion degrees. Protons and neutrons could then clump to form atomic nuclei. Hydrogen and helium nuclei appeared. After 100,000 years, the temperature had dipped to 3,000 degrees. Electrons bound with the nuclei, creating full-fledged atoms. At this point, photons, the energetic particles of light and other forms of electromagnetic radiation, were freed from a long bondage with matter. In a sense, a glowing fog that had permeated the infant universe was dispelled. The universe began to assume its familiar appearance of darkness punctuated by islands of starlight.

This bursting forth of photons left an afterglow that radio astronomers can readily detect today in every corner of the universe. This diffuse background of photons has cooled to three degrees above absolute zero—the average temperature of the universe today. These cooled photons are fossils of the high temperatures that once existed.

WHAT HAPPENED in the perhaps two billion years between the afterglow and the roaring to life of the first quasar? Obviously, the galaxies formed. Today they are organized into rich clusters and superclusters. One of the great debates in cosmology is how those clusters arose. James Peebles of Princeton University contends that the galaxies formed first, then congregated. Soviet theorist Yakov Zeldovich argues that galaxies arose out of clouds of primordial gas that collapsed into thin sheets. These "pancakes" then fragmented into galaxies.

"A new problem," said Peebles, "is that we suddenly don't know what galaxies are made of. We thought it was mostly stars. Now there's evidence for huge amounts of dark, unseen matter within the galaxies. Stars could actually be minor components."

This dark matter could be black holes, dim or burned-out stars, lots of Jupiter-size objects that were not quite massive enough to ignite into stars, or subatomic particles. The most fascinating candidates are those tiny neutrinos that condensed out so early in the big bang.

Neutrinos resemble electrons, but they almost never interact with matter, largely because they are so insubstantial and carry no electric charge. They blithely zip right through the earth at the speed of light. Trillions have just passed through this page.

Neutrinos are made continuously in stars. But those that concern cosmologists are the big-bang neutrinos that still bathe us.

Few cosmologists paid attention to neutrinos until 1980, when Soviet and American experiments indicated that these supposedly massless points of energy might in fact have a very small mass. If so, that would be cosmos shaking. Big-bang neutrinos are nearly as numerous as photons of light. They could therefore account for more than 90 percent of the mass of the universe.

"Ordinary matter may be like caps of snow on top of mountains of neutrinos," a leading cosmologist, Jaan Einasto of the Tartu Astrophysical Observatory in Estonia, told me. "Neutrinos could well explain a striking new structure we are seeing in the universe. The galaxies and clusters now all seem to be strung out along long intersecting filaments. In between the filaments lie great voids—regions with no galaxies at all."

Viewed from afar, the universe thus would look like an airy sponge (page 747). The newfound voids that pock this sponge may be as big as 300 million light-years across. This sponge could well be shaped around a skeleton of neutrinos with mass.

"By the time ordinary matter decoupled from photons, the neutrinos had already clumped and started to build a structure," explained Alex Szalay of Eotvos University in Budapest. "Matter would then simply have fallen into the neutrino's prefabricated gravitational traps."

Computers have begun simulating how neutrinos themselves might have clumped following the big bang. "We end up with filamentary structures with big voids in between—just like the observable universe," said Berkeley astrophysicist Simon White.

We may not even be made of the dominant material of the universe. That news could further deflate our egocentric notions of humanity's importance. It need not. Some scientists are arguing seriously that this forbiddingly large and existential universe was absolutely necessary for life to evolve.

"The elements life needs had to be cooked up in stars," suggested John Barrow. "The cooking time to get them was at least ten billion years. The universe had to be rapidly expanding all that time. The universe *has* to be large for life to have evolved."

"What is the fate of the universe? Will it expand forever? Will the stellar fires eventually go out? Will all energy dissipate and the cold descend?" Astronomer Allan Sandage was ruminating at the Mount Wilson Observatory office in Pasadena on the subject of eschatology—the philosophy of final things.

"Or will the universe one day collapse on itself in a big crunch? Will, as St. Peter described, 'the heavens being on fire . . . be dissolved and the elements . . . melt with fervent heat'? If that happens, the universe might bounce back out of the crunch and be reborn."

Until the prospect of neutrinos with mass, astronomers could not find in visible galaxies even 2 percent of the mass needed to cause the universe to collapse. Massive neutrinos could indeed be what has long kept the universe balanced right on the edge between the cold and the crunch.

Most evidence now indicates the universe will expand forever. The question, however, is far from resolved. We simply can not measure the size, the age, or the hidden mass of the universe with enough confidence.

The death of the universe either by fire or attrition remains many billions of years off. "The universe is still in its youth," said University of Hawaii astronomer Brent Tully. "It is probably past adolescence and into the full blossom of its experience. It's still evolving. There's still lots of material to make new stars. It's a very vigorous universe."

EVERY TWO WEEKS physicist Marvin Marshak drives four hours from the University of Minnesota to a defunct iron mine near the Canadian border. He descends some 600 meters to a chamber where on occasion bats flap around a bank of 432 iron-ore slabs. Shielded by the earth from cosmic rays, each slab contains eight steel tubes filled with gas (next page).

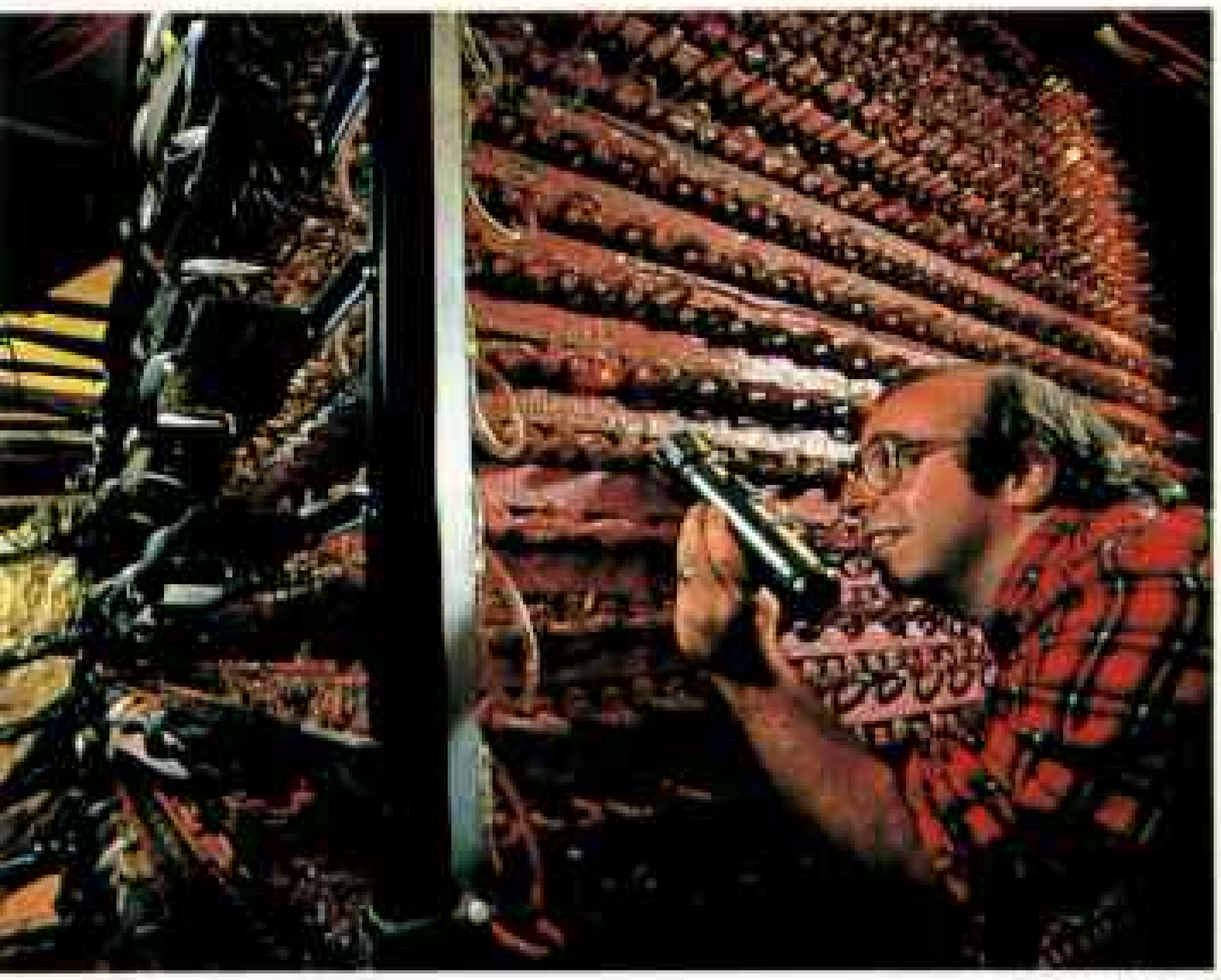
Marshak is hoping to catch one of the trillions upon trillions of protons that help make up those slabs in the act of decaying. If that should happen, the energy released would charge up particles in the gas-filled tubes. The event would be electronically recorded on one of the tapes that Marshak travels north biweekly to change.

"If we can see a proton go away—convert itself into energy," said Marshak, "then we can argue that the whole universe is dying."

Proving that protons—and hence all matter—can decay would have profound implications for many areas of physics. Therefore scientists around the world are conducting experiments like this one in Minnesota.

In the universe's hot early days, protons and their precursors theoretically decayed and re-formed continuously. At today's cooler temperatures they would only decay, and at a vastly slower rate.

"If you lived to be 200, one proton in your body might decay," said Marshak. The other 10^{28} atomic particles would not notice.



JIM BRANDENBURG

COSMIC MAYBES

IF PROTONS DECAY or if neutrinos—freed when the universe was one second old—have mass, the universe is a different sort of place than could have been imagined even ten years ago. These are profound "ifs." Certain theories predict their reality, but the proof is not yet in.

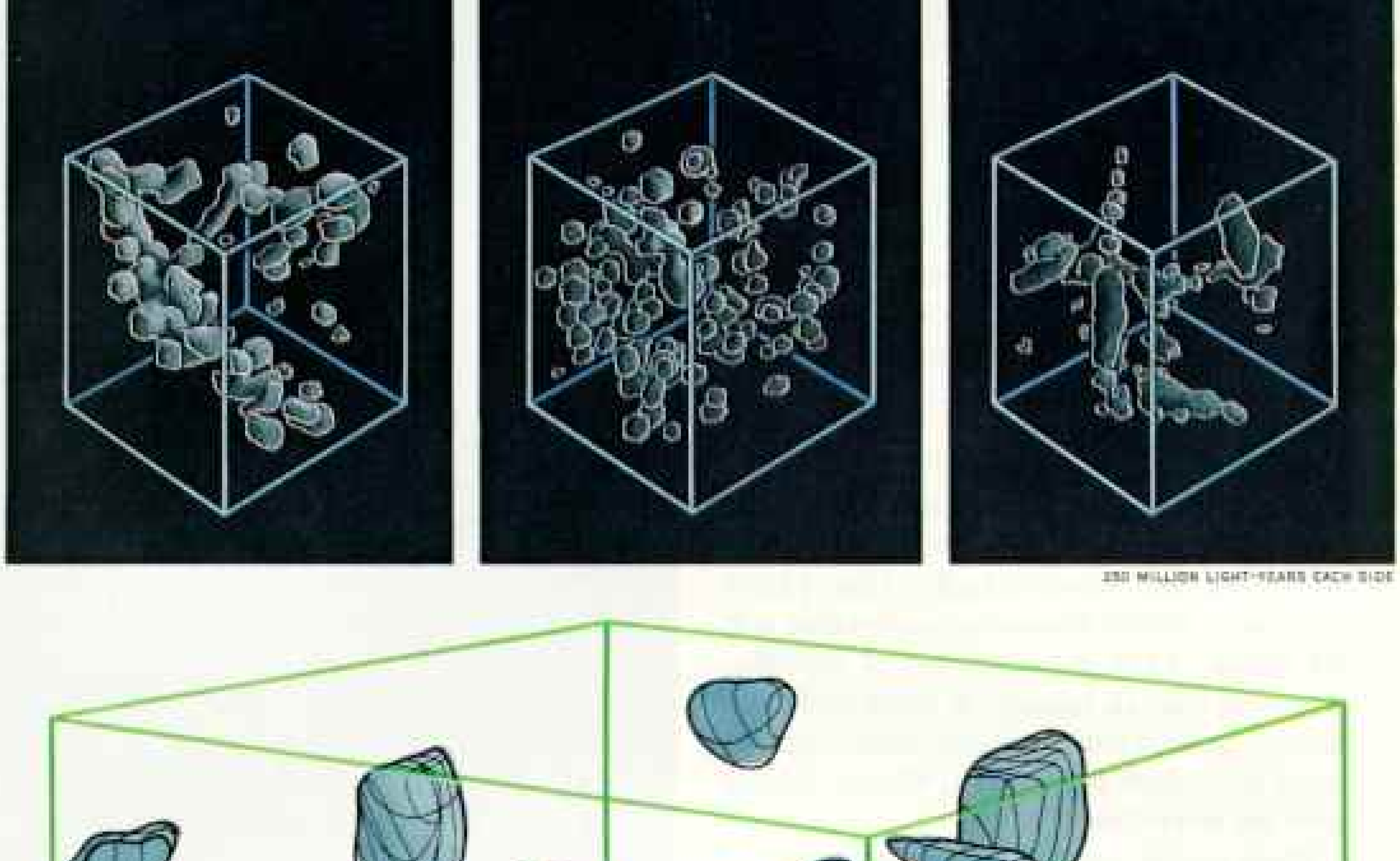
*Deep within a Minnesota iron mine that shields a proton-decay experiment from interfering cosmic rays, Marvin Marshak of the University of Minnesota (***upper left***) inspects his detection apparatus. If protons—heavy subatomic particles in the nuclei of atoms—decay, they do so extremely slowly. An unimaginable number must be monitored in hopes of seeing a single event. If such events are proved, this conclusion would follow: Matter is not fundamentally stable and will evaporate in some far future.*

*Neutrinos are thought to be as numerous as photons of radiation, yet they all but defy detection. John Learned of the University of Hawaii (***left***) is part of a project to suspend thousands of spherical sensors in the Pacific Ocean to search for highly energetic varieties of neutrinos.*

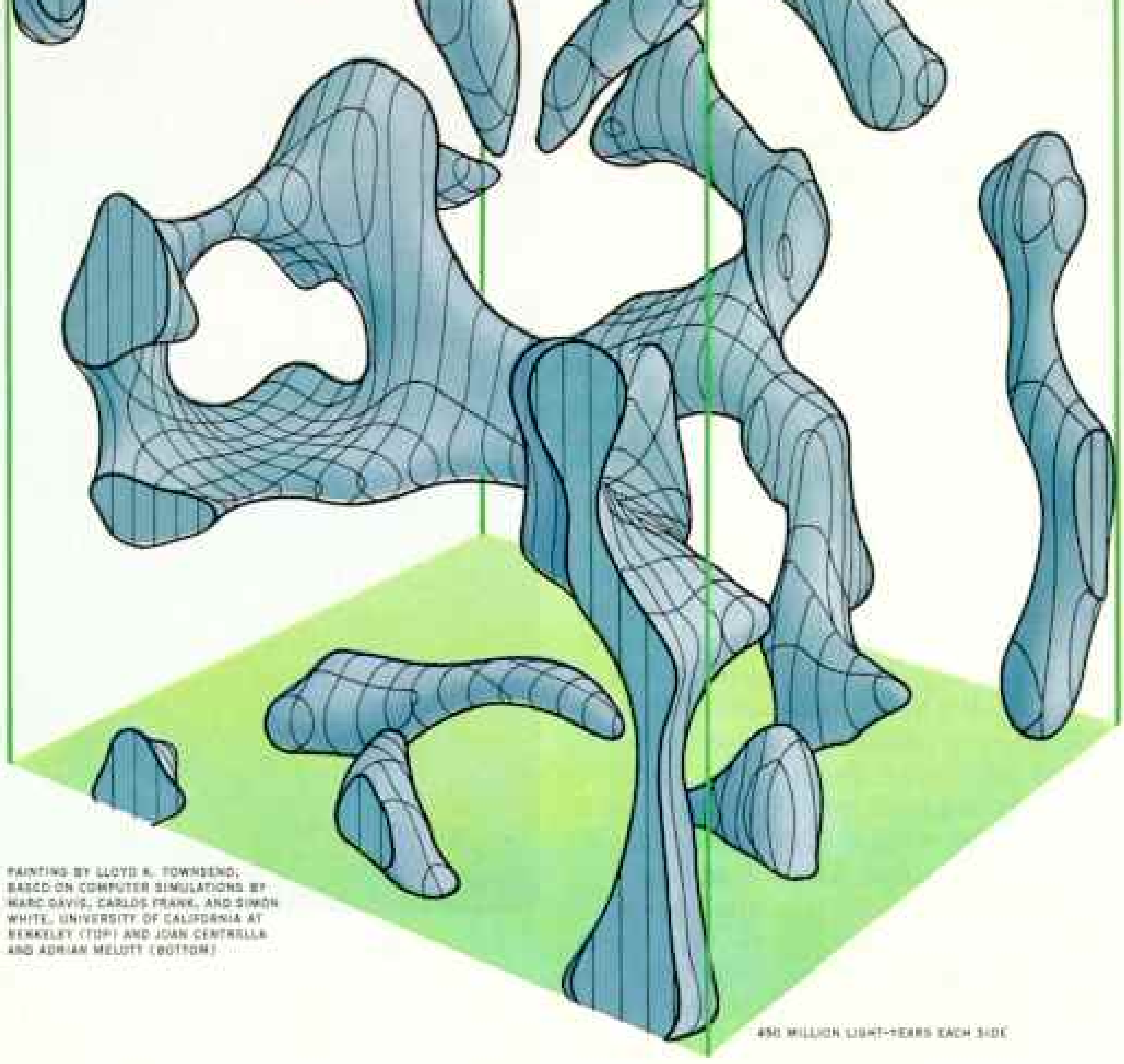
Even if it took 100 million neutrinos to equal the mass of a proton, neutrinos could still account for more than 90 percent of the mass of the universe.

The effects of such mass on the universe's structure have been computer simulated. A section is modeled (dark cubes, **above right***): (***1***) as it is seen to be, (***2***) as it would be if neutrinos have no mass, (***3***) and with the assumption they do have mass. The apparent universe has a fibrous structure like the heavy neutrino model.*

*Using a computer at Lawrence Livermore National Laboratory, Joan Centrella and Adrian Melott have derived a model that includes neutrinos with mass but omits other matter (***right***). A structure like this might have been present in the early universe with neutrinos in giant strands and clumps concentrating gravitational fields that would attract matter after it was freed from its bondage with radiation.*



250 MILLION LIGHT-YEARS EACH SIDE



PAINTING BY LLOYD K. TOWNSEND; BASED ON COMPUTER SIMULATIONS BY MARC DAVIS, CARLOS FRANK, AND SIMON WHITE, UNIVERSITY OF CALIFORNIA AT BERKELEY (TOP) AND JOAN CENTRELLA AND ADRIAN MELOTT (BOTTOM)

450 MILLION LIGHT-YEARS EACH SIDE

In a universe expanding into a cold and empty starless night, proton decay would be matter's last gasp. It would take many trillions of years for all matter to decay into energy. Those diffuse sputterings of energy, however, would be unable to rekindle star fire in a universe where the temperature hovered close to absolute zero.

SO WHAT IS THE POINT of a universe that ends in such oblivion? The more I begin to comprehend the universe, the more that question bothers me. I have no answer, beyond some memories that will not decay. They are of scores of striving, inquiring human beings, in front of blackboards, behind computer terminals, and on top of cold, dark mountains, who just think stars are beautiful.

These people continue to take giant steps. Last January they launched IRAS—the Infrared Astronomical Satellite. Over 11 months IRAS, a joint U. S.-British-Dutch telescope, will chart infrared emissions across 95 percent of the sky.

IRAS is mapping star-forming regions and making energy profiles not only of the Milky Way but also of thousands of galaxies previously too faint to see in the infrared. IRAS can detect dust grains too cold—10 to 16 degrees above absolute zero—to radiate significantly at other wavelengths. Some scientists suspect that much of the missing mass needed to one day close the universe is hidden in such heretofore unseen ultracold dust.

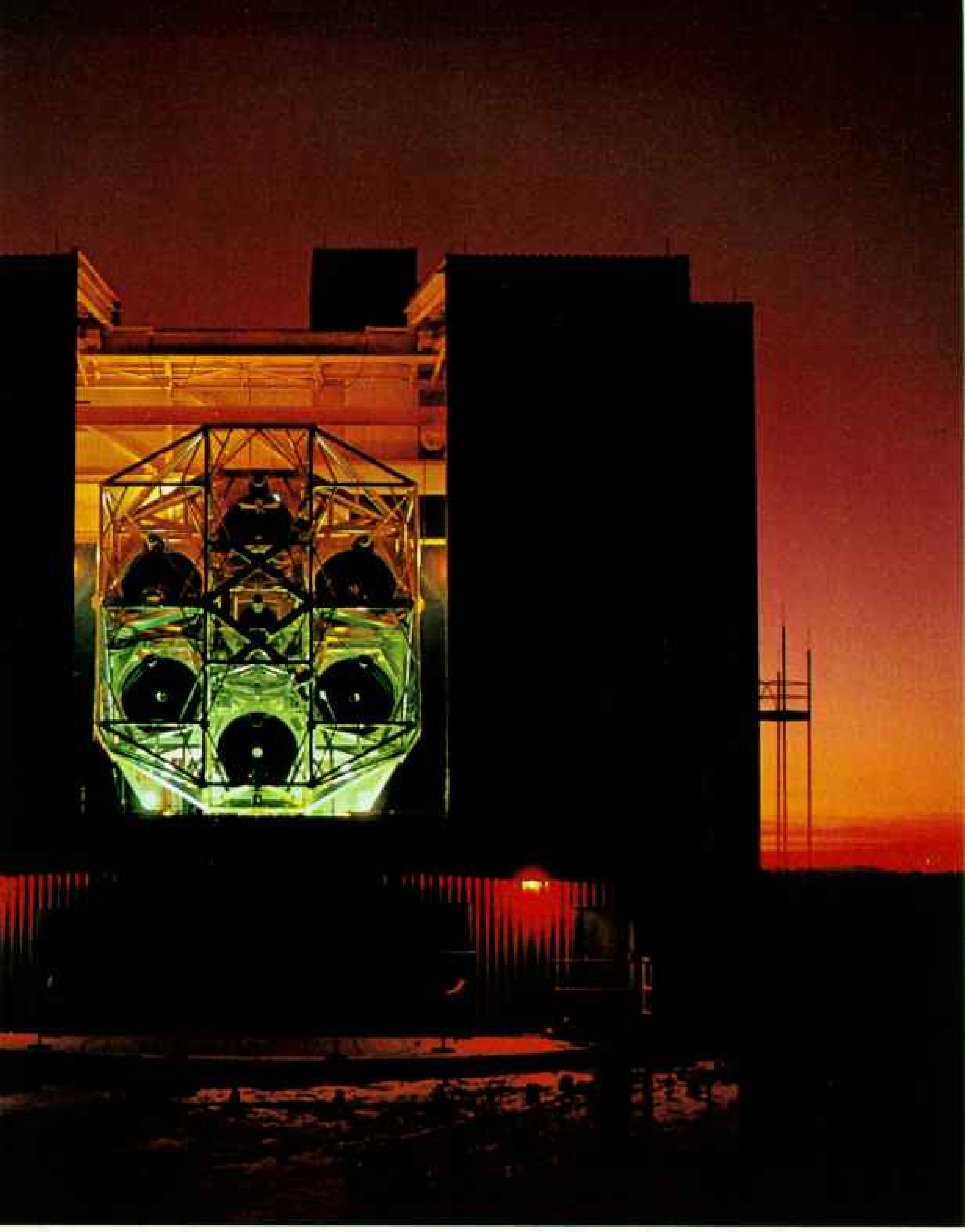
Astronomers will take yet another step in 1986, with the Space Telescope, the first big optical telescope to be placed above earth's obscuring atmosphere. It will see seven times deeper into space and detect objects one-fiftieth as bright as can earthbound telescopes. It will revolutionize astronomy.

"The Space Telescope is not going to solve all our problems," its director, Riccardo Giacconi, cautioned me. "But it will teach us how to look at things in a different way. A whole new set of questions will come up.

"What's important," Giacconi added, "is that the human brain is now capable of understanding what's out there. We are spreading the light of reason out across the universe."

And that may just be the point of it all. □

With otherworldly eyes, *the joint Smithsonian-University of Arizona Multiple Mirror Telescope (MMT) looks out from atop Mount Hopkins near Tucson. The telescope's six*



72-inch mirrors, with resolving power equivalent to a single 272-inch mirror, were designed to be integrated by lasers. But moths fluttering on the evening breeze interrupted the beams. Now the images of cosmic objects are coordinated by a video system. The MMT is particularly suited to examine quasars, using their ancient light to probe the most distant margins of space and time.

The Thames: That

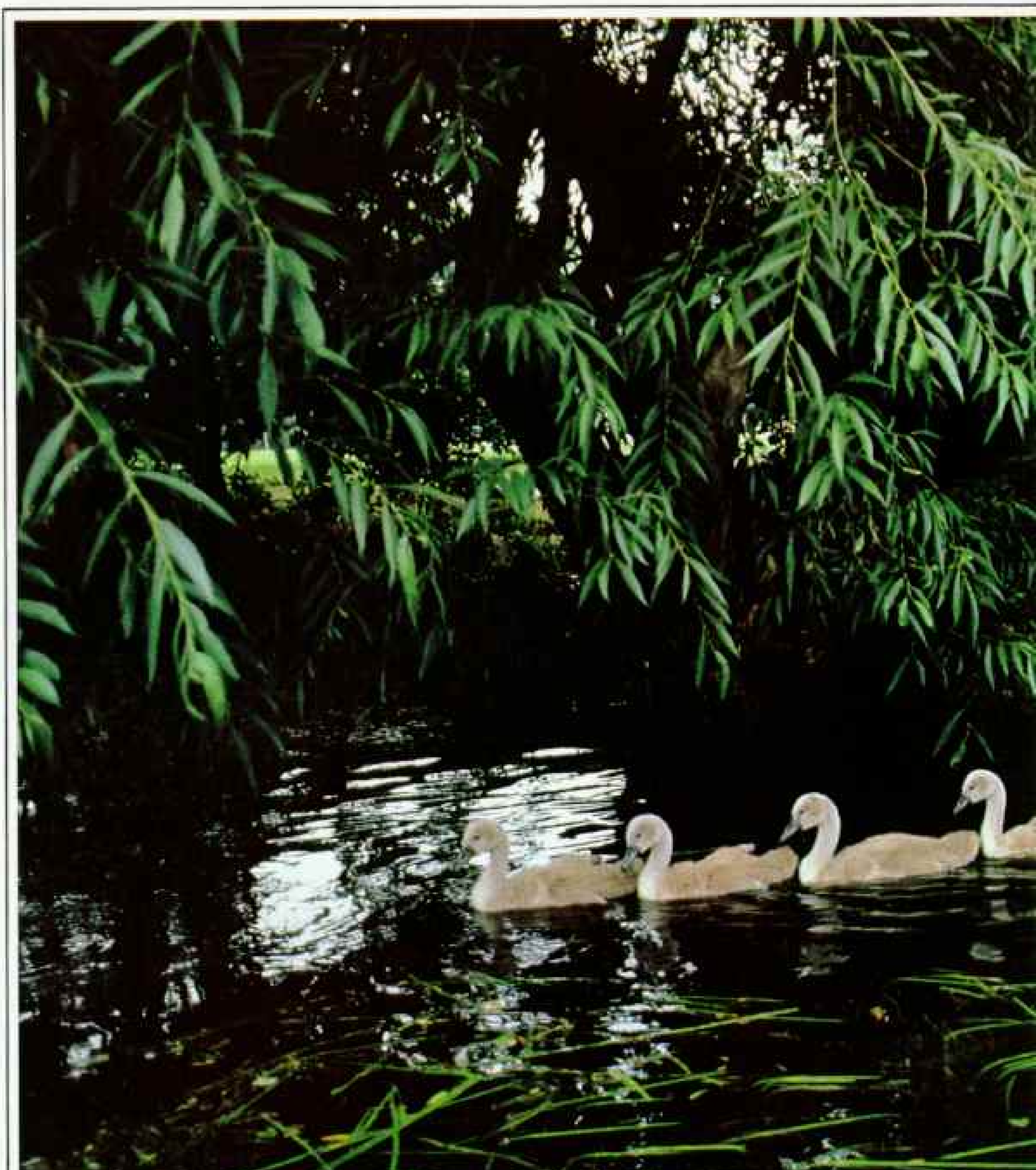
By ETHEL A. STARBIRD
NATIONAL GEOGRAPHIC SENIOR WRITER

Noble River

Photographs by O. LOUIS MAZZATENTA

SENIOR ASSISTANT EDITOR

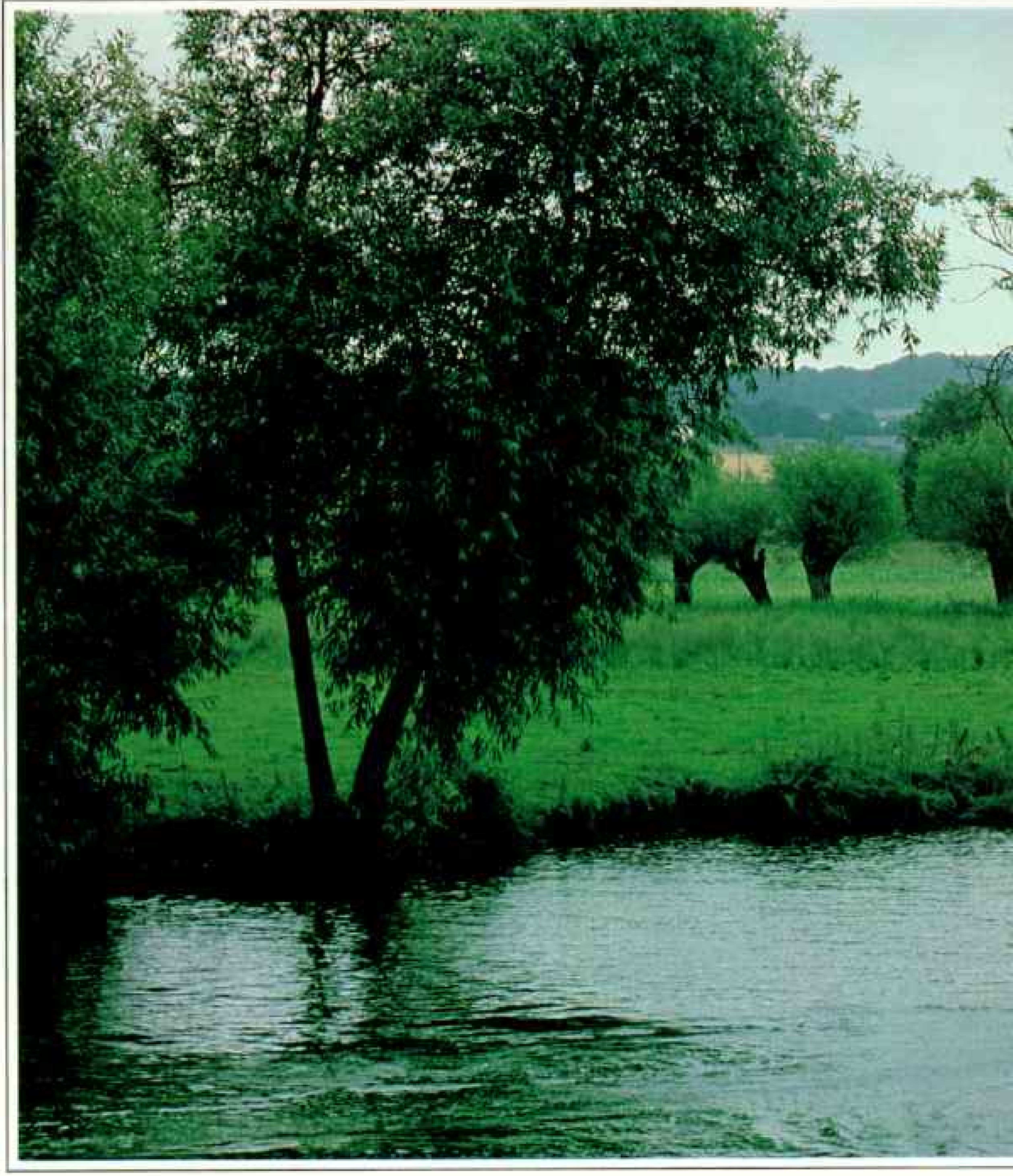
***With nostalgia ahead** and cares astern, a foursome goes punting during a lull in the Henley Royal Regatta. Genteel but never idle, invigorated by a cleanup, the historic River Thames runs through the soul of England.*



Alice was beginning to get very tired of sitting by her sister on the bank, and of having nothing to do. . . .

Alice's Adventures in Wonderland
LEWIS CARROLL (CHARLES DODGSON)

Taking a leaf from the 19th-century classic, a summer idyll unfolds at Oxford on a Thames tributary. Alice Liddell, daughter of an Oxford dean and friend of the author-artist, inspired the character depicted in the original manuscript (**right**).



The reaches down to Pangbourne woo one for a sunny sail or for a moonlight row, and the country round about is full of beauty.

Three Men in a Boat
JEROME K. JEROME

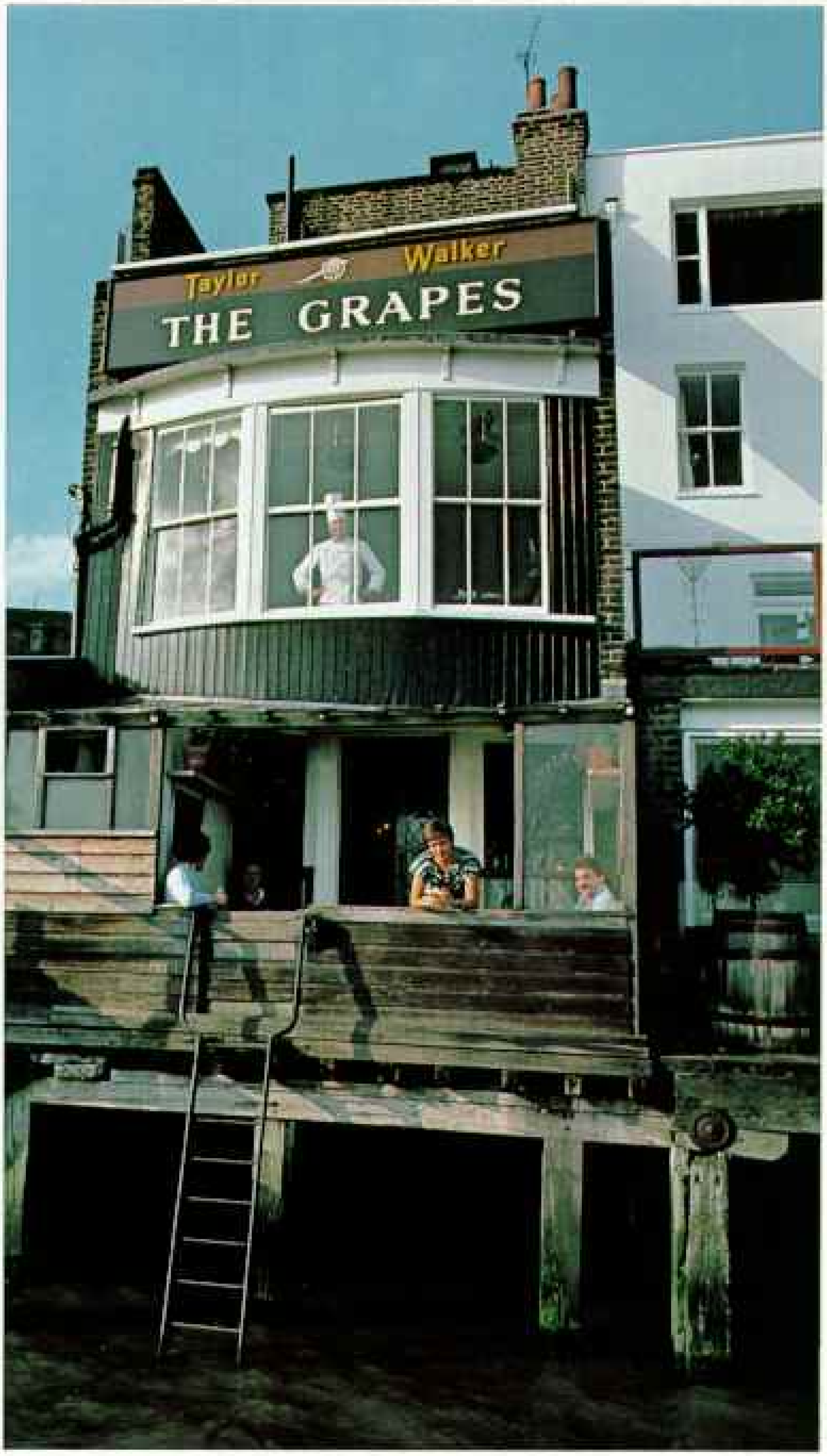
***Narrative flows** easily on the upper Thames, where a trio of chums from Cambridge University follow Jerome's classic 1889 voyage of mishaps. Lacking only a stand-in for Montmorency, the novel's capricious fox terrier, the students rowed about 180 miles round trip from Hampton Court to a landing near Ewelme, Jerome's grave site.*

Winding 146 miles, the freshwater Thames retains an unsullied innocence that has long attracted the young at heart. Also near Pangbourne scurried the creatures of Kenneth Grahame's Wind in the Willows. *At Teddington the Thames feels the tide though still 90 miles from the sea. The river has inspired authors from Wordsworth to W. H. Auden, canvases by Canaletto, and the* Water Music *of Handel.*

London's river saunters past the haunts of Charles Dickens. A pub called The Grapes (**above right**) claims to be the original Six Jolly Fellowship Porters, "a bar to soften the human breast" in Our Mutual Friend.

St. Saviour's Dock (**above**) was Folly Ditch, where the murderer Sikes met his end in Oliver Twist.

Architect Nicholas Lacey surveys abandoned warehouses, blighted like so many others after jumbo



container vessels moved shipping downriver. Lacey would "convert loading bays to balconies, leave old cranes where they are, make the creek a marina." He lives nearby in a renovated 19th-century grain warehouse.

A crazy wooden verandah impending over the water. . . .

Our Mutual Friend
CHARLES DICKENS

The barges drift
With the turning tide
Red sails / Wide
To leeward, swing on the heavy spar.

The Waste Land
T. S. ELIOT

***For old times'** sake a flotilla of sailing barges and smaller smacks lumbers through a race on the lower Thames. As late as 1900, barges did yeoman duty when some 2,000 hauled bricks, hay, coke, oysters, and other cargo along the coasts and across to the Continent. But gradually they bowed to swifter transport, and today only about 50 survive, many elegantly restored for parties.*

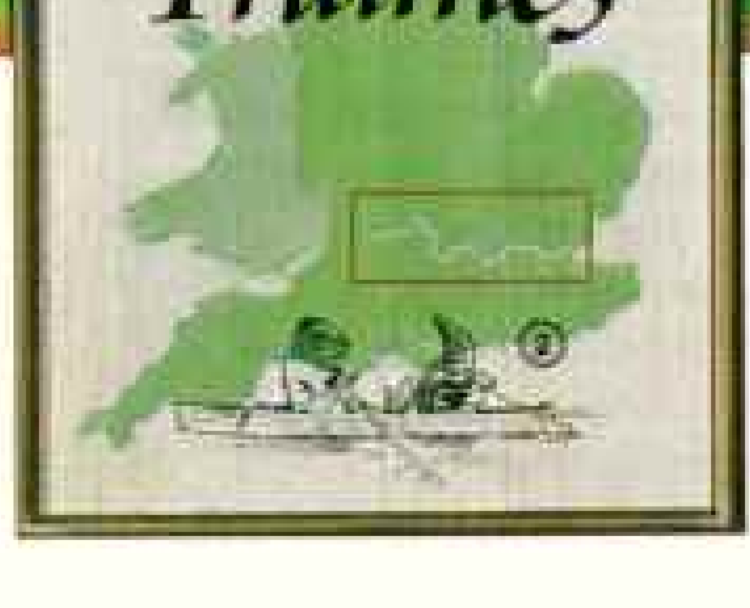
Nearing the North Sea, the Thames widens to more than five miles, bearing an effluent vastly cleaner than during the sailing barges' heyday, when London's exploding population discharged its waste directly into the river, spawning cholera epidemics. As recently as 1950, the Thames was considered dead. Yet, remarkably, after an intense antipollution campaign, it is now rated as the world's cleanest urban estuary.

OLD FATHER THAMES—his head pillowed in the Cotswold Hills, shins soaking in the North Sea—meanders a mere 236 miles across southern England. Yet few world-class rivers anywhere have etched a more enduring impression on as many millions for as many years.

Much of the biography of Britain was written in blood along its banks. A global trade of unprecedented proportions was long transported on its tides. Here monarchs ruled and the poets sang their sweetest.

Writers Defoe, Masefield, Wordsworth, Spenser, Kipling, Johnson, and Pepys all were gifted devotees of this "most loved of all the ocean's sons." So, too, were painters Constable, Turner, and Whistler, who captured its moods on canvas.

Down the river's serpentine roadstead sailed the ships that once made Britain the major maritime and merchant nation on earth. And on its foreshores rose the lasting glory that is London.



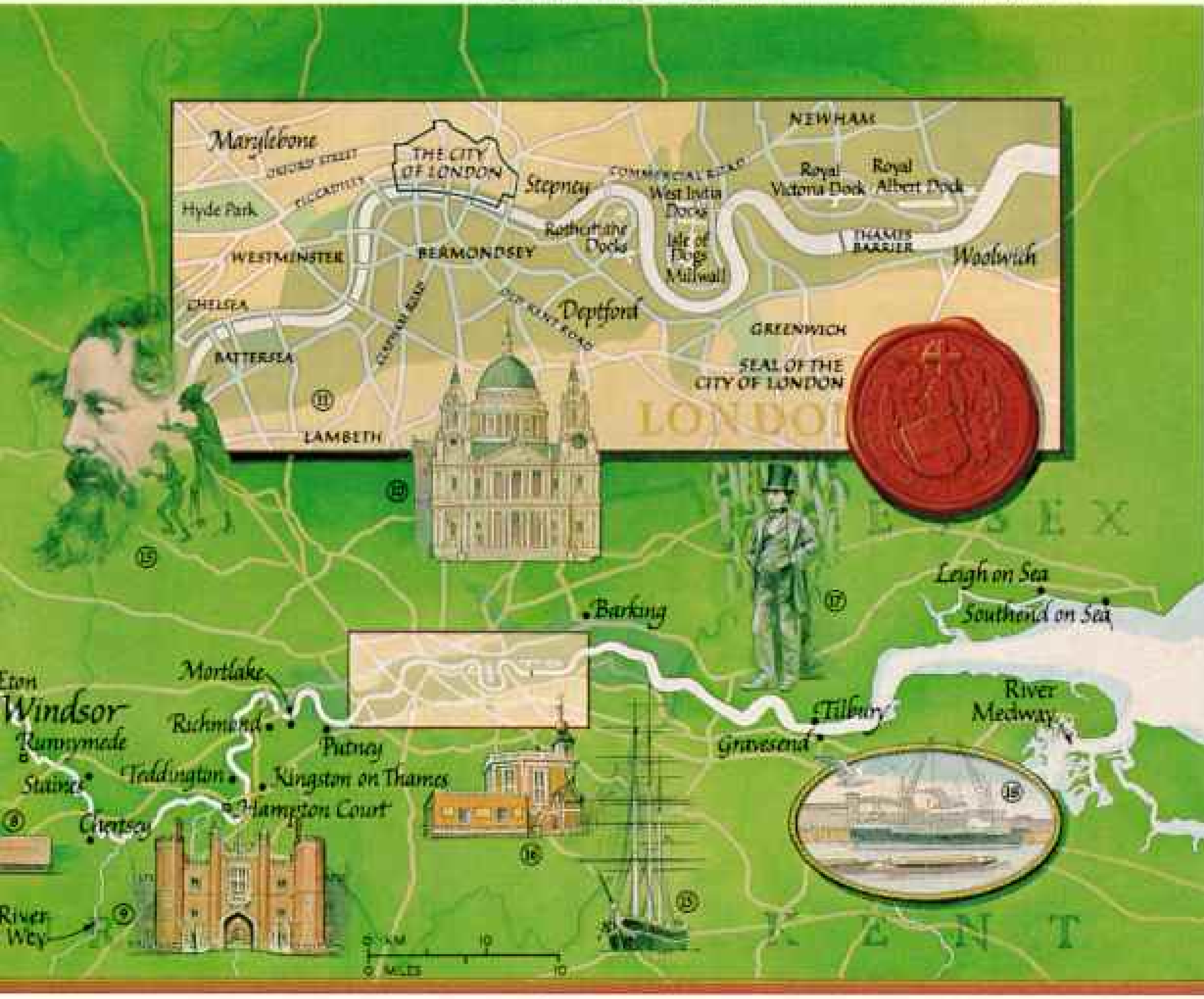
FERTILE WATERS have inspired works as timeless as Alice's Adventures in Wonderland *(1) and* The Wind in the Willows *(2). St. Sampson's Church (3) commands Cricklade and holds artifacts dating from the tenth century, while Halfpenny Bridge in Lechlade (4) recalls gentler times and tolls. A statue of Old Father Thames graces St. John's Lock and Bridge (5). Oxford's Radcliffe Camera (6), completed in 1749, is now part of the Bodleian Library. Henley on Thames (7) features a fashionable regatta.*

Birthplace of this history-haunted river remains a matter of dispute. Officialdom says Thames Head, where no running water, in fact hardly any water at all, has been seen in years. Others place its origin at Seven Springs (higher even than Thames Head), whose dribbling output spawns the River Churn, a Thames tributary.

Either way, the first depth reliable enough to carry a canoe in most seasons starts at Cricklade, where I, too, began my mid-March rambles downstream. Lazing along beneath sparse sunshine, I paddled for miles through a countryside little changed in a thousand years. Church towers pinpointed rare patches of civilization; cows, crows, and coots were my only companions. In all, a placid panorama that conjures up images of England in its infancy.

At Newbridge, marked by two inviting inns, the river begins winding between townless water meadows to reach Oxford, home—since the 12th century—of Britain's oldest university.

PAINTING BY WILLIAM H. BOND, COMPILED BY GRAHAM J. TRUSCOTT, BOTH NATIONAL GEOGRAPHIC STAFF



*Runnymede (**8**), including an acre given to the United States in honor of John F. Kennedy, saw King John accept the Magna Carta. Hampton Court (**9**) was expanded by Sir Christopher Wren, who also rebuilt St. Paul's Cathedral (**10**) after the Great Fire of 1666.*

*The river's flood stage (**11**) illustrates London's need for the Thames Barrier. London's Globe Theatre gave Shakespeare (**12**) a stage, just as its waterfront stirred Charles Dickens (**13**). Royal barges included Queen Mary's shallop (**14**), built in 1689; the 19th-century Cutty Sark (**15**) evokes the golden age of clipper ships. Greenwich time was launched at the Old Royal Observatory (**16**), which stands at 0° longitude. An enormous steamship engineered by I. K. Brunel (**17**) sailed from London's docks, now eclipsed by Tilbury's (**18**).*

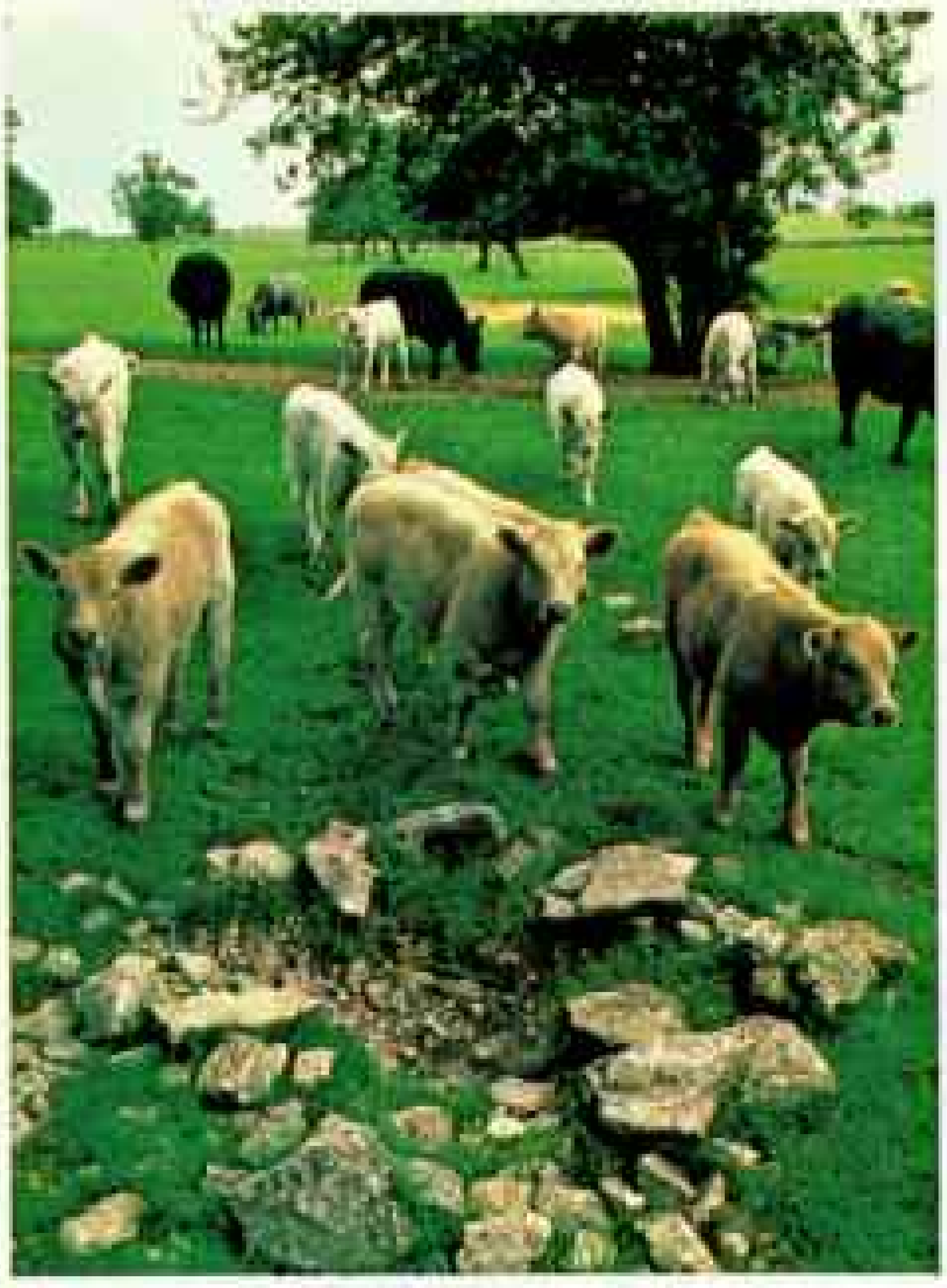
Holidays had almost emptied its 35 colleges; ten of them were thriving before Columbus's time. Priestlike in their black robes, academicians bicycled about, looking like so many levitated ghosts of medieval days. Traditions cling like lichens to the university, adding to its musty charm. Carefully controlled access to its cloistered quadrangles magnifies the mystique. Amid splendid Gothic architecture the famous of tomorrow, as of yesterday, learn how to become that way. The university's Somerville College has the distinction of having educated two of the world's three women prime ministers—Indira Gandhi of India and Margaret Thatcher of Great Britain.

In 1913 a native son named William Morris gave up bicycle repair for horseless carriages. His legacy lives on as the sprawling BL (British Leyland), which endows Oxford with its present split personality: half gown town, half motor city.

Chartering a river cruiser below Folly Bridge, I rode the rain-swollen current between banks well sprinkled with the most patient of all people—the Thames fishermen. For sheer numbers and inertia, no one else comes close. Rain, shine, or under skies usually tattletale gray, they stare the day away, eyes fixed on float or pole tip. For two hours I watched a dozen diehards being drenched by a downpour near Abingdon. But for an occasional flip of a can top or break to rebait, they might have been frozen in amber.

The best they can hope to hook are such coarse fish as roach, chub, carp, or bream, which they usually return to the river. As an extra handicap, anyone wishing to fish private stretches must pay a fee to the owner or a fine to the magistrate.

Match angler Bill Biggs of Wallingford usually baits his hook with bread or worms. "But maggots are best for tournaments. Just set out a piece of rotting meat and wait for a fly to lay eggs on it. Once the maggots hatch and fatten up, they take to wandering. You got to keep 'em cool, like in the fridge." Mrs. Biggs withheld her opinion of this arrangement.



You can wait *till the cows come home for water to spring from usually dry Thames Head, the river's official but disputed source* ***(above)****. Downstream, Cricklade Cricket Club members punt to a Sunday match, escorted by their loyal mascot, Toby.*

Bill thinks the Thames is deteriorating as an anglers' river. "Too many boats, too rapid a runoff; they tear away weeds fish need to feed and breed."

Caretakers of the upper river try their best to control its flow of fresh water; more than 1,400 million gallons on an average day pour into the tidal Thames at Teddington. They're equally concerned about its purity, since it supplies 75 percent of the needs of 12 million inhabitants of the Thames basin. Five percent of what gushes from London taps may have had previous users.

The upper two-thirds of the Thames became a major thoroughfare about the time man first settled beside its willow-shaded waters. But as obstructions multiplied and railroads emerged as prime movers, cargo barges all but retired from the upper river; recreational craft run it today.

Freedom of navigation was first challenged when shore owners began to impound the flow by building weirs to trap fish and turn mill wheels. As a sideline, some bankside bandits closed their weirs to create shallows, then charged stranded boaters

Meandering lazily, *the upper river invites a cruiser upstream between Oxford and Lechlade (**left**). Sweeping bends disguise the fact that the freshwater Thames has been straitjacketed with 44 weir systems and accompanying locks. Weir building to turn a mill or trap fish had become so prevalent by 1215 that one clause of the Magna Carta prohibited the practice—to little avail. Today's weirs maintain a steady level, although some 20,000 boats make formidable queues on busy weekends as they await passage through locks. At Whitchurch Lock, Fred Maggs (**below**) sells homegrown spinach and rhubarb to passing mariners. As lockkeeper, he's seen plenty of incompleat yachtsmen. "A poodle fell in the lock, his owner dived to the rescue, and I had to fish 'em both out," he told the author.*

*Tradition is serious business at Swinford Bridge, one of only two toll bridges remaining over the Thames. There Philip Bateman (**above**) collects twopence from motorists. A public outcry has accompanied the bridge owner's attempts to raise the toll to tenpence.*

***Town and gown** share the embrace of the Rivers Thames and Cherwell, which loop around Oxford (**above**). The university, oldest in the United Kingdom, began in the 12th century and has grown to 35 colleges. In 1913 William Morris started making cars in Oxford; his Morris Garage, which built the famed MG, has since been absorbed by BL (British Leyland).*

Since 1815, Oxford rowers have challenged each other on the Thames with a racing style designed to eliminate competition by bumping the boat ahead. During Eights Week final competition last year, Oriel College remained Head of the River. After months of training and rigid discipline, the crew lets off steam by destroying an old shell in a bacchanalia called the Bump Supper.

outrageous fees to set them afloat again.

Today's 44 weir systems, all publicly owned, can for the most part maintain a critical water level. Otherwise, with an average drop of only 1.5 feet per mile, its waters would spill all over the place at times, barely wet an ankle at others.

Strict regulation usually assures enough depth to float the average cruiser as far upstream as Lechlade. But waiting in long queues to enter locks around the weirs can consume much of a summer holiday.

With some 20,000 craft barricading the banks and milling around on the upper Thames, the lockkeeper's lot is not always an easy one. Ask Fred Maggs. In a sylvan setting once stirred only by oar, paddle, and punt pole, he passes some 400 powerboats a summer weekend through the lock he tends at Whitchurch.

IAN YEOMANS

Many of the craft he handles are operated by inexperienced skippers who come in here broadside, wrong end to, and belly up to the bank. Lockkeepers learn early to keep their cool.

"One of those ridiculous days, this bloke wraps a rope around his foot, and I had to unravel him. Another ran into the barrier and broke all the crockery. An angry old gal jumped ashore and asked the way to the nearest rail station; she'd never known till her husband took the helm she'd married a closet Captain Bligh."

Judging from peak traffic days along this otherwise tranquil Thames, majority opinion seems well expressed in Kenneth Grahame's *Wind in the Willows*, penned near Pangbourne in 1907: "There is *nothing*—absolutely nothing—half so much worth doing as simply messing about in boats."

So spoke Water Rat, who, with Mole and Badger, roamed estate country west of Reading and Caversham. And author John Galsworthy was so taken with Mapledurham House that in 1922 he made it the fictional home of the Forsytes of *Saga* fame.

OBVIOUSLY, there's something about this gentle countryside with its drowsy, dreamlike quality that brings out the whimsy in writers. At Oxford a shy university don named Charles Dodgson amused three youngsters with make-believe while rowing them on the river. His tales later found fame as *Alice's Adventures in Wonderland*.

Some of today's better known upper Thames-siders march to a higher decibel drum. Led Zeppelin's lead guitarist lived at Pangbourne; The Who was based at Goring,

Old school tie *lives on in the Oxford College barge* (**above**), *restored by the Swan Hotel. The barge holds a wedding reception for Robert and Morag Trives, facing camera at left. To remain neutral, the hotel painted the exterior both Oxford's dark blue and Cambridge's light blue. Once clubhouses for rowers, such barges are now decaying. A preservation fund helps refurbish four, including the Corpus Christi barge* (**left**), *where students help with a job that may cost $30,000.*

home of lead man Peter Townshend.

On my spring run down the stretch above Reading, floodwaters were "going like clappers" over wide-open weirs. Frozen raindrops clung to bare branches like premature pussy willows, and even rooks remained nestbound awaiting better weather.

With all its bluster, this season appeals to me more for river cruising than crowded summer. Relaxed lockkeepers at their jolly best called ahead to make sure the next gates were open, and leafless trees permitted longer views of coming attractions.

Lightly inhabited reaches, with their infrequent vintage towns and villages, diminished as I approached congested Reading. The sometimes lionized, sometimes despised Oscar Wilde commemorated his prison confinement here by penning "The Ballad of Reading Gaol."

DESPITE the fellowship and unhampered passage that come so easily on the wintry Thames, summer is the time for some of the river's main events. Like the Henley Royal Regatta, the grand prix of race rowing.

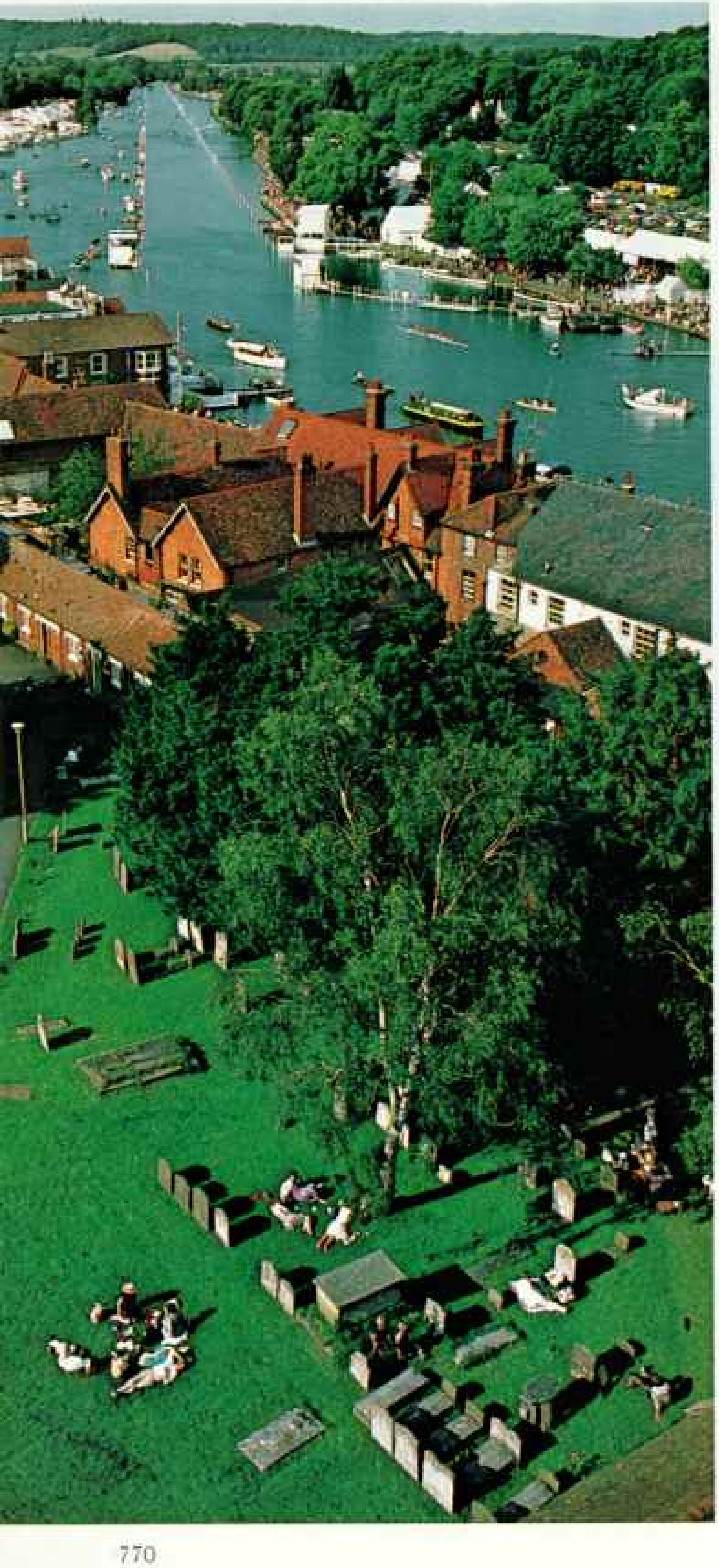
Here, for four days in July, I watched top oarsmen from around the world bend their backs to win a coveted Henley trophy. But the milling crowds around me seemed to have other matters on their minds.

Temporary bars drew more attention than the boats. And beyond the booms that bound the 1.3-mile course—a rare straight reach in the upper Thames—an impromptu parade of lovingly preserved punts, canoes, skiffs, steam launches, and slipper-stern runabouts recalled those gracious yesterdays when the freshwater river was more of a country lane, less of a motorway.

Soon after the Henley stands go back into storage, a more intimate pageant passes by in search of newborn swans.

These elegant, arrogant creatures have been mooching meals on this swanny river for at least the 800 years that they have been designated as royal birds. By decree, the crown owns half the population between Sunbury and Pangbourne; the other half is divided between two London guilds: the Vintners and the Dyers.

To establish ownership of each year's hatch, representatives of all three of the



***To be seen** is the goal of most at the Henley Royal Regatta—an annual tradition since 1839—where picnickers bring life to a sunny cemetery near the grueling 1.3-mile course (**left**). Rain or shine, every punt needs a parasol (**right**). But for the entrants, who represented ten nations last year, it's determination that counts. English onlookers dodge*

the scull of an American contestant in a women's singles event ***(below)****. Unlike most regattas, where each race pits several crews against one another, the Henley extravaganza runs only two boats per heat. Thus as many as 100 races, timed a tense five minutes apart, are held on the first of the contest's four days.*

groups boat this stretch in late July for an annual rite known locally as swan-upping.

Following their six-skiff flotilla from Marlow up to Henley, I watched the swan-uppers carefully corral and mark some 35 cygnets according to parentage.

Zoologist Dr. Mike Birkhead of Oxford University was more concerned with numbers than ownership. "Over the past 30 years, the swan census along here has declined drastically—down from a thousand in the 1950s to about 200 last year.

"Dead ones all come to me to autopsy. The greatest killer is lead poisoning, caused by ingested shot that fishermen leave around. Unless this type of line weight is outlawed—and soon—we may lose the rest."

John Turk of Cookham, the Queen's veteran swan keeper, blames some of the loss on boating. "Noisy, powerful cruisers leave the swans few quiet nesting areas. Fifty years ago, in the days of hand propulsion, this wouldn't have happened. Everyone knew how to behave and did. No hollering, screaming and, blessedly, no transistors."

In Tudor times music making added to

Swan song? *New concern for the mute swan mingles with an old ritual called swan-upping. It divides each year's crop of cygnets among their three traditional owners—the crown, the Worshipful Company of Dyers, and the Worshipful Company of Vintners. The latter guild* **(left)** *toasts swans marked on board and returned to the water. A private campaign* **(above)** *sounds the alarm. With a healthier Thames have come more fish, more fishermen, and more lead weights on the bottom. Swans ingest the weights along with bits of gravel to aid digestion. The result: About 3,000 swans die of lead poisoning each year, including the birds whose gizzards yielded these sinkers* **(above)**. *Leader trailing from a bill* **(below)** *underscores the species' vulnerability.*

the pomp and pleasure of royal revels on the river as monarchs commuted in ornate barges and shallops to their Thames-side palaces at Greenwich, London, Richmond, Kew, Hampton Court, and Windsor.

Only Windsor Castle survives on the upper Thames as a royal residence.* Even before I turned the last bend above it, I could see the magnificent old crenellated walls floating above the trees like some storybook confection. Small wonder this has been a

*Anthony Holden wrote of Windsor Castle in NATIONAL GEOGRAPHIC, November 1980.

Kings, queens, and paramours *held affairs of state in Hampton Court Palace, flanked by a traditional Thames narrow boat. Thomas Cardinal Wolsey built the*

palace and in 1525 presented it to Henry VIII in a vain attempt to recoup royal favor. Later, Sir Christopher Wren expanded it, envisioning an English Versailles.

favorite retreat of the House of Windsor, the name the royal family adopted in 1917.

Soon after the castle's spacious Home Park drops astern, open fields along the south bank signal arrival at Runnymede. It was here that rebellious barons forced King John to temper royal prerogatives by acceding to the Magna Carta in 1215. One of its terms clearly prohibited *kidelli*, or weirs, on the River Thames. To which no one for centuries paid the slightest attention.

Now the estately Thames yields to the bungaloid Thames, stitched along its edges with modest suburban homes. But elegance takes one last bow at Hampton Court. Here in the early 1500s Thomas Cardinal Wolsey, who had amassed England's largest fortune by exploiting his privileges as both priest and politician, erected a mansion fit for a king. And so it became in 1525, when the cardinal tried to bolster his waning popularity at court by presenting the property to Henry VIII. (The maneuver failed.)

The palace, enhanced by Sir Christopher Wren's alterations to the original design, retains its grandeur. And affable Gen. Sir Rodney Moore as the Queen's representative in residence. He and Lady Moore have nearly 2,000 Thames-side acres of woods, parks, lawns, and gardens on which to roam and run their dogs.

"Wolsey was a bit of a health nut," he said. "He chose this spot for its safe distance from plague-prone London, then had his water piped under the Thames from a spring three miles away. He also installed more than 50 jakes, or latrines, to serve the 280 guest rooms, a luxury even royalty lacked."

The Moores waved me off as I set forth afoot along the towpath for the tidal Thames, birthplace of England and empire.

THE RIVER was longer in labor than either. Tributary of the Rhine for unknown millennia, it finally parted company from continental Europe about

GORDON W. GAHAN

Testing the waters, *young Atlantic salmon, called parr, are released in 1980* **(above)**. *Will the fish tolerate the Thames' once foul estuary, enter the North Sea, and return? Two years later, fisheries scientist Peter Gough* **(right)** *holds an 11-pound salmon from the class of 1979, captured during sampling with electrified rods that stun the fish for netting* **(left)**. *The salmon comeback after 150 years testifies to a river reborn.*

8,000 years ago. This evolved after melting ice and sinking land flooded the valley that is now the North Sea to sever Britain from the Continent.

From across the English Channel, Romans, Saxons, and Danes (in that order) sought to renew the connection through conquest. The Thames became a handy highway upon which they drove their ambitions—with varying success—across much of southern England. In 1066 the Normans came over from France and managed to stay. After that the English, pretty much of a mixed stock by then, were kept reasonably busy fighting each other.

Among pre-Norman invaders, the enterprising Romans made perhaps the greatest mark on the countryside. Julius Caesar crossed the Thames in 54 B.C. to subjugate the Britons. But it was the occupation troops of Claudius a century later who laid out road routes still in use, founding—near the farthest downstream fordable point on the river—the future cosmopolitan and capital city they called Londinium.

No one knows where or when the first London bridge was built, but there was only one local crossing until the 18th century. An ancient pier base recently unearthed near old Billingsgate fish market dates from Roman times and may well be an original (following page). Today 28 spans lace the tideway between Teddington and the Tower of London.

With so much traffic moving on and over the Thames, its bottom silt became a remarkable repository of antiquities. Mud flats and shore sites once awash still yield old litter from which archaeologists continue to piece together England's past.

Jimmy Ryan excavates on his own. Booted in Wellingtons and armed with a metal detector, he's one of dozens of mud larks who venture over the embankments each weekend in search of buried treasure.

"Me grandparents both sides was Irish

Spanning the past: *Massive timbers (**below;** scale shows 20 cm) unearthed near today's London Bridge date from before A.D. 70 and once supported a Roman bridge. The founders of Londinium and their successors left a riverbed strewn with artifacts to tantalize archaeologists and treasure-hunting mud larks. One collector displays long-buried musket balls, buttons, knife blades, and pipes, most dating from the 16th and 17th centuries. Low tide finds a group cratering the foreshore (**facing page**). Digging requires a legal permit, with restrictions that include an excavation depth of six inches.*

JON BAILEY, MUSEUM OF LONDON

tinkers; got me love of gold and silver from 'em natural. Somethin' for nothin' is in me blood. Trick is to know what the beeps mean; beginners spend all their time muckin' up bottle caps. This 'ere's a Victorian paste jar I just picked up. Top's solid silver. Last week I found me a Roman coin."

From the number of these reportedly retrieved from the riverbed, it would seem that the legions of Caesar and Claudius were careless with their loose change.

By the year 410, when the centurions went home for good, the native population—descended for the most part from less sophisticated Celts and Belgae—was pretty much Romanized, and London had become one of the largest cities north of the Alps.

Other invaders came and went. Despite their sacks and sieges—and rather regular plagues—London continued to grow, becoming by 1850 the largest city in the world. And so it would remain until preempted by New York City in 1910.

B*UT THE PACE* of life along London's traditional main street—the River Thames—has slowed in recent years to a near standstill.

As master of London's ornate old Tower Bridge, Lt. Comdr. Anthony Rabbit (RN Retd.) commands a long and lofty view of the Thames in transition (page 780).

"Twenty years ago, we'd raise the bascules an average of eight times a day to accommodate an endless parade of oceangoing vessels patronizing our dock system. At capacity then, 20 cargo and passenger ships could berth in the Upper and Lower Pools downstream from London Bridge. We seldom draw up three times a week now."

Anthony's bridge on the bridge overlooks a more reassuring sight: a riverfront ornamented with such venerable symbols of England's durability as the sprawling Houses of Parliament, Westminster Abbey, the Tower of London, and a scattering of cozy pubs that were already dispensing beer and cheer when the *Mayflower* set sail.

Some decry the coming of the high rise, claiming the cityscape is beginning to "look like a badly tended asparagus bed" or a "clutter of concrete filing cabinets." But when it comes to altering the look of London the Thames traveler sees, no one is

All the river's a stage *for London after dark, with Tower Bridge* **(above)** *taking star billing. A 4.5-million-dollar renovation completed last year enclosed and restored two high walkways between the towers, long barred to the public. Thus another attraction will contribute to a popular tourist area that includes the Tower of London, where a ripe slice of life may include punk rockers* **(right)**. *Said one, referring to his life-style: "This is all that's left."*

Little is left of the "great street paved with water, filled with shipping" that poet John Masefield knew. During the bridge's first month of operation in 1894, it was opened some 600 times. Today Lt. Comdr. Anthony Rabbit (RN Retd.), master

of Tower Bridge, and his crew (**left**) *perform the task perhaps three times a week. The real action has gone 26 miles downriver, where Tilbury docks get the lion's share of United Kingdom shipping.*

What the Thames now supplies London with was once unthinkable and undrinkable—its water. The upper river pours an average of 1.4 billion gallons a day into the tidal Thames. After purification the water fills three-quarters of the needs of the Thames basin's 12 million people. Here in 1859 the first halting steps were taken to implement a sewer system—not because uncleanliness was next to godlessness, but because it was next to Parliament.

apt to outdo Christopher Wren, who spent much of his 91-year lifetime filling up the city, including many gaps left by the Great Fire of 1666, which destroyed more than half of it. Among his masterpieces still in place: Chelsea's Royal Hospital, St. Paul's Cathedral, and the Royal Naval College at Greenwich, where time begins its daily circuit of the world.

THE PASSING YEARS have taken their toll on some of London's less lovable landmarks. Derelict wharves and warehouses—those great gray ghosts of the city Charles Dickens knew and novelized—sag along the shoreline, as black and bedraggled as roosting buzzards in the rain.

The West India, Millwall, East India, and Royal Docks—huge enclosed ship basins where the aroma of spices and spirits, grain and lumber long scented the air—now stand empty awaiting new uses and users. Authorities hope to have the dock area's 2,000 acres of prime land and 450 acres of water fully re-utilized within the decade.

The first moves already have been made to convert abandoned riverfront warehousing to residential, office, and store space.

The tidal Thames has no intention of lapsing into ghosthood. Far too much is

"**When the tide's in,** you're part of the river," says Eily "Kit" Gayford, feeding a panhandler (**left**) off the Buccaneer, her houseboat moored near Battersea Bridge. Equally at home on terra firma, she heads ashore (**below**) to cheer a sick friend. Kit steered canalboats during World War II, wrote a book, lectured, came to London as a charwoman, then found peace on the Thames: "I'm absolutely dotty about the river."

happening here to fit the changing times. And too many people—now as in ages past—cherish a close bond with the river.

Like Eily "Kit" Gayford, a pensioner who still does a bit of charring because "it keeps a little jam on the table." Proud owner of a homey 40-foot houseboat moored at the Chelsea end of Battersea Bridge, she has a ringside seat on whatever moves Old Father Thames makes.

She can lie in bed, sip her tea, and enjoy an outdoor show always worth watching. Diving ducks and cormorants fishing, starlings doing aerobatics around the bridge at dusk. "If I ever have to pack it in for an old folk's home, it'd better be one on the river."

Cheyne Walk behind Kit's tie-up has attracted other Thames admirers. Hilaire Belloc, Oscar Wilde, George Eliot, and Henry James all lived in the neighborhood for a spell. So did Sir Thomas More, who often counseled Henry VIII on friendly bankside strolls. (The king repaid this kindness in 1535 by having his host beheaded for refusing to acknowledge the monarch as head of the church.)

And Thomas Carlyle, the "sage of Chelsea," resided a few blocks from More's place most of his life.

In "The River's Tale," Rudyard Kipling

gave Old Father Thames a mind of his own:

I walk my beat before London Town,
Five hours up and seven down.
Up I go till I end my run
At Tide-end-town, which is Teddington.
Down I come with the mud in my hands
And plaster it over the Maplin Sands.

Users of the lower Thames soon learn to mesh their movements with the river's. Watermen rely on its swift flow (as much as four knots) and its tidal changes (21 feet at London Bridge) for both extra speed and safety. And George Osborne gears his day's cockling to times he can pilot his 41-foot boat in and out of Leigh on Sea, where his family has been a fixture since 1669 (page 786).

"We been cocklin' 'ere for donkey's years, 1850 about. I started serious in 1927. It was dicey durin' the war, and mos' cocklers quit. 'Ard work it was back then, diggin' by 'and, doubled up like a 'airpin. Now we suck 'em up with power pumps."

Which is what we did for four hours off Southend on Sea, once a thriving beach resort. Its most enduring attraction—the longest pleasure pier on earth—still spider-legs across the flats for a mile and a third. The pier is now closed to the public, and its days may be numbered.

In late May 1940 cockle boats (called bawleys) like George's left Leigh and Southend far astern as they joined a ragtag fleet of small Thames craft on a mission of mercy that gave England one of its finest hours: the evacuation of Dunkirk.

When the operation ended on June 4, Thames skippers and their plucky nonmilitary armada—at least a third of Dunkirk's rescue force—had helped ferry some 338,000 survivors to safety.

LIKE GEORGE OSBORNE'S, Donald Pascoe's livelihood is linked to the Thames. I joined him aboard the 200-foot tanker he skippers—the *BP Rapid*—near the confluence of the Thames and the Medway.

Cruising cityward through a thinning curtain of fog, Don gave even distant objects a wide berth: "When you're hauling a quarter million gallons of petrol, you learn to keep a very thin upper lip."

A licensed Freeman of the Company of Watermen and Lightermen of the River Thames, Don belongs to a time-honored trade whose roots run deep and strong among bankside families. He, like his antecedents, had to serve a seven-year apprenticeship learning to operate every type of workboat on the waterway.

There were 4,750 registered watermen on the river 25 years ago; about 500 today. "Only a boy with a close relative in the business can apprentice today, and prospects for steady work aren't promising."

As his son Guy well knows. "I've been licensed five years and I'm still a floater. It's like waiting to fill a dead man's shoes."

A motley fleet of modest-size workboats still rides the tides as far upriver as Richmond: tugs, lighters, barges, scows, dredges, and hoppers. But large seagoing cargo carriers now ply to Tilbury, 26 miles downstream from the City of London. There huge containerized and bulk ships load and unload without employing tug, lighter, or many men. Two decades ago the Port of London Authority employed 31,000 dockhands, today only 3,500.

Gravesend, just across the way, proved the final port of call in 1617 for a newly minted Christian from colonial Virginia. On her way home from a triumphal London tour, the American Indian "Princess" Pocahontas, who saved Capt. John Smith and married English settler John Rolfe, died and was buried here—in the chancel of St. George's Church, the church register says.

At Woolwich, 17 miles upriver from Gravesend, Don eased the *BP Rapid* between stainless-steel-hooded towers of the Thames Barrier, monument to man's determination to protect London from an enemy as formidable as many it has known.

Today's threat: a surge tide that occurs when low atmospheric pressures and gale winds whip up abnormally high seas in the North Sea. Piling atop already excessive seasonal tides, this huge hump of water follows the path of least resistance up the River Thames. Experts estimate the loss in hundreds of lives and billions of dollars if one should hit London with full force.

It almost happened in 1953, but the surge rolled over downriver seawalls, diverting most of the water onto vulnerable lowlands, where 300 people drowned.

Engineer Charles Draper, a naval reservist on rescue duty there, saw what can happen, and thought about an answer. "All anyone had ever done was raise the embankments with every scare," he said. "Unless something different was done, the Thames would become a walled ditch that no one could see. The city and all of southeast England are still sinking and ocean levels are rising, increasing the tide levels more than two feet a century.

"We needed something that wouldn't obstruct navigation and wouldn't overwhelm the landscape." From his concept and efforts of other experts emerged the massive, movable Thames Barrier, seven years and 700 million dollars in the making. "Our floodgates, unlike the guillotine type, lie flush with the riverbed and revolve upward to a damlike position when needed."

FULLY AS IMPRESSIVE an accomplishment: bringing the river back to life. As early as 1800 the lower Thames was already dying, strangling on London's ever growing effluent. Pollution bred killer diseases: In the years 1849 and 1854 cholera claimed a total of 25,000 victims in the immediate area.

In 1858—Year of the Great Stink—Parliament chambers were curtained with draperies dipped in disinfectant to protect parliamentary noses from the noisome river. Burgeoning industry and newfangled flush toilets added their wastes to these already troubled waters.

By 1861, when Queen Victoria's consort, Albert, died of typhoid, the first steps toward piping sewage out of London were under way. The effluent was to be discharged into the river at Crossness and Barking, names reflecting the reaction of those unfortunate enough to live there.

Until midway in this century the tidal Thames remained one of the worst polluted bodies of water in the world. Improvements started before World War II were heavily damaged by German bombs. When Queen Elizabeth II ascended the throne in 1952, only a few eels remained of the once rich fish life in London's river. Even barnacles had lost their grip.

When Old Father Thames hit the comeback trail, his recovery was miraculous, thanks to the strict standards of the Thames Water Authority and industry's cooperation in meeting its tough demands.

In the past 30 years pollution has been reduced 90 percent; water birds and marine creatures have reestablished themselves in gratifying numbers. Even undesirable refugees have reappeared: Shipworms are again chomping away at piers and pilings.

The Water Authority nets fish-life samples from intake lines at the West Thurrock Power Station. On the day of my visit, biologists collected 4,000 individuals of 20 species within four hours. In all, 104 species have been recorded since censusing began with near-zero populations 15 years ago.

By far the most welcome returnee is the salmon, once plentiful but absent for 150 years (pages 776-7). To Mike Bulleid, regional fisheries officer, the arrival and registering last summer of 116 healthy specimens (weighing as much as 13 pounds) at the weir pool below Molesey Lock fully justifies the expense of restarting the spawning cycle—more than $200,000 to date.

"We've planted 184,000 young in nursery streams since 1979. The first lot was due back in '82, and some made it. Salmon are extremely sensitive to pollution. That they survived the tidal stretches means the Thames cleanup is where it should be."

Improved water quality has also aided the lifesaving activities of Thames Division, Metropolitan Police, whose mission is to protect people and property along the river.

I sheltered from a shower one day in the division's unique floating station beside Waterloo Bridge, Sgt. Richard Chinnery in charge. "We get a lot of jumpers around here; it's easy to go over Waterloo." Of the 140 or so who end up in the river each year, whether accidentally or on purpose, the division manages to rescue about half. In the old days, river filth greatly shortened survival time.

Constable Frederick McKenzie has seen some strange sights wash past his post. "I'm at this window one day, and a face floats by not ten feet away. Framed by a bonnet, lookin' a bit like ol' Victoria herself, but not blinkin' an eye. Boated her at Waterloo Pier. Seventy if she was a day, and none the worse for wear. She'd tried to do herself in but didn't seem too put out she hadn't made it."

Yokes and baskets *unload cockles as they always have from a bawley boat at Leigh on Sea* (**above**). *In the galley* (**below**) *Stevie Lawrence, at left, serves a rib-sticking breakfast to his uncle, George Osborne. Their vessel, the Renown, is the successor to one manned by other Osbornes when the "little ships" evacuated Dunkirk. An injury kept George behind—only to learn that a brother and cousin died when the boat struck a mine.*

The Thames Division, 31 years older than its parent organization, the Metropolitan Police, descends from a private security force formed in 1798 to stop theft on the river. Then, an estimated 11,000, or one-third of those in river trades, were known thieves.

Among the division's pleasanter chores: patrolling the 4.2-mile course from Putney to Mortlake for the Boat Race, sort of an aquatic Ascot.

First run in 1829, the contest decides which university—Oxford or Cambridge—has the superior eight-oar crew. The appearance in 1981 of petite Susan Brown as the Oxford team's coxswain marked the first time a woman had ever participated in the race—one of the most notable innovations since oarsmen started gliding on sliding seats instead of slipping to and fro on fixed sheets of greased glass.

A timeless Thames tradition, race rowing has been growing here since the early watermen, transporting fares in wherries and skiffs across London's river, began competing with each other.

For all its many curves, the river now caters to some 280 rowing clubs and about 11,000 rowers.

Several of these in single sculls skimmed the river like water striders as I took my last intimate look at the River Thames. Fishermen still sat as statue-like as when I passed their way a month before.

A lone mud lark scuffed through low-tide silt, gulls wheeling and screaming in his wake. Calm dogs and Englishmen set a brisk cadence along the water's edge at Kew. Below Albert Bridge a bowler-hatted gentleman fed a mallard couple from his briefcase full of bread crumbs.

To these—and thousands more—the River Thames *is* England. Regardless of what deters its progress, it always gets to where it's going. * * *

BULWARK AGAINST DISASTER

The Thames Barrier

LIKE legionnaires challenging Neptune, steel-cowled piers linking movable gates take shape eight miles downstream from London at Woolwich (***above***). Now completed, this engineering colossus may forestall floods such as one recalled by an 1850 magazine engraving (***facing page***). Experts estimate that a similar inundation today could cost billions of dollars in property damage.

The barrier is specifically designed to protect London from the devastation of a surge tide. That phenomenon occurs when a low-pressure system drags a mound of water from the Atlantic into the North Sea and adds it to already high seasonal tides. The long-term danger is compounded by rising ocean levels and the sinking of southeast England, together

ILLUSTRATED LONDON NEWS

causing tide levels to rise at least two feet per century. Compared to a surge, the normal turn of the tide at Leigh on Sea (***above***), averaging about 15 feet, is negligible.

The last major surge hit in 1953. London itself was spared by the failure of seawalls downstream, where some 300 people died. A witness to that disaster, then Royal Marine Charles Draper (***right***) evolved a concept to protect London based on the simple gas cock, here held in his hand. The engineering firm Rendel Palmer & Tritton then designed the ingenious rising-sector barrier.

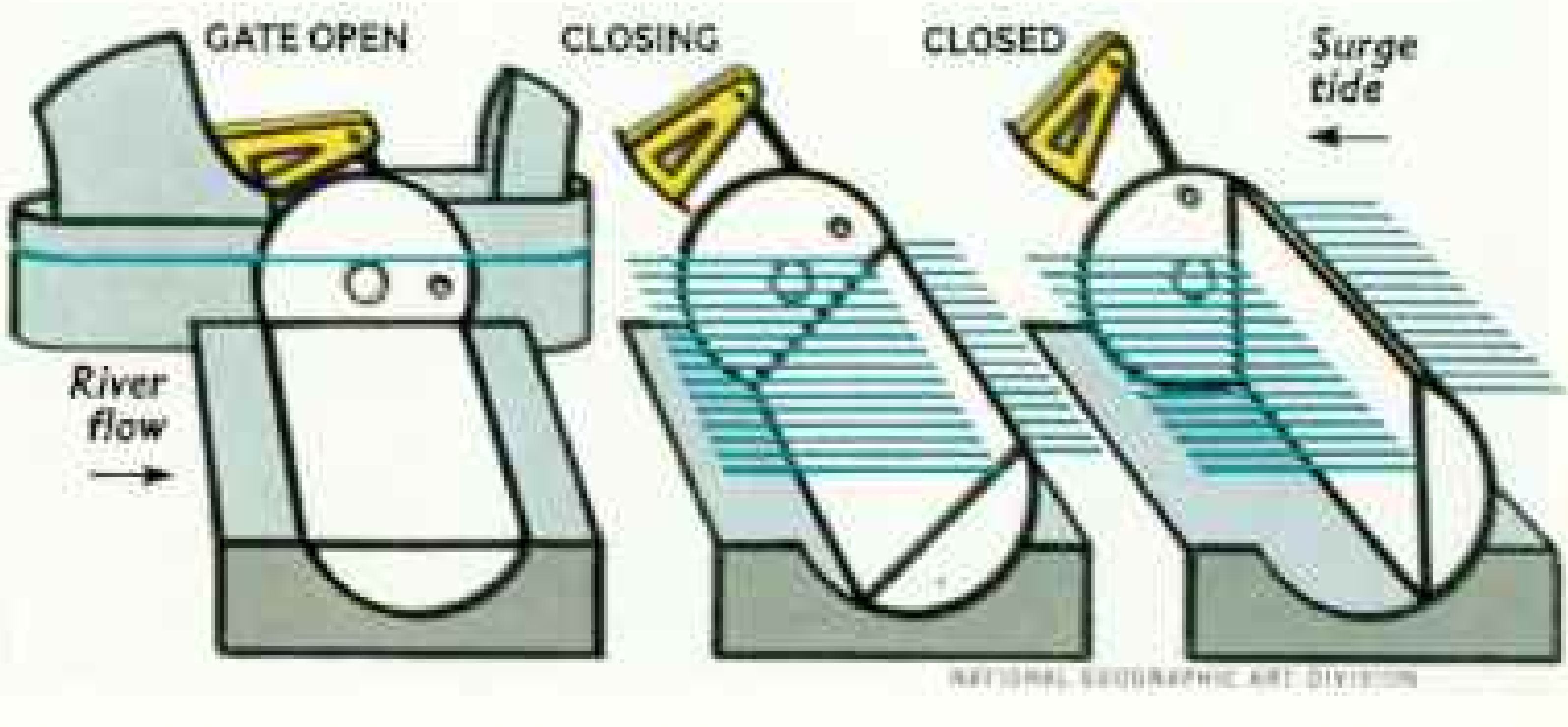
The barrier is composed of ten separate movable gates built side by side across the river and interspersed with concrete

GORDON W. GAHAN

piers filled with controls.

When not needed, the quarter-moon-shaped gates pivot to lie flat in the riverbed, allowing open channels between piers for river traffic. In a flood, the gates—each 60 feet high and built to withstand more than 9,000 tons of water—are lifted into place by massive rocker beams (***above*** and ***right***). In rising, they operate on the same principle as a gas cock, which shuts off flow by imposing a barrier.

The entire flood-control project has swallowed more than a billion dollars—700 million for the barrier alone. But with 1.4 million people and 45 square miles of real estate at risk, it may be money well spent on the day London needs to tame the Thames. □



NATIONAL GEOGRAPHIC ART DIVISION

GOOD TIMES AND BAD IN APPALACHIA

Wrestlin' for a Livin' With King Coal

By MICHAEL E. LONG
NATIONAL GEOGRAPHIC SENIOR STAFF

Photographs by MICHAEL O'BRIEN

WHEN ALFRED WOOTEN finishes the morning shift in a mine near Beckley, West Virginia, there are two things mainly on his mind. First a cigarette (***left***). Miners cannot smoke underground because of the possibility of explosion. Then a shower in the company bathhouse. Like most other miners, he cleans up with common kitchen detergent. "It gets the dirt better than soap," he says of the black specks that seem to insinuate themselves into the very pores of his skin.

After showering, Wooten puts his mining clothes into a wire basket fastened to a pulley chain, hoists the clothes 40 feet to the ceiling for quicker drying, and heads for home.

As a foreman employed by Eastern Associated Coal Corp., Wooten makes $36,000 a year. He has a $46,000 ranch house in nearby Crab Orchard and vacations once a year with his family in Georgia or Florida. He also owns three sedans and two pickup trucks. "I have a good life," he says. A flicker of worry crosses his face as he adds, "I'm one of the lucky ones."

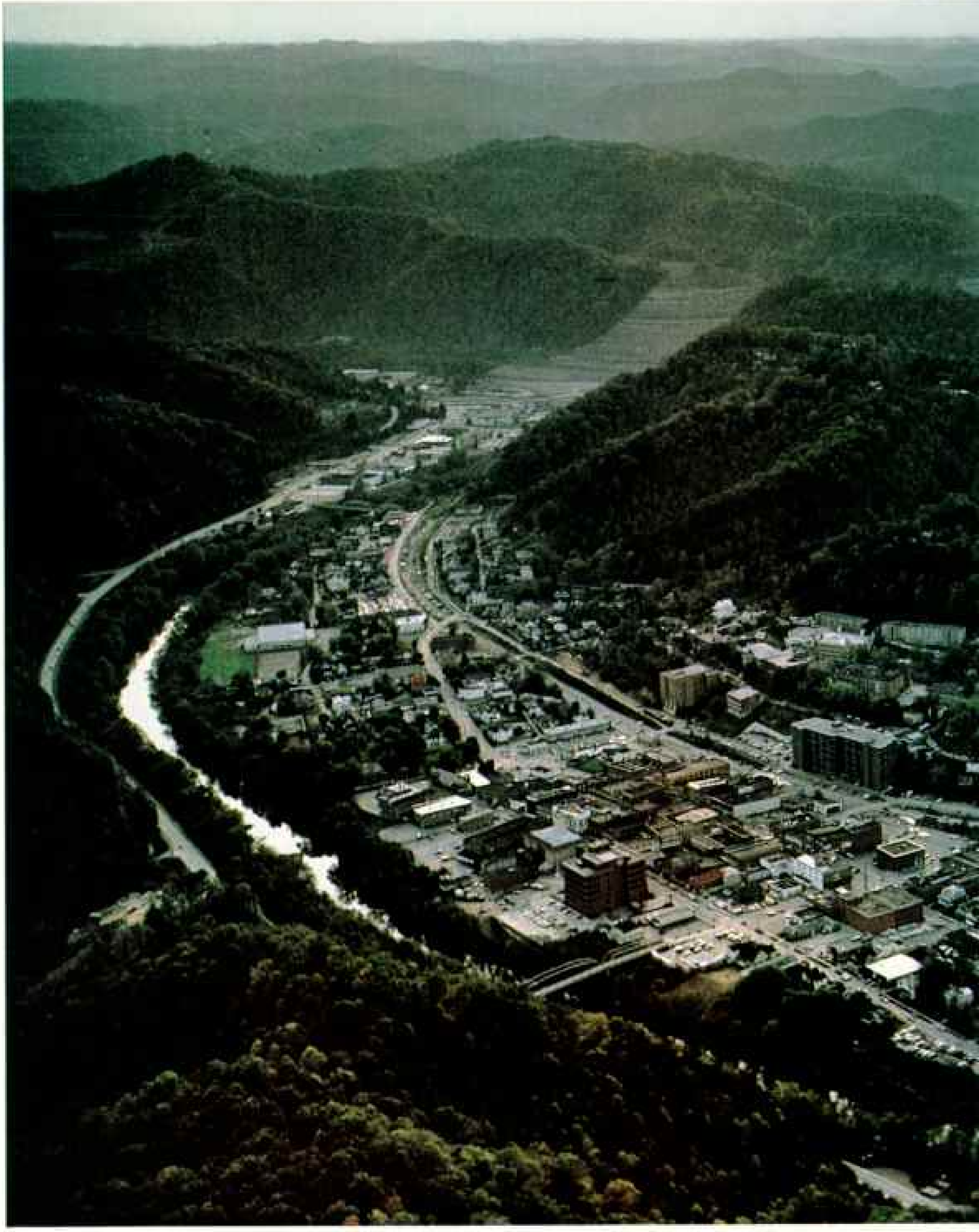
He explains: "Up till a couple years ago, things were goin' strong. It was easy to get a job. Then about 60 percent of the miners in the Beckley area were laid off. Ten mines shut down. People are standin' in lines for butter and cheese."

What Wooten is describing is the waning of the coal boom of the 1970s. Propelled by the increase in

oil prices, the pendulum of prosperity swung high. King Coal was back, only to be wounded by worldwide recession, the decreasing demand for electric power, and the decline of the steel industry.

Yet last March 500 Beckley area miners returned to work. Does that presage a turnaround? Replies Dennis Saunders of Beckley, president of the United Mine Workers of America, District 29, "Lord, if I had that crystal ball. . . ."

Meanwhile, sharing a common plight, miners share a common bond. A bumper plate (***above***) on a car at Bald Knob spells it out. Pride.



GIRDED by the Levisa Fork of the Big Sandy River, Pikeville was once a sleepy county seat in eastern Kentucky. The hanging in 1890 of Ellison Mounts, a cohort of the Hatfields in the Hatfield-McCoy

feud, provided some excitement.

Then in 1905 the Chesapeake and Ohio Railway came, opening the area's immense coal deposits to transport, and today Pike County leads the state in coal production, with 24.3 million tons shipped in 1981.

Pikeville's three banks have total assets of 560 million dollars, making the town the third largest banking center in the state, despite a population of only 5,000.

"WORK—it's the most beautiful word in the English language," says Arthur M. "Smiley" Ratliff. Mine operator and real estate entrepreneur, Ratliff sits in front of his Rolls-Royce—he has owned as many as five at one time—and the mansion on his 20,000-acre estate near Tazewell, Virginia.

"I've never had a vacation or a drop of alcohol," says Ratliff. "God didn't create us to play golf. He created us to conquer the planet. He created us for victory!"

At 57, the victorious multimillionaire looks for a new world to conquer—uninhabited Henderson Island in the South Pacific, a dependent territory of Great Britain. Ratliff first tried to buy Henderson, then offered the 50 residents of nearby Pitcairn Island $800,000 to build an airstrip and improve their life-styles. In return, he wants permission to live on Henderson. The British are considering his proposal.

"This is my grand finale," says Ratliff, undaunted by Henderson's cliffs. "Me and my boys will doze a road up those cliffs in 30 minutes.

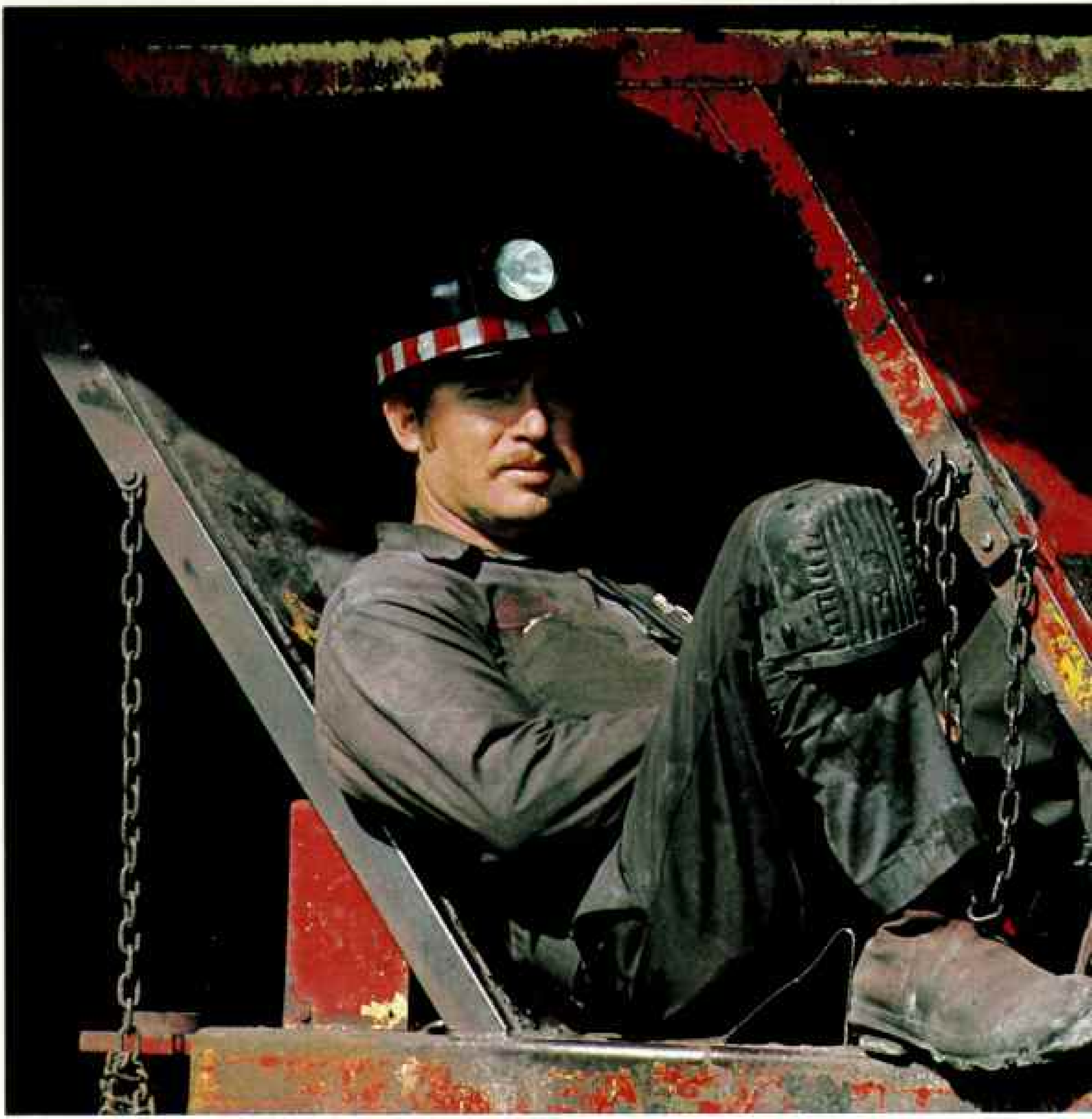
"I've mined all the coal, built all the buildings, fought all the battles. Now I'd like to go down hearin' the bugles blow. Hell, I don't want to end up feedin' the cats or goin' to picture shows."

WINNER in last year's race for the presidency of the United Mine Workers of America, Richard L. Trumka (***left,*** at right) greets a miner in Mullens, West Virginia, during his campaign.

A third-generation miner and a lawyer, Trumka, 33, is the youngest president of a major American labor union.

DRAWN BY ROBERT CROHAN, COMPILED BY MARGUERITE B. HUNSIKER
NATIONAL GEOGRAPHIC CARTOGRAPHIC DIVISION

Heart of Appalachia, the tri-state area of Kentucky, West Virginia, and Virginia contains some of the world's best coal, low in ash and sulfur, high in heat content.



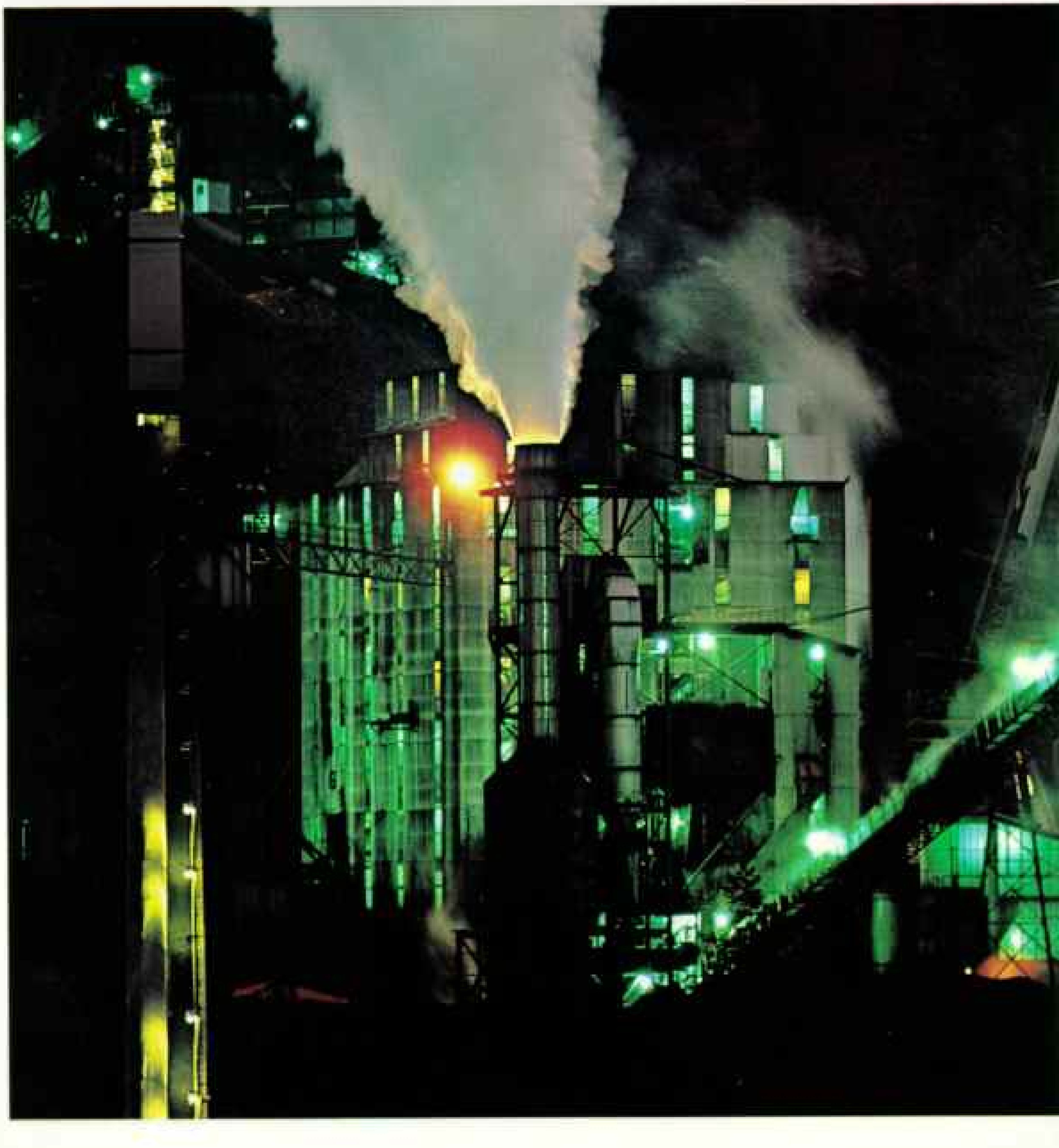
IN TRAPEZOIDAL SEATS, miners on a "mantrip" will be a bit more comfortable when the vehicle starts down a 30-degree slope. "Then they're sitting more upright," says Ralph DeBoard, superintendent of Eastern Associated Coal Corp.'s Keystone No. 5 mine near Beckley.

Rubber kneepads identify the men as "low coal" miners. Here the coal seam, which determines the height of the miners' working area, is a mere 36 to 41 inches high. Like infantry under fire, the men crawl hundreds of feet on their hands and knees to the seam. Torsos tipped, some extend their masonry hammers like a crutch as they sidle through the blackness with a crablike gait.

In a "high coal" mine, an Eastern operation at Bald Knob where the seam is six feet high (***right***), a miner shovels coal on cleanup duty. Another scatters crushed limestone on exposed coal to render the explosive dust inert.

WORLDWIDE competition is the prime factor in today's energy equation, according to Raymond A. Bradbury, president of the Martin County Coal Corporation near Inez, Kentucky. "The miner in Appalachia is competing not only with other American miners, but also with oil workers in Saudi Arabia and Venezuela and miners in South Africa and Poland," he says.

At Martin County Coal's preparation plant (***below***), where raw

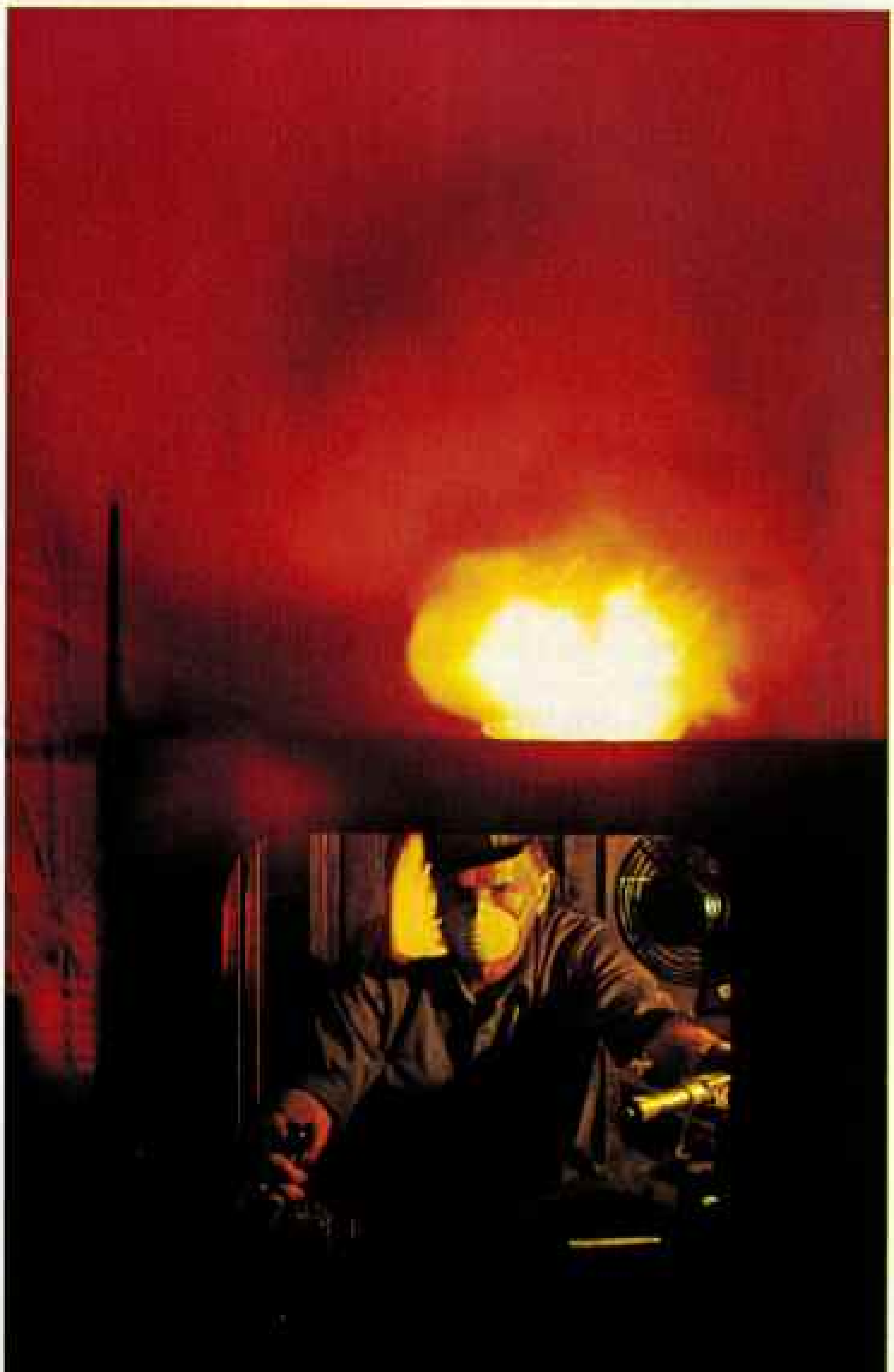


coal is cleaned, cost-conscious Bradbury runs a "tight ship." That and a long-term contract to supply steam coal to an electric utility have enabled the company to keep everybody working.

Last year, recession slightly reduced the demand for steam coal. But the market for metallurgical coal, used to make coke to fuel blast furnaces, fell more than 50 percent from 1976 to 1982 as domestic steel production declined.

At the Jewell Smokeless Coal and Coke Corporation in Vansant, Virginia, where a locomotive pulls a load of lava-like, freshly made coke (***below***), 600 employees were laid off last year. "We were operating only three days a week," says Jewell's president H. C. Van Meter.

Coke production returned to normal after the company secured a contract with a Michigan steel firm. "We're in better shape than most," says Van Meter. "The coke industry is depressed around the world, not just here in Virginia."

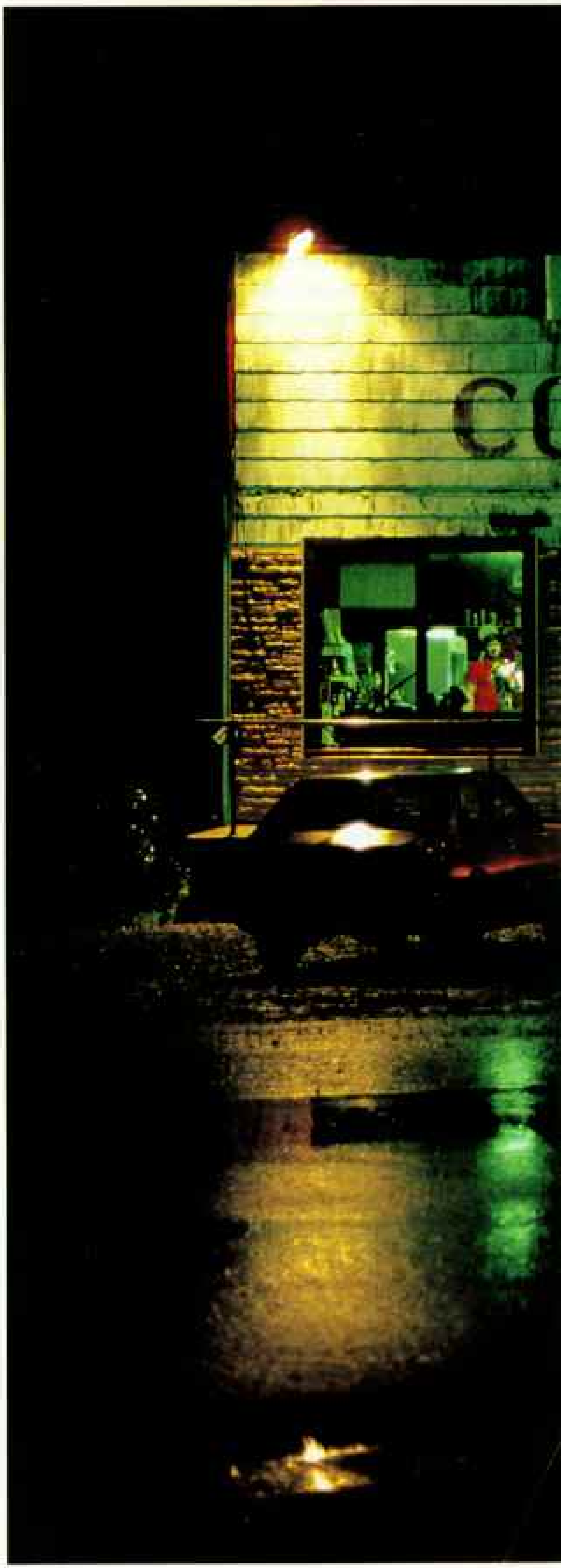


SATURDAY NIGHT in Coal City, West Virginia—population 2,000—isn't what it used to be when the mines boomed. Business at the tavern (***right***) is down 50 percent.

Three years ago a miner could saunter up to the bar and be in a fight before he was halfway through the first beer. "It was a rough place," says miner Gary "Rags" Cox. "You could see just about anything in here. Once a guy blew out a sign with a shotgun. I dived behind the coolers."

Then Clyde Bell, a lean, taciturn miner, took over as manager and restored order. "All of 'em's good, honest coal miners," says Bell. "If one has a dollar, everybody has it. You won't find a better bunch of people than in Coal City."

At a music festival frequented by miners in McClure, Virginia, Hope Randolph (***above***) sings bluegrass, the foot-tapping music rooted in Appalachia.



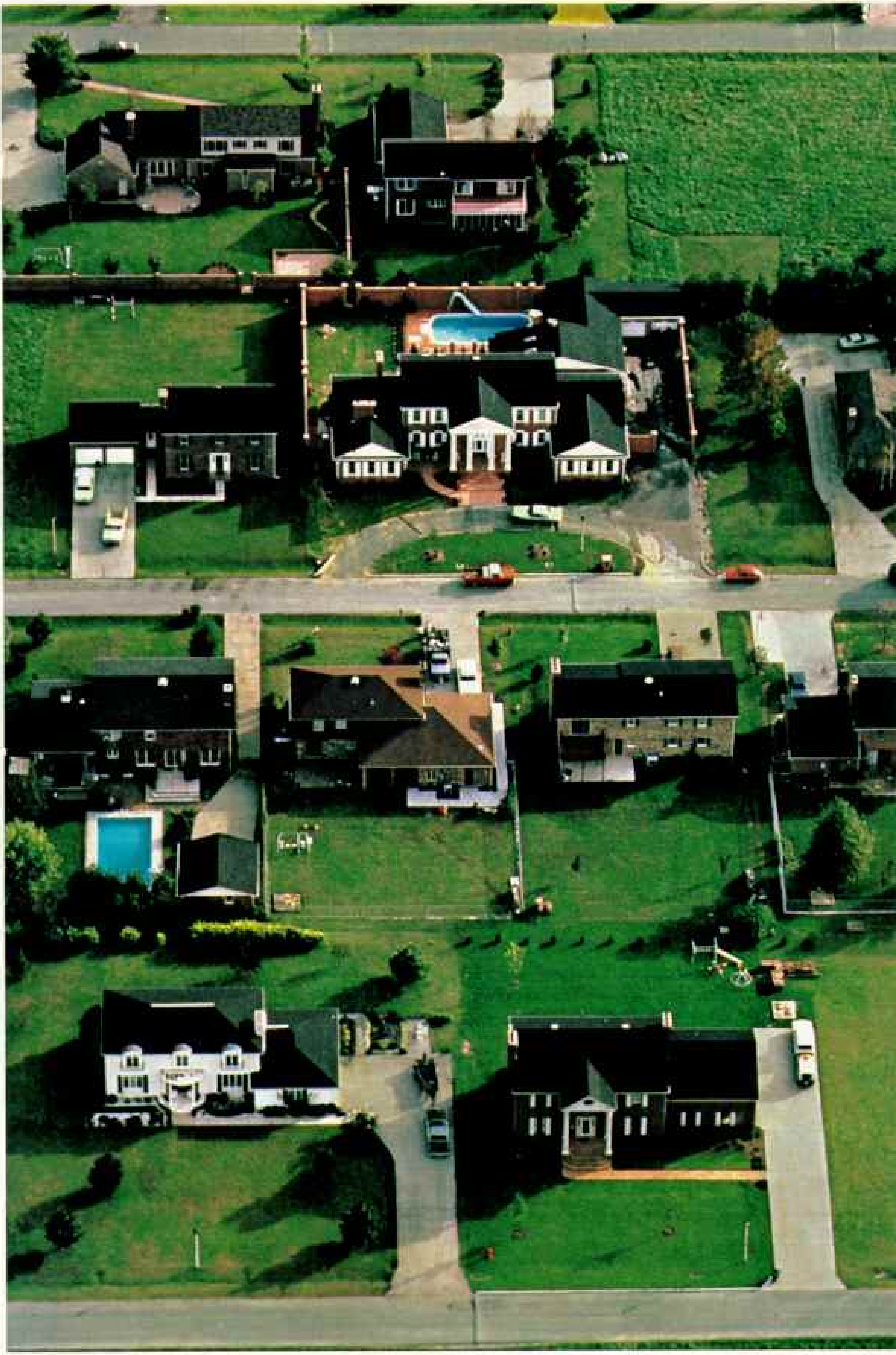

POOL
AL CITY CLUB

BREATH OF LIFE for a victim of black lung, an oxygen tube is fitted to retired miner Jesse Harless by Daniel Morikone of Martin County Home Health Care, Inc.

Black lung, or pneumoconiosis,

caused by decades of exposure to coal-mine dust, has killed many thousands of miners, but eventually the incidence of the disease is expected to decline greatly with dust controls imposed by the federal government in 1969.

Harless, who lives by himself, keeps the pistol for protection. The rifle is owned by his son. Harless also relies on Grizzly, his huge black dog. "A stranger here would get his leg took off," he says. "The insurance man won't get out of his car."



PILLARS and prosperity go together in an area of Pikeville known as the Bowles Addition, named for the family who once owned the property.

With few exceptions, the incomes of the mine operators, contractors, lawyers, doctors, accountants, and others who live here are tied in some way to coal.

The addition's 50 homes range in price from $90,000 to more than $600,000, with a median price of around $300,000. The owner of the lot at top has turned down an offer of $125,000.

"The people who live here are not the idle rich," says resident Henry Stratton, an attorney. "They're working wealthy, not investor wealthy."

Within a ten-mile radius of the town there are more than a hundred people with a net worth of a million dollars or more, making the area one of the largest concentrations of millionaires in Kentucky.



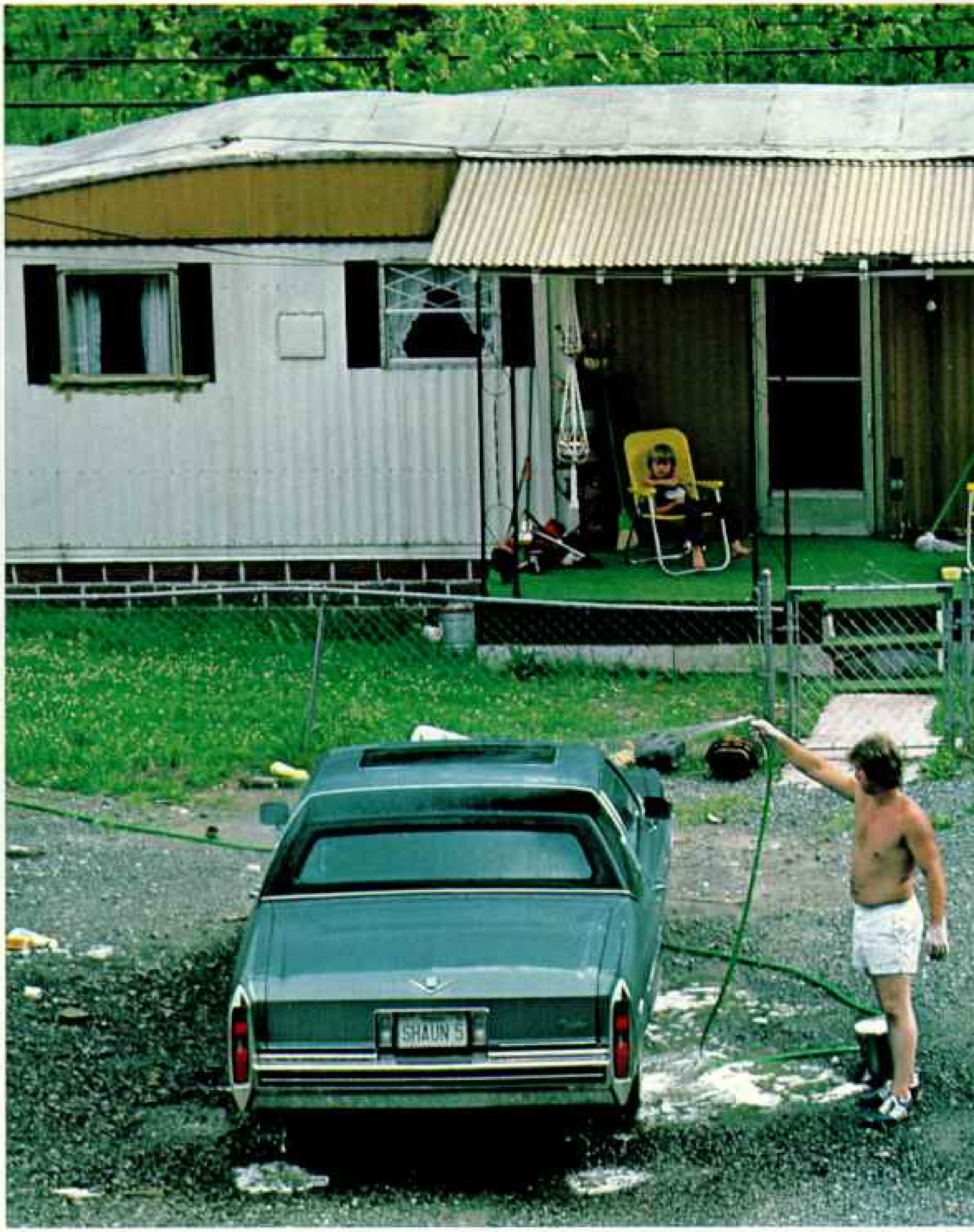
MUSIC IS THE SPICE of life for Phil N. Bradbury (***above***), but mining pays the bills. As superintendent of surface mines for the Martin County Coal Corporation, Bradbury, 29, made $54,000 last year.

In the garage of his home in Prestonsburg, he plays the organ while his wife, Carol, listens. Above them hangs a picture of his idol, southern rock star Greg Allman.

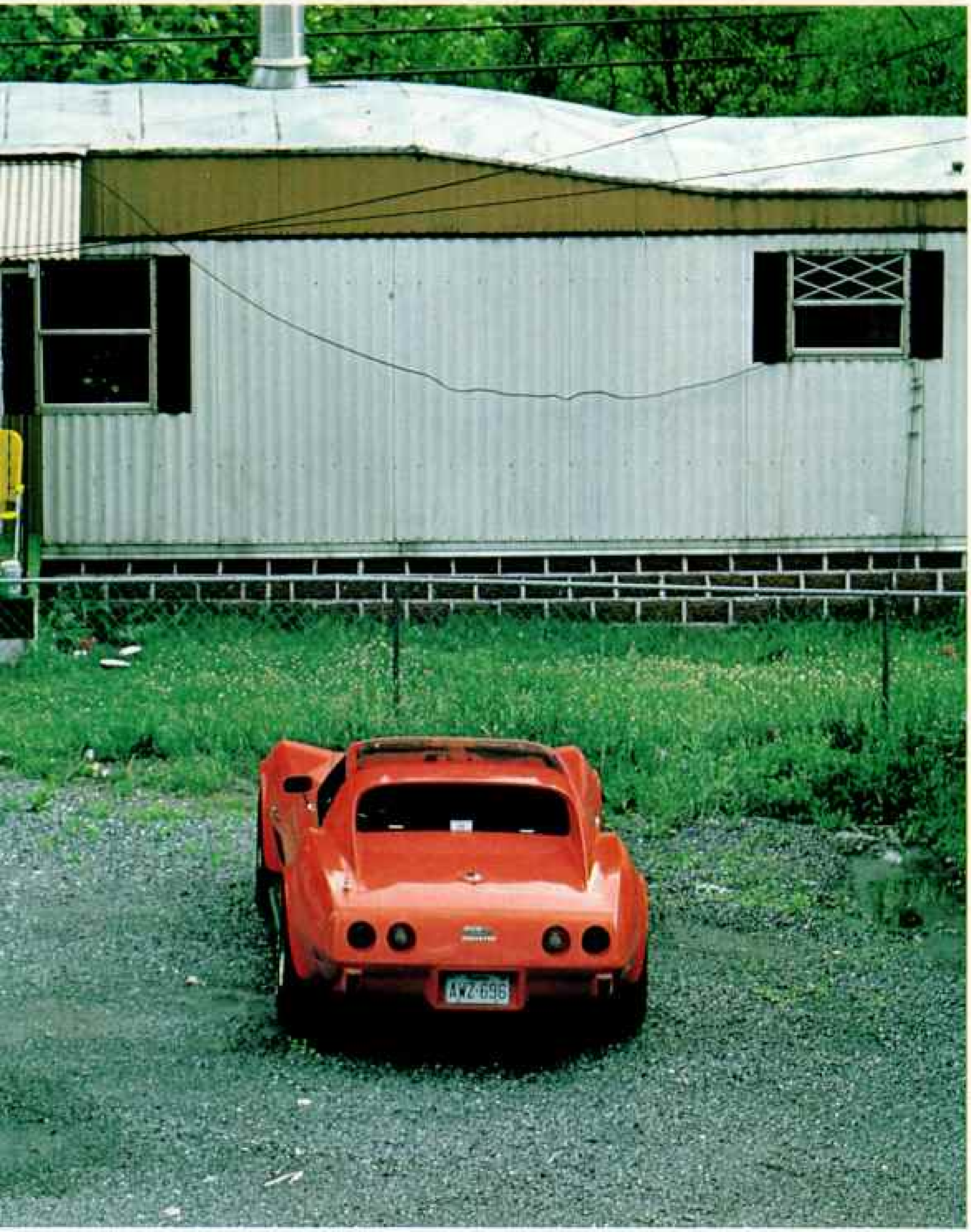
"My job is blasting surface material and rock to get at the coal," says Bradbury. Taking a high-tech approach to the task, he switched from a slide rule to a computer (***above left***). Pit foreman Donald Sparks observes.

"We're looking for the ideal formula before we shoot," explains Bradbury, "just enough explosive to break the rock into sizes that our equipment can handle. We don't want to lug around boulders as big as Volkswagens. The computer also tells me, before we blast, how much coal we'll get and how much money we'll make."

Can a surface mine be reclaimed as pastureland? Last year officials of the Martiki Coal Corporation joined agronomists from Morehead State University to answer the question. Object: to build up topsoil on a 250-acre pilot plot at Martiki Mine (***left***), near Inez, through manure from swine and poultry operations.



GOOD TIMES or bad, coal is a continuing challenge to Gary Baker of Prater, Virginia, who has had "more downs than ups" operating small mines. "You might make it good for six months,"



he says, "then fall on your face for a year."

Baker employs a dozen people—"my friends and neighbors"—and pays them as much as $25,000 annually. He works a seam until it runs out, then moves on.

While his new home is under construction, Baker lives in a trailer and hoses down his 1982 Cadillac, whose license plate celebrates his son. He has sold the 1976 Corvette.

DRIVE the 22 miles from Inez to Paintsville on State Route 40 and you'll discover what this area of eastern Kentucky is about.

Relentless curve follows relentless curve, announced by highway markers that wriggle like snakes. "There's only two spots on this road where you can pass a coal truck," a resident cautions.

Among the pines, oaks, and sycamores that flank the road, sandstone boulders brood, as big as tanks. A succession of corridors—here called hollers—crease the hills, with names like Buttermilk, Greasy Creek, Pigeon Roost, Chestnut, and Lower and Upper Wolf Pen.

On a mountain, the road swerves below the home of a retired miner (*right*). The U. S. Postal Service knows the area as Boons Camp KY 41204. But local people also call it Spicey Mountain, because a woman named Spicey opened a tavern here in 1934. Before that it was called Yallerstore Gap. An old-timer remembers that his great-uncle's son had a yellow store here then.


30

"WHO'S YOUR TEACHER?" Douglas Moore asks young Robert Nichols on the day before school begins in Lovely, Kentucky. Moore has cut hair for three generations of Nicholses. "I don't like the long hair and beards now," says Moore, "but I still cut them." When lunch is ready, his wife, Eulah, stomps on the floor of their apartment above the shop.

The ecstasy of faith shines from Lorraine Jude's face at her baptism in a creek near Pilgrim (***right***). "It is the spirit of the Lord working within her," says Baptist minister Ernest Hale, at left.

YOUNGSTERS RIPEN like an October afternoon in rural West Virginia, slowly and in their own

good time. Chatting and swinging, Art Sanda and Elizabeth Maschal make their own entertainment at Meadow Bridge. "You couldn't run fast enough to make me want to raise my kids in a city like Chicago," says a parent.

BANJO PICKIN' bluegrass style, Earl Butcher, 67, of Boons Camp sends his grandniece Stephaine Spears shuffling across the grass (***below***).

"I started to play music when I was eight," says Butcher, who grew up in a log house nearby. "I had a homemade banjo with a head of groundhog hide. Sometimes my mother would be aggravated by my playin' and git the broom after me. I'd leave the house and go on the hill to practice. There was a coal seam on that hill. My father dug it for years to heat the house."

Butcher remembers "loadin' coal for 28 cents a ton in 1931. They held a stopwatch on you. They wanted 16 shovelfuls a minute, yes sir." Once a lump of coal "big as my livin' room" fell on his right leg. Blood spurted. "I first-aided myself with a burlap tourniquet," he says.

A month after a back operation ended his mining career, Butcher suffered a ruptured appendix. "I asked the doctor what was wrong, and he said, 'I'll tell you when you wake up, and if you don't wake up, you don't need to know.'"

At the Martin County Senior Citizens Center in Inez (**below**), retired logger and town character Jack Smith discusses with Sarah Whitt the large potato he has just bought for $1.50. "I told him," Sarah recalls, "that I'd not give over 50 cents for it even if I hadn't had a potato for a long time."

The center buses retired people to the grocery store and the doctor and serves them a hot noonday meal. "We take care of our own here," says Homer Marcum, editor of the *Martin Countian*. "We value our elderly people as family." ☐

GLORIOUS BRONZES OF ANCIENT GREECE

Warriors From a Watery Grave

By JOSEPH ALSOP

FOR ART LOVERS and history buffs, the new pilgrimage center is Reggio Calabria. Among all the splendors Italy offers, this smallish, undistinguished provincial capital in the far Italian south is not one I should normally choose to visit. Yet the pilgrimage is well worth it nowadays because of Reggio's museum, which has on display two of the world's rarest and most remarkable works of art.

These are two heroic bronzes, more than six feet tall, of nude warriors ready for battle—except that time's accidents have deprived them of their spears and shields. They are almost certainly of the period extending from roughly 450 to 400 B.C.; and they are by one or perhaps two of the leading sculptors of the noblest era of the noble art of Greece, when Phidias, the most famous of all the famous Greek sculptors, flourished and the Parthenon was built.

They are the first important pieces of sculpture in bronze from this marvelous period that have been seen in countless hundreds of years. We have a fair number of sculptures in marble, like the famous Elgin marbles from the Parthenon, but even they were more a part of the architecture. Phidias and his leading contemporaries worked almost exclusively in bronze, except when they had superimportant commissions, where there might be funds to pay for gold and ivory.

The two bronzes were found in only 25 feet of water off Riace, a small coastal village 80 miles northeast of Reggio Calabria. They were probably loot lost at sea on the way to Rome from a Greek city, perhaps Corinth, very rich in art, which was brutally sacked by a Roman army in 146 B.C. In the sea the bronzes remained until found 11 years ago by a chemist

Veteran journalist and historian **Joseph Alsop** has been studying and writing about ancient Greek artworks for more than two decades.

*Rare masterworks of ancient Greek bronze statuary, a young warrior (**below** and **facing page**) and an older companion were lost for centuries until recovered by divers off Italy.*

LIBERTO PERUGI (FACING PAGE); FULVIO RIZZO from Rome, Stefano Mariottini, while snorkeling on holiday. On his last morning he decided to go out one last time with his mask and fins.

He spotted something dark outlined against the bottom, swam down, and to his horror found what seemed to be a human arm protruding from the sand. He surfaced at once, then dived a second time and gingerly touched the arm. It was bronze, and he discovered that it belonged to a large statue of a male figure. Scrabbling in the sand, he discovered a second statue a few feet away.

He saw no trace of a ship in which the bronzes might have gone to the bottom, and no such trace has been found to this day. This suggests that the ship carrying the bronzes ran into a powerful onshore wind—whereupon the frightened captain threw the heaviest objects in his cargo overboard, to lighten ship and gain seaway.

As soon as Stefano Mariottini left the beach, he telephoned Dr. Giuseppe Foti, then archaeological superintendent of the region of Italy containing Reggio Calabria and Riace. Mariottini was later rewarded by the Italian government with the equivalent of $145,000—of course a tiny proportion of the bronzes' market value.

Dr. Foti at once arranged for a guard on the place where the bronzes had been found. He then secured the help of divers from the carabinieri—the Italian national police—in raising the two bronzes. These proved to be representations of warriors, one about 20, formidable in his first athletic pride and

STAATLICHE MUSEEN PREUSSISCHER KULTURBESITZ, WEST BERLIN (ABOVE); SOPRINTENDENZA ARCHEOLOGICA DELLA TOSCANA, FIRENZE (BELOW)

***Commanding attention** even in its blighted state, the first statue to be retrieved draws a crowd around the recovery team on the Riace beach (**facing page**). Stefano Mariottini, at center, had chanced upon the figures while spearfishing 400 feet from shore. Archaeologists named the older soldier Warrior B, shown here, and the younger, Warrior A.*

*A fifth-century B.C. Greek cup (**above**) celebrates the art of casting such bronzes in pieces. As two men work at the furnace, another plies a hammer to finish a work in progress. A gamma-ray photograph (**right**) reveals soldering on the left wrist of Warrior B and a section of the iron armature inside. Part of the statue's internal support structure, the armature extends from the arm into a core around which the hand was cast.*

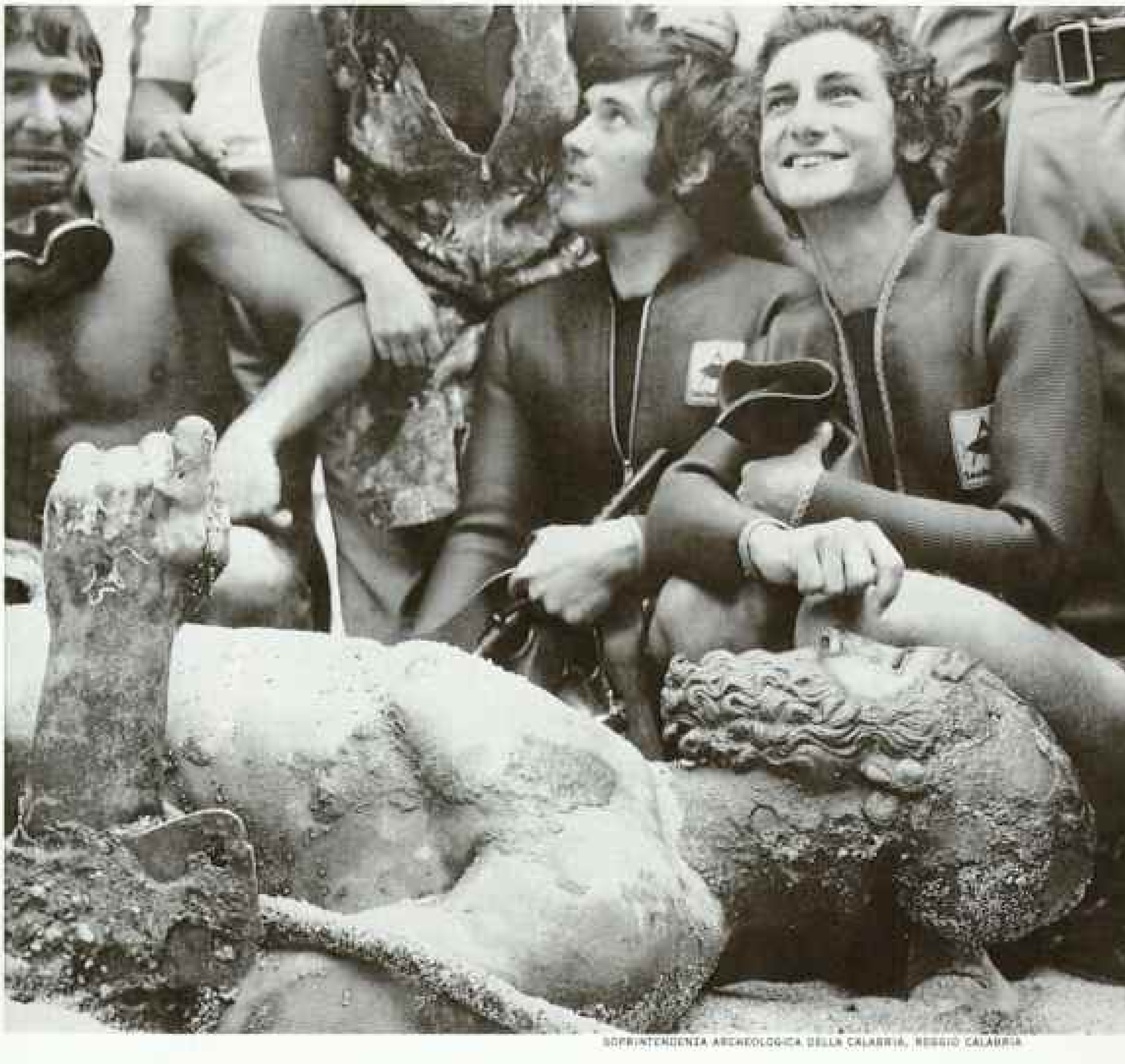
power, the other, about 30, more gracefully built but still splendidly athletic.

The people of Riace tried to prevent the statues' being taken to Reggio Calabria. But with the carabinieri's help, Dr. Foti took the bronzes to Reggio for restoration.

THE BRONZES were heavily encrusted and corroded. Dr. Foti recognized that the facilities in Reggio were inadequate. After two years' work, he sent them to the Italian government's archaeological restoration center in Florence. Its expert team went to work with specialized modern instruments, but endless patient handwork was still needed; six more years went by before the restoration was completed.

While the statues were incompletely restored, Professor Werner Fuchs, a German scholar, pronounced the bronzes the work of Phidias himself. Many Italian scholars (who tend to be nationalistic) held that the bronzes at least came from the period of Phidias, but outside Italy the preliminary verdict of many other scholars was that the bronzes were "late"—meaning perhaps as late as A.D. 100-150, and certainly later than the most creative centuries of Greek art, which ended around 320 B.C. Late Greek sculpture is no nine days' wonder. Hence there was no great burst of excitement until the restoration was completed and the glorious, near-intact statues were at last ready to be shown.

The most eminent students of Greek art at once began to go to Italy to see the bronzes.



SOPRINTENDENZA ARCHEOLOGICA DELLA CALABRIA, REGGIO CALABRIA

IN REBORN GLORY, ***Riace's ancient warriors stand guard in Reggio Calabria's national museum after eight years of intensive restoration. Missing are the pair's spears and shields as well as the helmet once worn by Warrior B, right. Traditionally, nudity in Greek statuary denotes heroism.*** LIBERTO PERUGI

SOPRINTENDENZA ARCHEOLOGICA DELLA TOSCANA, FIRENZE

Centuries in the sea *left the statues with unsightly mineral encrustations, presenting restorers with a monumental task. Technicians used scalpels and pneumatic hammers to remove concretions from the back of Warrior B* **(top)**, *revealing a lustrous finish* **(bottom)**. *More delicate areas required ultrasonic tools and micro-sanders.*

Who made the statues? What monument did they grace? How did they end up in the sea? No one knows, but the mystery detracts little from the warriors' esteemed place among the world's small, priceless store of heroic Greek bronzes.

Among them was former Oxford professor Martin Robertson, author of the authoritative *History of Greek Art*. After studying the bronzes, he wrote: "I have no doubt now they are fifth-century originals. . . . The extraordinary impression they make is partly due to our being used to classical bronzes in Roman marble copies, and the real thing comes as rather a shock."

I DECIDED I must go to see these bronzes, now established as from the noblest era of Greek art. I stopped in London to talk with Professor Robertson, who confidently gave the statue of the young warrior a date of about 450 B.C. The statue of the older warrior, he added, was probably made some years later—perhaps as late as 430 B.C., the eve of the death of Phidias. "Some scholars even hold that this statue is by another sculptor," Professor Robertson went on. "I incline to believe it's by the same man made at a later date. The concept is the same in both cases, although the style has evolved. The bronzes probably come from a unified group, such as the hero statues that the Athenians commissioned from the young Phidias.

"There's nothing to say the bronzes are not by Phidias. But we have no bronze by Phidias to judge by. I think 'bronze originals by a leading master of the time of Phidias' is the sensible verdict."

Professor Evelyn B. Harrison of the Institute of Fine Arts in New York has spoken for dates in the lifetime of Phidias. Professor Peter von Blanckenhagen, also of the Institute of Fine Arts, gives the bronzes the same dates as Professor Robertson but believes the two bronzes are by different masters. The one important holdout for a late date for the bronzes is Professor Brunilde Sismondo Ridgway of Bryn Mawr College.

Add the pro and con votes. The overwhelming majority favors a Phidian date. This is supported by the technical findings about the bronzes, as I learned in Florence.

Dr. Pier Roberto Del Francia, director of the archaeological restoration center in Florence, emphasized that fifth-century Greek bronzes cannot yet be precisely dated by such technical findings as the alloys used to make the bronzes. These only indicate "probabilities." All the same, it is impressive that both bronzes are made of the simple tin-copper alloy that Dr. Del Francia described as "normal" for Greek bronzes of the fifth century.

This evidence is reinforced by additional data on the statue of the older warrior, which was damaged in ancient times, probably by falling or being knocked off its base. Hence the right arm and half the left arm are skillful later replacements. While the rest of this statue is of the normal fifth-century bronze alloy, the replacements are made of a different alloy with a little lead added—normal for later work.

The young warrior and his companion are now installed in the fine museum in Reggio, drawing a flow of pilgrims to our first visible proofs of the Greek sculptors' achievement in the marvelous maturity of the classical style. The bronzes are electrifying—grand and powerful without any straining for grandeur or power, as only great works of art can be. The more effective of the two statues is the young warrior, the earlier work, from about 450 B.C. In proud first manhood, he is downright menacing. The older warrior would be just as effective if the helmet were not missing, and if he still had both his eyes in their original condition.

This statue's head was made to fit the lost helmet, and the upper part of the skull is therefore unnaturally hairless and pot-shaped, which causes a discord. As to the eyes, these were originally made of dark stones for the pupils, set in white stone to make a natural pattern, and were then inserted in the eye sockets and provided with metal eyelashes. The effect is remarkable, as the younger warrior shows, although his dark pupils are missing. But the older warrior has one eye missing, while the other eye was too concreted and misshapen to be completely cured by the restorers.

Dr. Claudio Sabbione, the curator who showed me around the museum, explained the absence of the older warrior's helmet and the spears and shields of both statues. Being removable, these must have been packed separately for shipment, and thus did not go to the bottom with the warriors.

I believe that both statues were the work of the same artist at different dates. Long delays are natural when an artist receives a commission for a whole group of important works, and 20 years is not abnormal. Undeniably, the feeling and the details of the two statues are different. Not only is the older warrior more gracefully made, but the muscles, veins, and general anatomy are far from a mere repeat of the young warrior. The overall feeling is more tranquil and classical—as befits sculpture tentatively dated as late as 430 B.C., just about when Greek art is thought to have attained complete classical maturity.

Yet the differences between the warriors go no further than would be accounted for by a single artist's evolution over two decades. To me, one detail loudly bespeaks a single sculptor: The scrotum of each statue has been similarly treated, carefully striated to suggest the crepe-like texture of the skin itself—an extra-realistic touch otherwise unknown in Greek and Western sculpture.

I HAVE ALWAYS been stirred by the long process of recovery of the lost human past that is a harmless and striking feature of the modern era. One of its more miraculous results has been the recovery within less than a hundred years of five great works of art that tell us a neatly connected story of the early development of large bronze sculpture in Greece—about which nothing solid was known only a century ago.

The Greeks started making large statues in bronze during the mid-sixth century B.C. An unidentified great sculptor then made the Piraeus Apollo, found in 1959 by road workers in the port of Athens and now in Athens' National Archaeological Museum. In 1896 French archaeologists found the Charioteer now in the Delphi museum, which was made half a century after the Piraeus Apollo. The Artemision Zeus/Poseidon, created after the Charioteer of Delphi, was fished up from the sea around 1930 and is also in the Athens museum. And now the two bronzes in Reggio Calabria carry this series forward into the noblest era of Greek art: the younger warrior to the time of the early career of Phidias and the older warrior to the master's later years.

So when I see these warriors I not only marvel at the sheer power and grandeur of the works of art. But I am also moved profoundly by the miraculously rediscovered chapter of history that had been long lost. □

Last of the Black-footed Ferrets?

By TIM W. CLARK

Photographs by FRANZ J. CAMENZIND
and the author

ON THE NIGHT of September 26, 1981, John Hogg's ranch dog killed a strange animal intruding too near its food bowl. John's wife, Lucille, persuaded the rancher to take the mink-like victim to Larry LaFranchi, a taxidermist in a nearby northwest Wyoming town, who identified it as a male black-footed ferret. LaFranchi called Jim Lawrence, a warden with the Wyoming Game and Fish Department, and Jim reached me, knowing I had been looking long and hard for just such a creature.

The news electrified me. For eight years I'd been searching in vain for this rare North American mammal. In those years only a handful of sightings had been confirmed; some people had already grimly dismissed it as another species forever lost. Did this sudden discovery mean that the animal had perhaps moved back from the brink of extinction? My colleague Tom Campbell and I rushed to the area with fresh hope.

A research project supported by your Society

Within a few miles of the killing site, we located and searched several prairie dog colonies. Black-footed ferrets, we knew, live in prairie dog burrows and prey primarily on those tunneling rodents. The ferrets have black feet and black-tipped tails. Black raccoon-like "bandit masks" lend them a thievish look. Their nocturnal habits may afford them protection against eagles, hawks, coyotes, and badgers.

We discovered other prairie dog colonies that might harbor ferrets and searched them, also to no avail. But just a few weeks

Captured for a moment *by a mesmerizing spotlight, a curious black-footed ferret peers out of the night. A few dozen of the elusive animals discovered in Wyoming are the only known population on earth.* DOUG BROWN

later a cowboy on an adjacent ranch reported seeing a live ferret while rounding up cattle. His dog had chased it into a prairie dog hole. The cowboy said he had gotten off his horse, crept on all fours to the burrow, and watched as the ferret bobbed in and out only inches away.

He guided biologists to the area, where later Steve Martin and Dennie Hammer of the U. S. Fish and Wildlife Service livetrapped a ferret and fitted it with a radio collar. The tracking device led the men to other ferrets, and eventually nine were observed.

It was shortly thereafter that we began surveying the same large dog town. Ranging over it with spotlights on the night of December 1, 1981, we were thrilled with our first fleeting glimpse of a live ferret. Over the next few weeks we recorded sightings of more than a dozen animals!

Still, the tragic fact remains that *Mustela nigripes* is regarded as one of North America's most endangered mammals. The entire Wyoming population may total about 60.

An enigma to science, the black-footed ferret was first reported in 1851 by John

Tim W. Clark, a biology professor at Idaho State University and head of his own research firm, has pursued ferrets for ten years. He reported on prairie dogs in the August 1979 GEOGRAPHIC.

James Audubon and John Bachman from a skin obtained at Fort Laramie, Wyoming. Since 1877, when a second ferret was discovered near Cheyenne, about 1,000 reports, as well as some 125 skins and skeletons, have come from the broad region reaching from Alberta to Texas, Utah to Nebraska. This area of the western Great Plains and intermountain basins coincides almost exactly with the range of the prairie dog, whose numbers Ernest Thompson Seton estimated at more than five billion during the late 1800s. Such hordes could have supported tens of thousands of ferrets.

The radical decline of the black-footed ferret was probably caused by settlers' elimination of prairie dogs, increasingly viewed as range pests. Eradication campaigns over the past century have employed cyanide, strychnine, and other poisons; gases, dynamite, and shooting, as well as plowing under the dog towns. In some states, prairie dogs have been reduced by 99 percent since 1900.

In our study area in northwest Wyoming, intensive prairie dog eradication was never pursued. We found ranchers there concerned for wildlife and its conservation, a live-and-let-live spirit that accounts for the ferrets' survival—and the hope of their restoration—in these rangelands today.

BOTH BY TIM W. CLARK

Frontier memories *fill Bob Edgar's open-air museum at Cody, where two Mustela nigripes* **(above)** *have become artifacts of the Old West. Once found in brush grasslands* **(left)** *from Texas to Alberta, the ferret was hunted by Sioux, Blackfeet, Crows, Cheyennes, and Pawnees for food, fur, and religious rites. A longtime Wyoming resident, Edgar helped researchers meet landowners in the study area.*

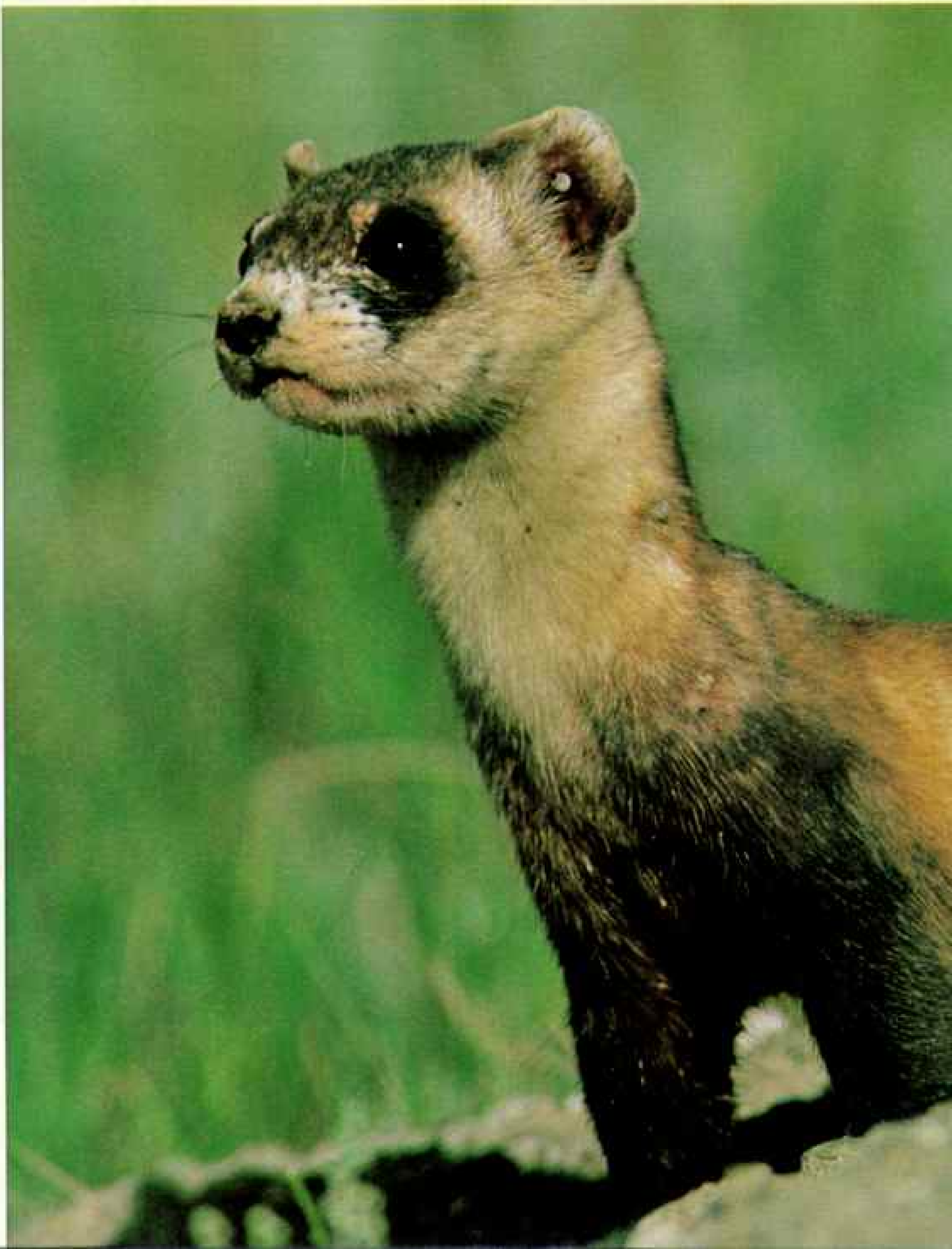
Working overtime *to feed her young, a female ferret, normally a nocturnal hunter, pulls the body of a white-tailed prairie dog (***left***) from its hole. Though known to eat mice, rabbits, ground squirrels, and other small animals, ferrets prey mostly on prairie dogs, making life more precarious for this white-tail carrying nesting material (***below***). Ferrets also rely on the gregarious rodents for shelter, inhabiting burrows in prairie dog towns. Thus when ranchers in many parts of the West tried to eradicate the prairie dogs, viewing them as threats to cattle and crops, the black-footed ferrets suffered as well.*

TIM W. CLARK (LEFT); FRANZ J. CAMENZIND

In 1973, when I began the Ferret Search project in Wyoming, timely support came from the National Geographic Society and many conservation organizations. Through wanted posters, postcard mailings, and newspaper and magazine articles, I solicited sighting records. Hundreds of resulting reports—most of them false alarms—were thoroughly checked out. Now, at last, our long years of effort were being rewarded.

Over four months of snow-tracking in the winter of 1981-82, we compiled evidence of 22 ferrets. Even the harsh breath of the Wyoming winter, seeping into my field quarters in a sheepherder's wagon, could not chill our spirits as my associates and I mapped each day's records.

One morning in the bleak predawn, I



lighted the kerosene lamp, freed my boots, which were frozen to the floor, and set about frying eggs on the small iron stove. My four colleagues, bivouacked in tents nearby, bustled into the wagon for breakfast.

"It's kinda crisp!" muttered Louise Richardson.

The thermometer read minus 38°F.

Had the ferrets been active again last

***A pound and a half** of intensity, an alert female scans the neighborhood. In one winter night of hunting, a ferret may visit 250 prairie dog holes within a range of 150 acres. Related species in Europe have been used by hunters for centuries to "ferret out" rabbits from burrows.*

FRANZ J. CAMENZIND

night, despite the frigid weather? The two previous evenings it had stopped snowing about 9 p.m., providing a clean page for the imprint of ferret tracks.

If the five of us worked fast, we just might, before nightfall, be able to cover the rest of the five-square-mile prairie dog colony. In the evening, when our total count added up to snow signatures of 22 ferrets, jubilation filled the creaking old wagon.

All of us involved in the ferret study agreed not to reveal our precise working location, for the slightest attrition of such a critically marginal population—however innocently caused—might tip the balance against survival.

THROUGH THE WINTER we concluded that the ferrets were solitary animals. We identified them by their hunting sites—"the salthouse ferret," "Section 17 ferret"—depending on where we found their tracks.

But in mid-March things changed. Tracks started overlapping, distances of nightly movements increased, and small scratched-out areas appeared around bushes. These actions suggested a hunt for mates at the start of the breeding season.

Earlier studies had reported a gestation period of 42 to 45 days. While waiting for nature to take its course, we mapped all the prairie dog colonies in a 130-square-mile area known to contain ferrets. These 21 colonies covered more than 7,000 acres and contained 111,000 prairie dog burrow openings. To inspect them, our team walked all told some 2,500 miles.

At last came a landmark day, June 28, 1982, when at 2 a.m. we spotted a mother carrying three tiny kits, one at a time, from one burrow to another. In an intensive effort to locate and count litters, we kept at least two vehicles and four people covering the ferret-occupied colonies every night. Quartering the rolling miles of grass and sagebrush, we swept the landscape with powerful six-inch aircraft landing lights, seeking the small, elusive animal that spends nine-tenths of its life underground. My associate Steve Forrest saw 16 ferrets in one night, a modern-day record!

Whenever we spotted the green eyeshine of a ferret, we stopped to map its location,

Too young to know better, *a juvenile dozes in the sunshine (**below**), an easy target for a large hawk, golden eagle, coyote, or badger. Born during spring, litters averaging three*

ALL BY FRANZ J. CAMENZIND

*young emerge from burrows in late summer to romp, explore, or yawn with fatigue (**left**). The mother then scatters these kits among nearby burrows, tending to them separately (**above**) till they can hunt by themselves. Among the medium-size members of the weasel family, black-footed ferrets rarely grow to more than two feet in length from the tip of the nose to the end of the tail.*

TOM M. CAMPBELL III (BELOW); LOUISE RICHARDSON

Worst days of winter *are best for ferret research, since tracks in the snow reveal much about the animal's behavior. Still, it takes an extra effort to fix breakfast in the field* ***(above)*** *when the temperature has dropped to minus 38°F.*

What the tracks can't reveal is where the species is heading: To a rapid extinction? Or to a gradual recovery through long-term conservation?

record its behavior, and determine if it was one of a group. When we sighted a troop of youngsters bobbing along behind their mother—nose to tail, pairs of eyes shining like headlights—we feared we might be seeing, as my colleague Denise Casey put it, "one of the last runs of the ferret train."

By mid-July, when they began regularly to pop up above ground, the playful kits appeared about three-quarters grown. The mothers, grimly attending to bringing in meat for their litters, by summer's end appeared haggard and worn. Moreover, the summer-fat prairie dogs—some males weigh four pounds—were no easy prey for a one-and-a-half-pound female ferret. One mother appeared repeatedly with new wounds on her already scarred face.

At last the mothers began dispersing their youngsters into different burrows during the day. Soon the young had to begin killing prey on their own, living independent, solitary lives.

We had identified 12 litters, an encouraging result. Now we knew that at least 38 new individuals had been added to the local ferret population.

TO AVERT the still threatened extinction of the black-footed ferret, we have coordinated our field studies and shared our findings with others just as deeply concerned. The Wyoming Game and Fish Department, taking the lead role in management, cooperates with other state and federal agencies.

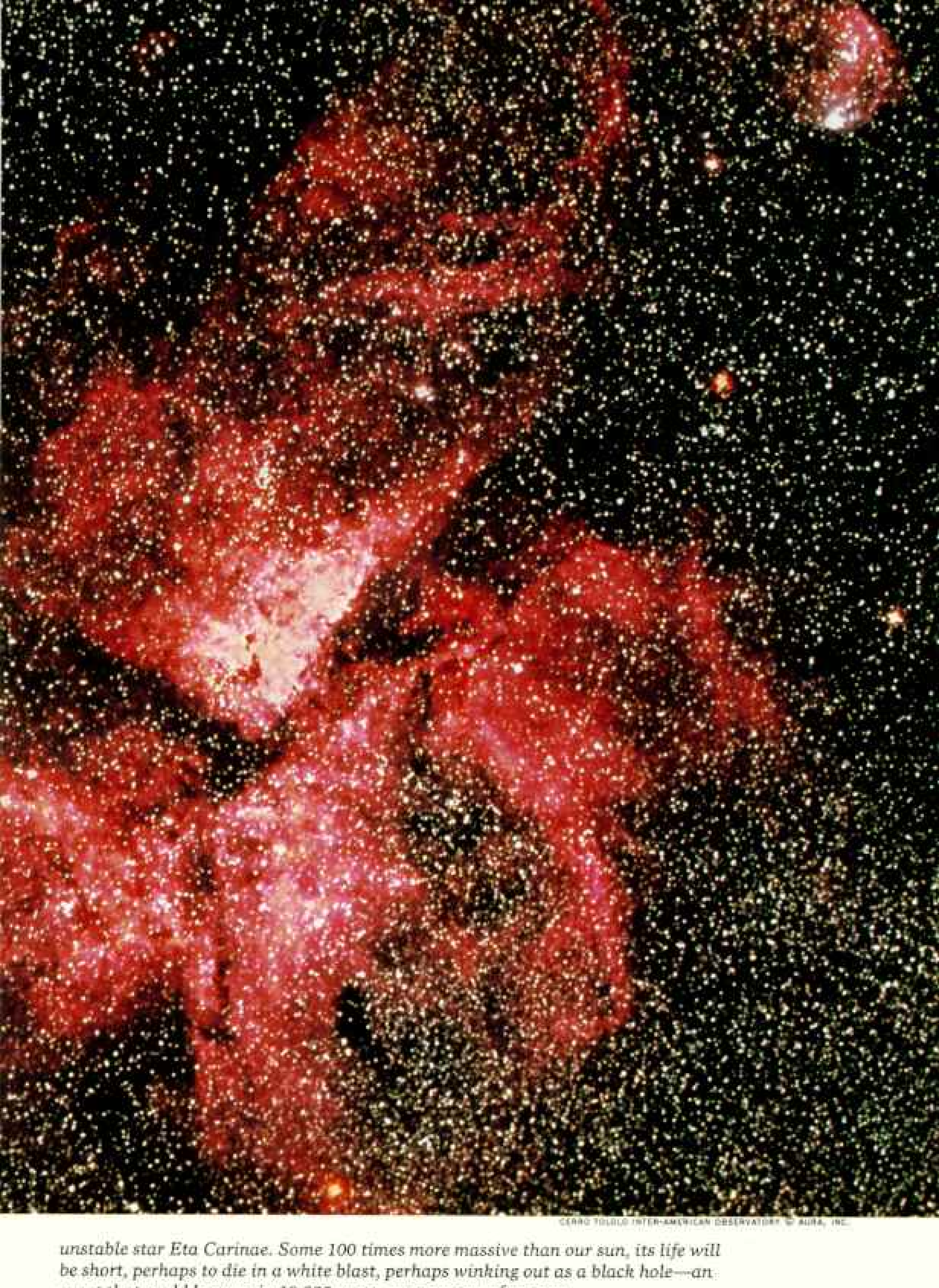
Equally important, of course, is the invaluable support of local ranchers who view protecting native wildlife as a historic responsibility.

Conservation of this small Wyoming population is possible, for the short term at least, barring a catastrophic epidemic fatal to ferrets or their prey. Recovery of the species to a healthy status—geneticists say 500 individuals are needed—is more problematic. Besides closely monitoring this population, we are seeking other aggregations of ferrets in remote areas throughout the West.

While I am hopeful for the future of this appealing animal, its survival hangs on the cooperation of many, and on the full understanding that the loss of a single species on this planet is irrevocable and a loss to all. □

Pinpoints of light, *some 50,000 stars, spangle the heavens in this view of but a minute fraction of the Milky Way, an average-size galaxy among the billions that fill our universe. Blossom of gas and dust, the Carina Nebula is home to the*

National Geographic, June 1983



CERRO TOLOLO INTER-AMERICAN OBSERVATORY © AURA, INC.

unstable star Eta Carinae. Some 100 times more massive than our sun, its life will be short, perhaps to die in a white blast, perhaps winking out as a black hole—an event that could happen in 10,000 years or tomorrow afternoon.

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WASHINGTON, D. C.

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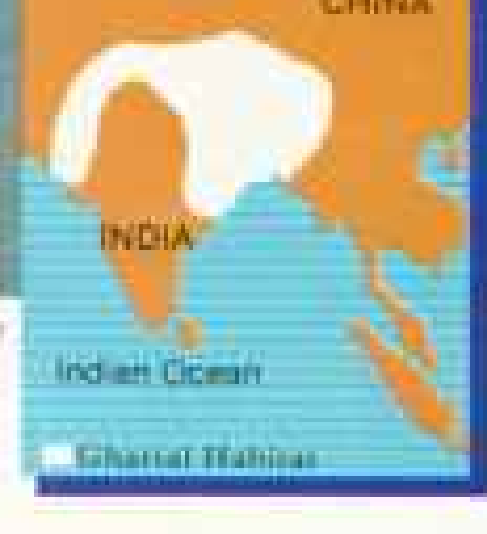

Photographed by Rajesh Bedi. ***Gharial:*** ***Genus:*** *Gavialis* ***Species:*** *gangeticus* ***Adult size:*** *3.65—4.57m* ***Adult weight:*** *500kg average* ***Habitat:*** *Deep fast-flowing rivers with high banks, deep pools, and sandbanks for nesting and basking. Present range includes Bangladesh, India, Nepal and Pakistan.* ***Surviving number:*** *200—400 adults*

Wildlife as Canon sees it: A photographic heritage for all generations.

Gliding in the water silently like a phantom, with long jaws studded with more than a hundred teeth, the gharial or gavial inspires fear at first sight. Actually, it is a fish-eater, and it virtually never attacks people. The gharial used to abound in the Himalaya-fed rivers in the north of the Indian subcontinent, like the Ganges, but with hunting and man-made changes in its habitat, it has become a gravely imperiled species.

The gharial could never be brought back should it vanish completely. And while photography can record it for posterity, more importantly photography can help save it and the rest of wildlife.

Photography can be a great help to conservationists, as in the study and observation of captive-reared gharials. Moreover, photography can help reveal the real nature of the gharial, and by doing so, it can make people see beyond that fearsome appearance and help them understand this unusual relative of the crocodile and alligator.

And understanding is perhaps the single most important factor in saving the gharial and all of wildlife.

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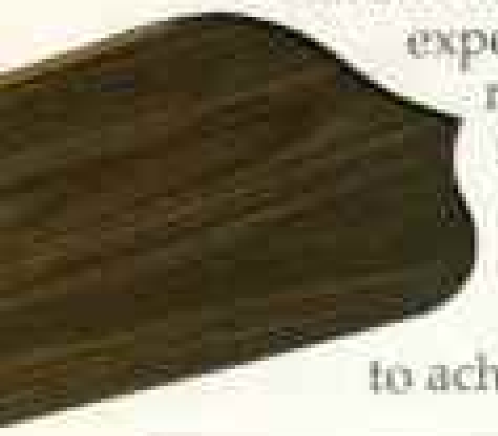

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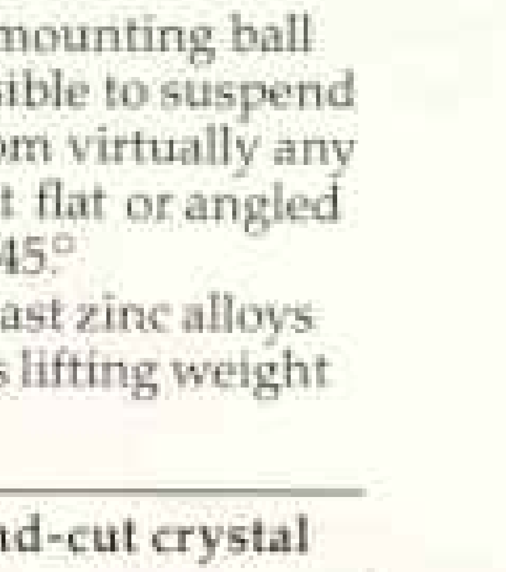

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Members Forum

PEOPLES OF THE ARCTIC

The peoples of the Arctic (February 1983) are imaginative, creative, and used to coping with all the challenges that the harshest environment could throw at them. Now a pervasive do-goodism of the welfare state has removed all those challenges that formerly brought out the very best of their creative efforts and that gave them a true sense of dignity and self-esteem in olden times. These are not people to whom indolence and a handout come naturally or with anything except the most evil side effects.

Kenneth O'Meara
Holland, Michigan

Animals adapt to changes in habitat, weather, and food supply, and human cultures modify and adapt to change—it's part of evolution. What happens when people are unwilling to change, unwilling to reevaluate or modify even one tradition or ritual? Then life can stop. The magnificent, mysterious bowhead whale may lose its tenuous hold on life. The Eskimos did not originally push the bowhead to the brink of extinction, but they may well be the ones responsible for pushing it over the edge. Is any tradition worth such a catastrophic price?

Ann Nofziger
Laguna Beach, California

Your article "Hunters of the Lost Spirit" is interesting and, as usual, most beautifully illustrated. We appreciate very much your photograph on page 154 of our BF-37 island in the Beaufort Sea. We are, however, distressed to see it identified as one built by our friendly competitors, Sohio.

Max D. Nalley
Exxon Company, U.S.A.
Anchorage, Alaska

Indeed we misidentified the island. Our photographer took pictures of both, and the one we showed was erroneously confirmed as the other.

Read with interest were the articles concerning the peoples of the Arctic. "Utility poles must be set in concrete and rocks atop the permafrost" (page 189). How are community sewage and water handled in permafrost?

Ernest D. Smith
Roy, Utah

In many small settlements waste is collected in barrels or plastic bags and removed. Larger and *newer communities may use aboveground pipes, insulated and usually heated, to carry water in and waste out. If plumbing lines are put in the permafrost, insulation and constant flow keep pipes from freezing and from disturbing the soil.*

I am astonished that the authors never refer to the outstanding and inspiring ethnographic collection of the northern peoples' cultures in the National Museum in Copenhagen. After all, the Danes have collected and diffused the knowledge of northern archaeology and ethnography for more than one and a half centuries.

Andrew Block-Bolten
Watertown, Massachusetts

ARCTIC MAP

I notice on your excellent map that you credit Robert E. Peary as "reported reaching" the North Pole in 1909. I realize that our Society supported him publicly at that time to the discredit of Dr. Frederick Cook, who claimed to have achieved the Pole in 1908. Is the choice of words on your map a reflection of doubt?

M. Van Ronzelen, M.D.
Salem, Oregon

National Geographic does not dispute Peary's claim in our note on polar exploration, but acknowledges the long-standing controversy.

Umberto Nobile captained the dirigible *Italia*, formerly the *Norge*, when it flew from Spitsbergen across the North Pole to Alaska and most of the way back in 1926. The airship crashed on the pack ice and deposited many crewmen before it became airborne again and disappeared forever over the horizon. Several independent rescues were attempted; Roald Amundsen crashed and perished on one of them. Amundsen never flew with Nobile across the Pole as indicated on your Arctic Ocean supplement map in the February 1983 NATIONAL GEOGRAPHIC.

Gerald H. Hagquist
Berlin, New Jersey

Roald Amundsen, along with Lincoln Ellsworth, flew with Nobile on the transpolar flight of the Norge *in 1926. The ill-fated flight of the* Italia, *which was a different airship, occurred in 1927.*

Allow me to add to your wonderful map a Dutch supplement. In 1596-97 the cartographer Willem Barents and Adm. Jacob van Heemskerck sailed to the Arctic. They wintered on Novaya Zemlya, and Barents died soon after. The names Barents Sea, Spitsbergen, Barentsburg, and other Dutch names recall their heroic voyage.

A. C. de Gooijer
Amsterdam, Netherlands

HUNGARY

In John J. Putman's "A Different Communism, Hungary's New Way" (February 1983), the map "Turkish Rule 1566" is incorrect and very misleading, because at that time the Turkish occupation covered only the center of Hungary. The western and northern portion of Hungary remained unoccupied under the rule of Ferdinand I, and the eastern part of Hungary, which is called Transylvania, was also not taken by the Turks. Transylvania was part of Hungary from the eighth century to when it was given to Romania by the Treaty of Trianon in 1920.

The Reverend László Hunyady
Colonia, New Jersey

At the height of Ottoman rule in 1566, Transylvania, like the principalities of Walachia and Moldavia, was a vassal state of the Turks and only nominally independent, and thus is not shown separately on this small map.

The only less sweet note in the on-the-whole Tokay-flavored article "Hungary's New Way" was the reference in the final paragraph to Communism wearing "a humanistic face." I would have opted to use the word "mask" instead. Mask implies a cover, a concealment from what's really behind it—in this case, the fact that Hungary is still a totalitarian, single-party-ruled state at the beck and call of its Soviet big brother.

Edwin P. Kulawiec
Washington, D. C.

Your excellent article on Hungary is marred by a historical error. It was not Emperor Charles III but Charles VI who was Maria Theresa's father.

Pedro J. Suarez
Dorchester, Massachusetts

Charles III of Hungary was Emperor Charles VI of the Holy Roman Empire, just as James VI of Scotland, when he succeeded Elizabeth I, was known as James I of England.

BEIRUT

Insinuations that Israel was the major cause of the destruction in Beirut (February 1983) reveal a political bias if not outright anti-Semitism.

Brian Schwartz
Lauderhill, Florida

I overheard a woman telling other women about the NATIONAL GEOGRAPHIC article on how the Israelis destroyed Beirut and killed its people. When I rechecked, I did not find it anti-Semitic.

Betty Hurwich-Zoss
Berkeley Heights, New Jersey

It is regrettable that William S. Ellis failed to mention that it was "Israel's wrath" plus the fact that "for ten weeks in the summer of 1982 the Israelis blockaded west Beirut" that finally brought peace to this unhappy and tragic city after eight terrible years of bloodshed. If, as Mr. Ellis says, "there is hope now that Beirut can rise from the rubble," let us at least offer some thanks to valiant little Israel.

Hy Grober
Teaneck, New Jersey

Your feature "Beirut—Up From the Rubble" was portrayed beautifully and in the classic tradition of NATIONAL GEOGRAPHIC, especially considering the political morass of that area.

Alan V. Clinscales
Springfield, Missouri

RAIN FORESTS

Your article on rain forests (January 1983) sounded an urgent need for environmentalists and naturalists in Malaysia to join hands to stop further forest exploitation. It is unfair not to consider also the allowance of a certain amount of land to be cleared for development, housing, industry, and cultivation to keep up with the ever growing population of a developing nation like Malaysia.

Vincent W. Y. Tung
Ipoh, Malaysia

Author Peter White replies: "My article brought forth the views of many people on three continents in favor of development as it affected them."

When quoting disputed figures, such as the 50 million acres of rain forests that disappear each year, and stating that magnificent timber is being devastated to satisfy the lunchtime chopstick citizens of Japan, I can only wonder just how much weight the mighty National Geographic Society carries with those who systematically eliminate the richest environment on earth, either for political or financial gain. You may presume that I am an active environmentalist who goes to jail and lies before timber trucks! In fact, I have never seriously thought about conservation; it was the powerful illustration and text that urged me to air passive opinion.

Richard Baker
Rayleigh, England

Letters should be addressed to **Members Forum,** *National Geographic Magazine, Box 37448, Washington, D. C. 20013, and should include sender's address and telephone number. Not all letters can be used. Those that are will often be edited and excerpted.*

On Assignment

"THE WHOLE of science is nothing more than a refinement of everyday thinking," wrote Albert Einstein. Had he been wrong about that, attempts to report on what is now known, or reasonably surmised, about the universe would stand about the same chance as a snowball in a black hole.

Some of the GEOGRAPHIC's universe team—enough for a pickup baseball squad, but by no means everyone who worked on that infinite story—assembled one Saturday in the bronze embrace of Robert Berks's sculpture of Einstein in front of the National Academy of Sciences in Washington, D. C.

Author ***Rick Gore*** had been first in the field. He was headed for Chile, to work on a story about the planets, when the focus suddenly expanded. The subject was now the universe, all of it. He then had an odd streak of luck. Almost everywhere he went, "the weather was rotten, terrible for observations, but fine for me. The astronomers had plenty of time to talk."

Photographer ***Jim Sugar*** has "little by little worked into scientific subjects. They're a graduate school of photography. I like to warm up my brain and see that it still works." He especially appreciates the combination of guidance and freedom given by illustrations editor ***Al Royce,*** celebrated for his meticulous research, crisp organization, and awful jokes.

FRONT, LEFT TO RIGHT: RICK GORE, BARBARA W. MCCONNELL, W. ALLAN ROYCE. CENTER: PATRICIA B. KELLOGG, JAMES A. SUGAR, BARRON STOREY, JAN ADKINS, DAVID JEFFERY. REAR, WILLIAM DOUTHITT
PHOTOGRAPH BY JOSEPH H. BAILEY

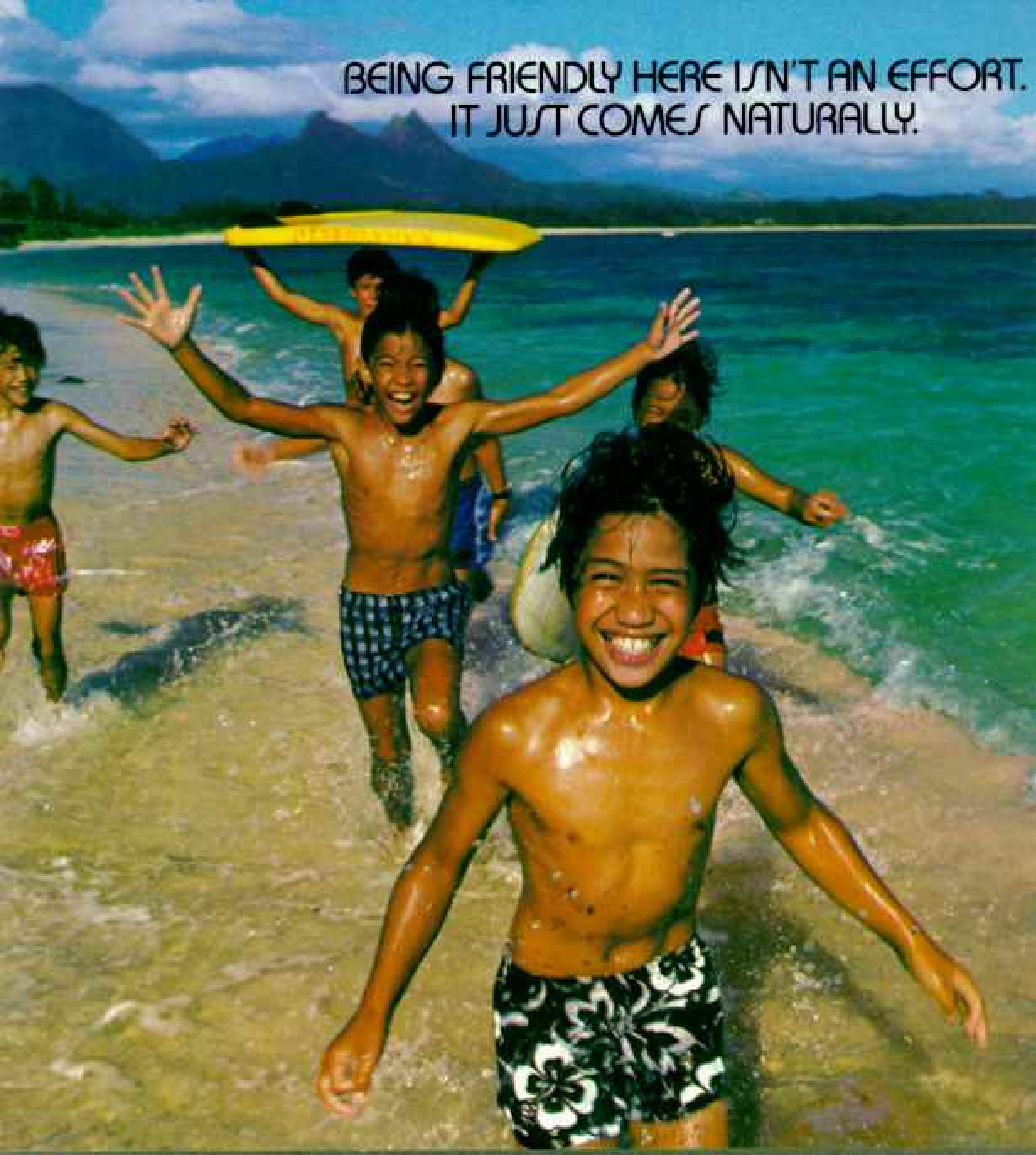
Art director for the project ***Jan Adkins*** (a sometime novelist and messer-about in small boats) worked with New York free-lance illustrator ***Barron Storey,*** who styled his paintings after the favorite teaching medium of astrophysicists even in this high-tech age—dusty chalk on screechy blackboards.

The story elements imploded back on headquarters like a supernova explosion in reverse. Layout editor ***Bill Douthitt***—who labors in a sunless interior room where writers, photographers, and other staff members wander in and out offering gratuitous advice—arranged and rearranged photographs, paintings, and text space to create a cohesive package.

With all the elements approved, it was then ***Dave Jeffery***'s task to write text for the photographs and paintings. Space was limited, but hadn't Einstein circumscribed the universe with $E=mc^2$?

Once text, photographs, illustrations, and captions were completed and pared to size, researchers ***Barbara McConnell*** and ***Pat Kellogg*** ("I volunteered. I wanted a mind stretcher") checked it all line by line, word by word, illustration by illustration with everyone quoted, consulted, and otherwise considered to be knowledgeable.

Accuracy is always a final aim, yet at its most fundamental, the universe will not submit to being verified. "The most beautiful thing we can experience is the mysterious."—Albert Einstein.



THE ISLANDS OF
HAWAII

In Hawaii, warmth is a way of life. It begins with our spectacular natural beauty. Warm wide sandy beaches. Dizzying waterfalls. Lush tropical rain forests. Kaleidoscopic sunsets.

And then there's our people themselves. A diversely rich blend of cultures, as warm and welcoming as the shimmering Hawaiian sun.

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Six Islands. One beautiful state.

COME FOR THE BEAUTY. STAY FOR THE PEOPLE.

In The Bahamas, you never run out of things to do. Until you want to. Get an earful of our islands. Explore a garden under the sea. Discover our warmth. Golf, sail, gamble, shop. Or renew yourself in the sun. All for so very few dollars—the most value at competitive prices. And it costs less to get here from most places in the USA.

For reservations or a brochure, including The Abacos, Andros, Bimini, Eleuthera, and The Exumas, see your travel agent or call 800-327-0787 toll free. In Dade County, 443-3821.

It's Better In The Bahamas

French bread.

If you plan to break bread in Europe, better take along BankAmerica Travelers Cheques. They're good for anything on the menu, in 160 countries around the globe. They're available in leading world currencies, and refundable in more than 40,000 places worldwide—including participating Hilton hotels and inns stateside.

But BankAmerica Travelers Cheques do more than travel well. These days, they come with free credit card cancellation and 24-hour emergency message service. They're also the only travelers cheques backed by BankAmerica Corporation, a leader among the world's foremost financial institutions.

In fact, to some bon vivants they're the only dough to carry.

BankAmerica Travelers Cheques. World Money.*

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FIND OUT HOW EXCITING ROOM FOR SIX CAN BE

1983 BONNEVILLE

You are in for a stimulating experience.

This is a car that was designed and engineered to civilize rough roads, as well as pamper you and your friends.

So go on, head for the open road. What you'll feel first is the quiet confidence of the standard 3.8 liter V-6 engine, or even more powerful available 5.0 liter V-8.

Then, as you encounter a curve, you'll see the real beauty of this exciting four-door sedan. And experience how smooth, responsive and comfortable our 1983 Bonneville really is.

This is what makes it a Pontiac. And what will make you a Bonneville lover.

Some Pontiacs are equipped with engines produced by other GM divisions, subsidiaries, or affiliated companies worldwide. See your Pontiac dealer for details.

GM

PONTIAC WE BUILD EXCITEMENT

The Toyota Tercel 3-Door Liftback really knows how to pinch a penny. Particularly when you purchase it. Because this front-wheel drive Tercel costs just $4998.* That's the same as last year. Not a penny more.

Tercel pinches pennies at the pump, too. The 1983 Tercel squeezes every gallon of gas to the tune of 50 Estimated Highway MPG, (39) EPA Estimated MPG. Remember: Compare this estimate to the EPA "Estimated MPG" of other cars with manual transmission. You may get different mileage depending on how fast you drive, weather conditions and trip length. Actual highway mileage will probably be less than the "Highway Estimate."

The 1983 Tercel. It lets you pinch pennies, but it *won't* pinch passengers. Tercel has more interior space than Honda Accord, Nissan Sentra, or VW Rabbit — more room than anything else in its class!**

Tercel doesn't scrimp on performance or durability either. It

OH WHAT A FEELING!
TOYOTA

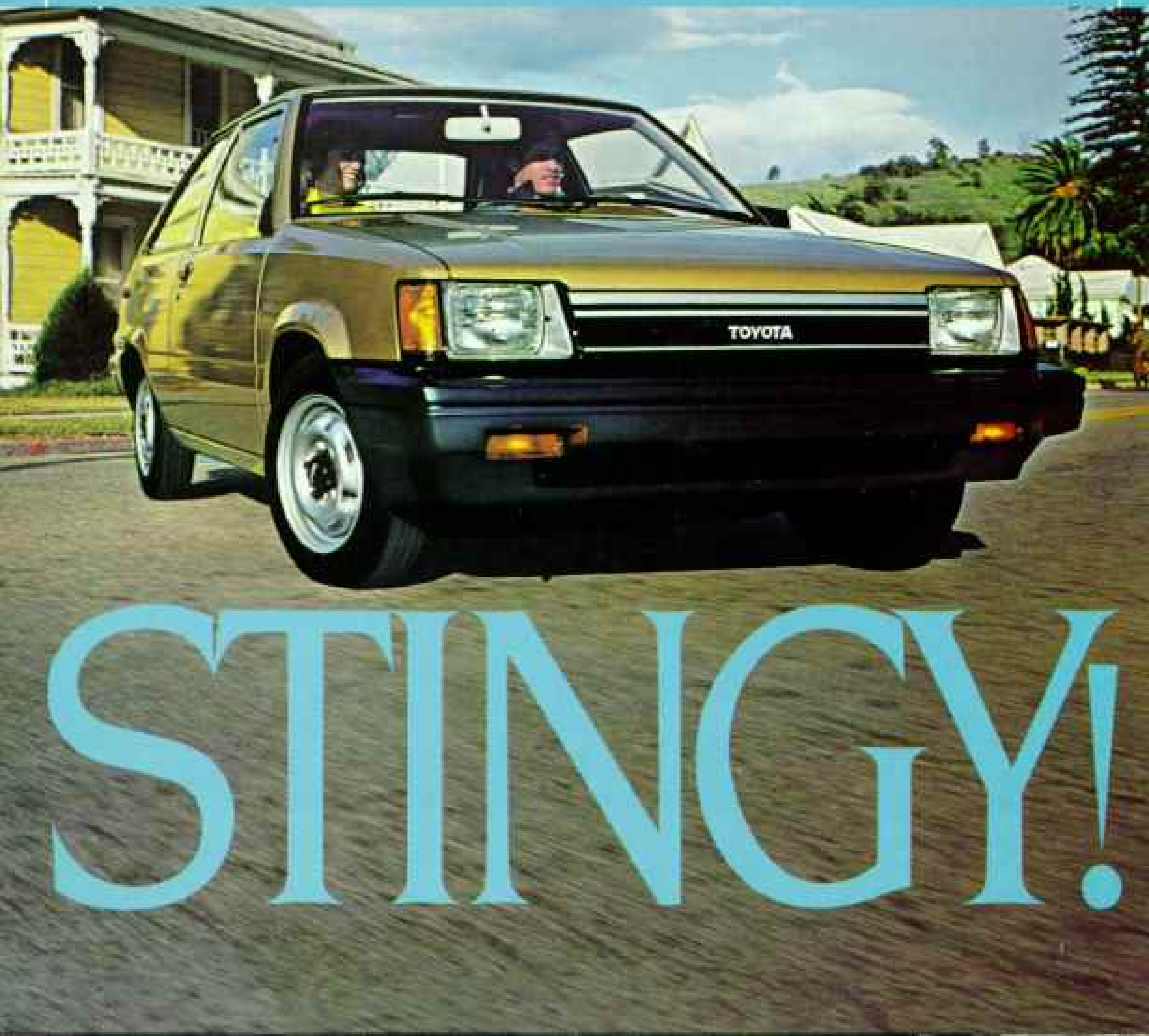
gives you a peppy 1.5 liter engine, rack and pinion steering, plus Tercel's body makes extensive use of galvanized steel to resist rust.

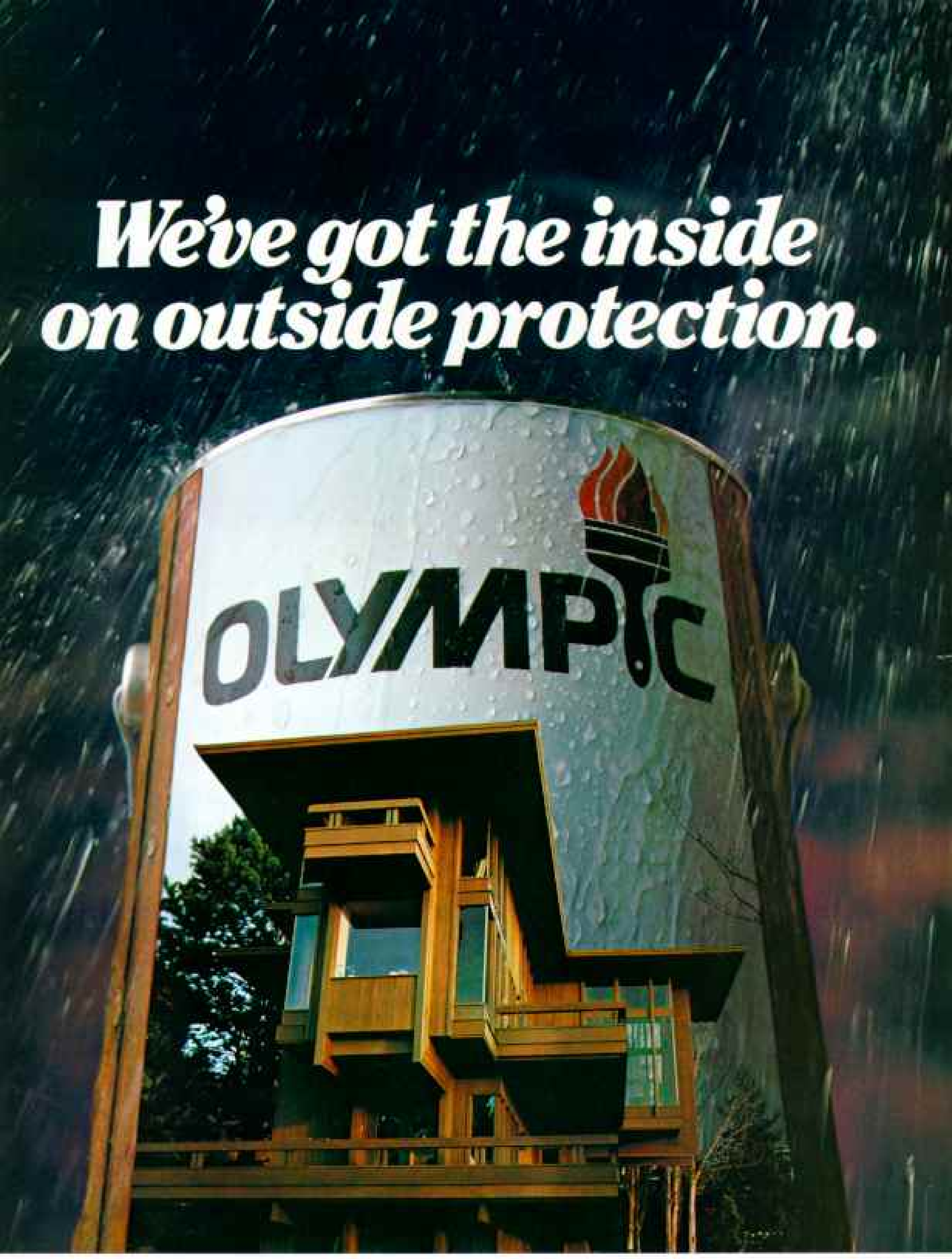
Be stingy. Pinch a penny, and listen to what it says. It'll say "Buy a Toyota Tercel!"

*Manufacturer's suggested retail price. Dealer's actual retail price may vary. Price does not include tax, license, transportation, optional or regionally required equipment.
**Subcompact car class as defined by EPA.

BUCKLE UP—IT'S A GOOD FEELING.

THE 1983 TOYOTA TERCEL PINCHES A PENNY UNTIL IT SAYS "OH WHAT A FEELING!"





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