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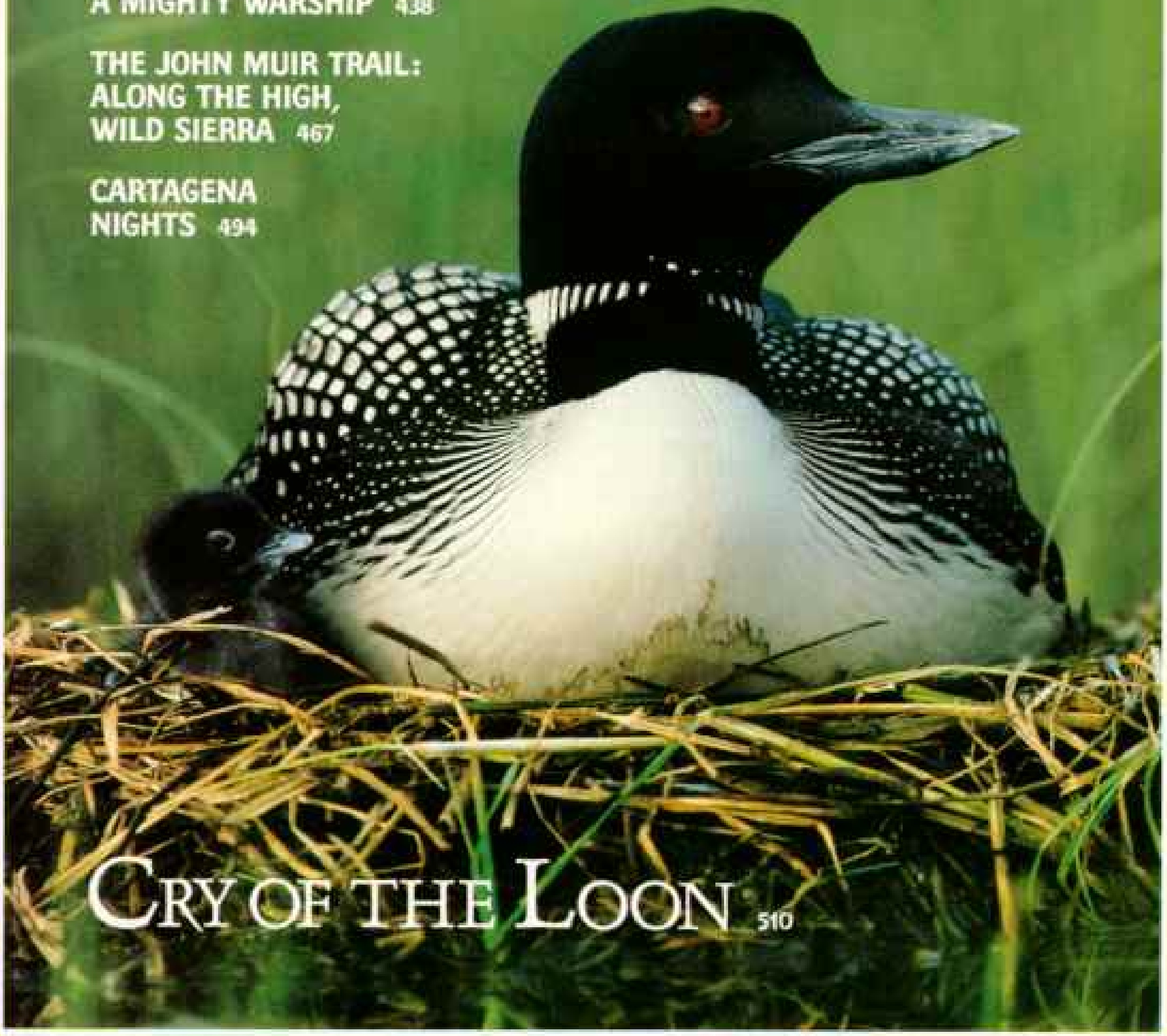
NATIONAL GEOGRAPHIC



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LOADING NUCLEAR WASTE

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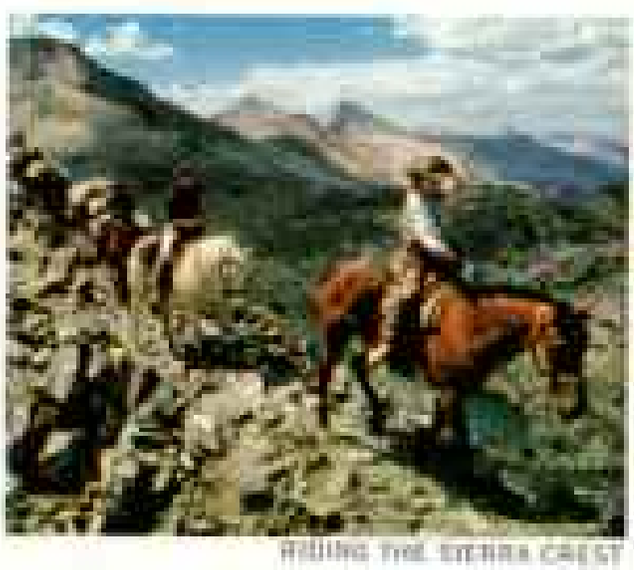
This invisible force has power to kill as well as cure. Charles E. Cobb, Jr., assesses the perils and benefits, from the atom bomb and radon to radiotherapy, X rays, and the controversial issue of nuclear power. Photographs by Karen Kasmauski.

SEAFLOOR YIELDS A CARVING

Kronan— Remnants of a Mighty Warship 438

The most powerful vessel of her day, Sweden's Kronan sank in 1676 with a loss of 800 lives, only a week after she first saw action. Naval historians have found her remains on the floor of the Baltic—and a microcosm of early shipboard life. By Anders Franzén, with photographs by Bill Curtsinger and paintings by John Berkey.



RIDING THE SIERRA CREST

The John Muir Trail: Along the High, Wild Sierra 467

From the summit of Mount Whitney to the valley of the Yosemite, author-photographer Galen Rowell explores the scenic 212-mile California trail named for the outspoken turn-of-the-century conservationist who devoted his life to preserving wilderness.

FAMILY FUN IN OLD CARTAGENA

Cartagena Nights 494

Carriage lamps and candlelight enhance the baroque facades of this historic Colombian port, whose massive battlements recall its reign as fortress city of the Spanish Main. By Bart McDowell, with photographs by O. Louis Mazzatenta.

LOON FAMILY PORTRAIT

The Common Loon Cries for Help 510

The unmistakable wail of this familiar water bird has been silenced on many North American lakes, where acid rain and other pollutants have spoiled its fishing and nesting spots. A high death rate in part of its winter range has raised new concerns about its future. Judith W. McIntyre and Michael S. Quinton report.

Cover: Environmental threats cloud the future for this common loon and a day-old chick. Photograph by Michael S. Quinton.

THE NATIONAL GEOGRAPHIC MAGAZINE
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SHUTTER OPEN

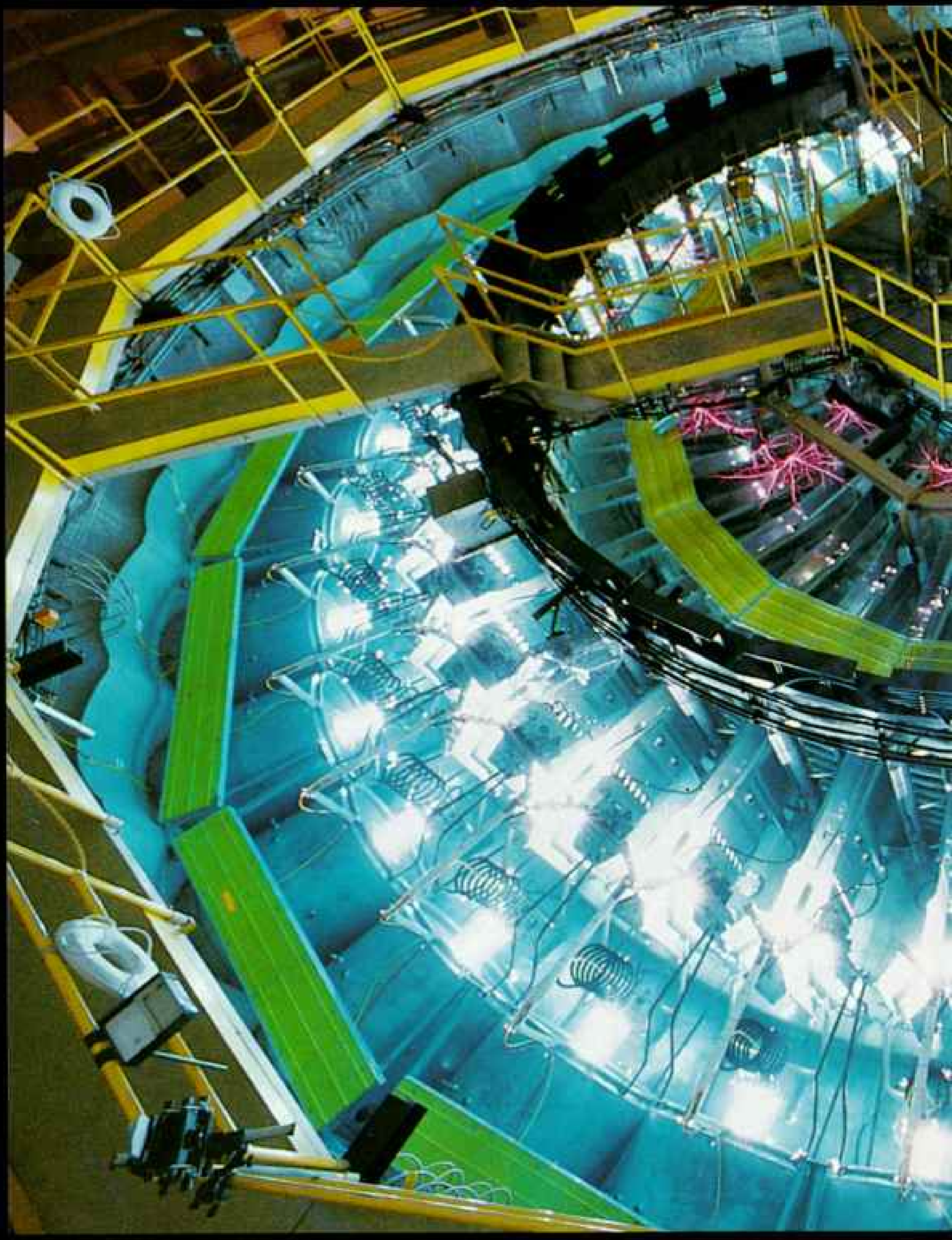
FROST

LIVING WITH RADIATION

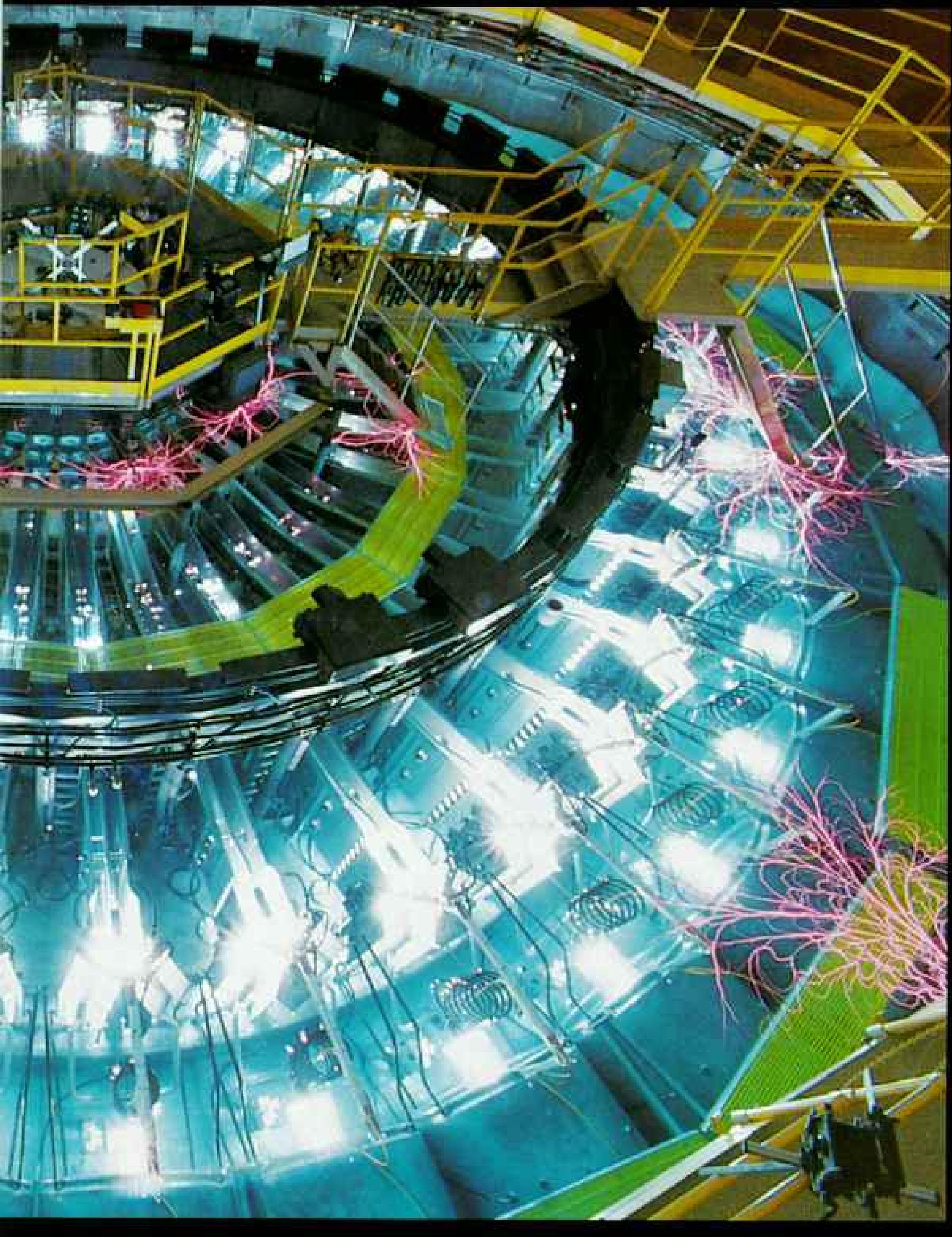
In an ultimate test of human judgment, radiation gives us the power to enhance our world or destroy it. For Bonnie Frost, radiation offers hope in her fight against cancer. At the University of California's Lawrence Berkeley Laboratory doctors pinpoint the tumor pressing against her spinal cord with a CT scanner, then treat it with heavy-ion radiation. The mask and brace keep her head perfectly still.

By
CHARLES E. COBB, JR.
NATIONAL GEOGRAPHIC EDITORIAL STAFF

Photographs by
KAREN KASMAUSKI



Attacks in space by radiation-producing weapons are simulated by the Saturn machine at Sandia National Laboratories in New Mexico, a site of Strategic Defense Initiative ("Star Wars") testing. From the perimeter of the 96-foot-wide tank, a 36-module accelerator fires 50 trillion watts of electricity at the center,



where the pulse of agitated electrons is converted into a beam of high-energy, noncontaminating radiation that simulates the X rays produced by nuclear-weapons explosions. In Saturn's core, the beam is focused on military circuitry and components, testing their ability to withstand massive doses under fire.

Scorched by the bomb, Hiroshima survivor Busuke Shimoe, 85, displays the jacket he was wearing on August 6, 1945, when the atom bomb exploded 1.3 kilometers away. Heat from the blast burned his body and fused the fingers of his right hand, but, astonishingly, he—and his clothing—survived. A crusader for disarmament,

Shimoe shows this charred cloth when words fail to describe the suffering he and other hibakusha, or atomic survivors, experienced. His wife and daughter were among the 210,000 who died in 1945 from the bombings of Hiroshima and Nagasaki. He is fighting cancer, a possible long-term effect of his exposure.

Bombed from below, the desert at the Nevada Test Site shows the cratered aftermath of nearly 600 underground nuclear tests conducted near Las Vegas by the United States and Britain. Craters form as soils displaced by the blasts settle back into cavities 500 to 2,500 feet below the surface. In the 1950s and early '60s the

Rhode Island-size facility conducted a hundred aboveground tests. Most testing went underground in 1963, with the signing of the Limited Test Ban Treaty. By then atmospheric blasts had added some 7 percent to the dose of radiation we receive naturally. In the years since, that figure has fallen to less than one percent.

THE ACCELERATOR pointing at Bonnie Frost's head resembled a ray gun that belonged in the bay of a spaceship. Outside the Lawrence Berkeley Laboratory, the California sun shone. Inside the vaguely intimidating accelerator complex, something called a wobbler hummed, creating "doughnuts" of energy.

Soon the electrically charged ions, circling the accelerator's 200-foot diameter a million times a second, would smash into Mrs. Frost's neck, striking the malignant cells of her chordoma, a massive tumor engulfing part of her spinal cord.

"This is radiation," Dr. Joseph R. Castro, chief of radiotherapy, explained, "but it does not cause harmful radioactivity. Not all radiation does." He meant that the accelerator particles do not transform into other tissue-damaging or cell-destroying elements. This plus the fact that the radiation burst peaks precisely on target makes the risk acceptable.

Mrs. Frost looked fragile and vulnerable when strapped into her chair before the formidable machine. "The first time," she said smiling, "I burst into tears and wanted to run away. All I could imagine was Darth Vader arriving. And then in walked little Dr. Castro."

I had met the slight Dr. Castro earlier. He made a remark that, I have since learned, governs every aspect of living with radiation: "You're always balancing risks against possible benefits."

Today, after six weeks of treatment, Mrs. Frost's tumor is under control, as are 80 percent of similar cases treated at the Berkeley lab. There is no question in her mind about the treatment's value. "People should be proud of this. It's a good, positive use of our tax dollar . . . and I happen to think I'm worth it."

My satisfaction with this success story conflicted with my feelings a few weeks later in Japan, at the other pole in the world of radiation.

Wang Sung Lee and his wife, Yong Le Bei, sat down before a desk at Hiroshima's A-Bomb Survivors Relief Department. On the desk in front of the Korean couple lay a map of Hiroshima with concentric circles indicating half-kilometer increments from the hypocenter of the first atom bomb ever dropped on a city. If they prove they were directly exposed to the bomb's radiation, they become eligible for free medical treatment.

I wondered why they had waited until 1988 to present themselves as A-bomb survivors. Mr. Lee explained that they had two daughters to think of. Although they were born years after the atom-bomb attack, potential husbands still might think them genetically injured and refuse to marry them; physical imperfection carries a taint in Japan. So the couple had waited, hoping their daughters would marry. In Japan I found that social stigma is one of the most widespread and incurable manifestations of radiation's effects.

RADIATION. Hardly a word in any language generates more anxiety. And living with radiation can in fact be frightening. Plants making nuclear-weapons materials also pollute our environment. Three Mile Island and Chernobyl, as well as other nuclear power plant accidents, have alarmed us. Nuclear waste is piling up.

Yet radiation, coupled with human ingenuity, performs many beneficial works also: Destroying the malignant cells of Bonnie Frost's tumor, sterilizing medical products and foodstuffs by killing harmful bacteria, tracking the progress of medicines through the body with radioisotopes and attacking cancer cells from within, dating archaeological and geologic events by radioactive decay rates, turning water to steam for electric power, and—soon—detecting plastic explosives in suitcases.

This means that for good or ill, radiation will remain an important part of our lives. To live with radiation is indeed to constantly weigh its risks against its benefits. Everywhere I traveled, I heard this debated. I found that definite answers were elusive, scientific knowledge worryingly incomplete, and opinion often contradictory.

Said Dr. Karl Z. Morgan, an early pioneer

Relieved of her immobilizing mask, Bonnie Frost sits unharmed after a dose of radiation. The type used in her treatment delivers peak energy precisely at her tumor, allowing doctors to use a significantly higher dose with little damage to healthy tissue.

in health physics: "It is incontestable that radiation risks are greater than published."

But said Dr. Norman C. Rasmussen, a nuclear engineer at the Massachusetts Institute of Technology: "There is a lot of evidence that low radiation doses not only don't cause harm but may in fact do some good. After all, humankind evolved in a world of natural low-level radiation." Said Richard Guimond of the Environmental Protection Agency: "We can't avoid living in a sea of radiation."

Almost all this exposure—some 82 percent in the U. S.—comes from natural sources. Cosmic and solar rays keep up a steady drizzle of gamma rays and heavy particles; solar storms vastly intensify these showers. Earth's atmosphere shields us from most celestial radiation; persons living at sea level receive far less than, say, residents of mile-high Denver.

Additional radiation emanates from rocks, soils, and groundwater. A common radioactive element is radium, one of whose decay products, radon, causes mounting concern.

Indeed our entire ecosystem hums with low levels of radiation, and that includes us: Radiation originates within our bodies, particularly with the decay of radioactive potassium in our muscles.

Man-made radiation—the other 18 percent—comes from everyday sources, primarily from medical X rays. Radioactive sensors activate 26 million household smoke detectors. Uranium gives the gleam to false teeth. Mantles in camping lanterns emit radiation.

BUT just what is radiation anyway? Although the term is broad enough to include sunlight and heat, radio waves and microwaves, it is most often used to mean ionizing radiation. Every radioactive substance contains unstable atoms, or radionuclides. They want to become something else—something stable—so they change or decay. With each change energy is released. A radionuclide may transform itself many times before becoming stable. An atom

of radioactive uranium 238 goes through 14 changes before stabilizing as lead 206. These sequences are known as decay chains. That energy—or radiation—produces charged particles or ions from once neutral particles.

If body tissue and cells become ionized, abnormalities in DNA can result. Cancer and birth defects can also result from exposure to ionizing radiation.

Some radiation takes the form of particles: alpha and beta. Some comes in the form of high-energy electromagnetic waves: X rays and gamma rays. And there are neutrons too, some emitted by devices humans make.

The energy of radiation moves invisibly. That helps account for the fear it instills. I saw evidence of radiation at Sandia National Laboratories in Albuquerque, New Mexico. Fuel rods of a nuclear reactor were emitting beta particles in crystal-clear water 30 feet deep. As they slowed down, the particles created a soft blue light known as Cerenkov radiation. "We keep the water pure," said nuclear engineer Theodore Schmidt. "You could drink it." But I didn't want to.

RADIATION'S POWER and mystery exacerbate a deep cultural anxiousness.

"Myths have become attached to radiation," said Dr. Spencer Weart, director of the Center for History of Physics at the American Institute of Physics. "One of the oldest is ray symbolism."

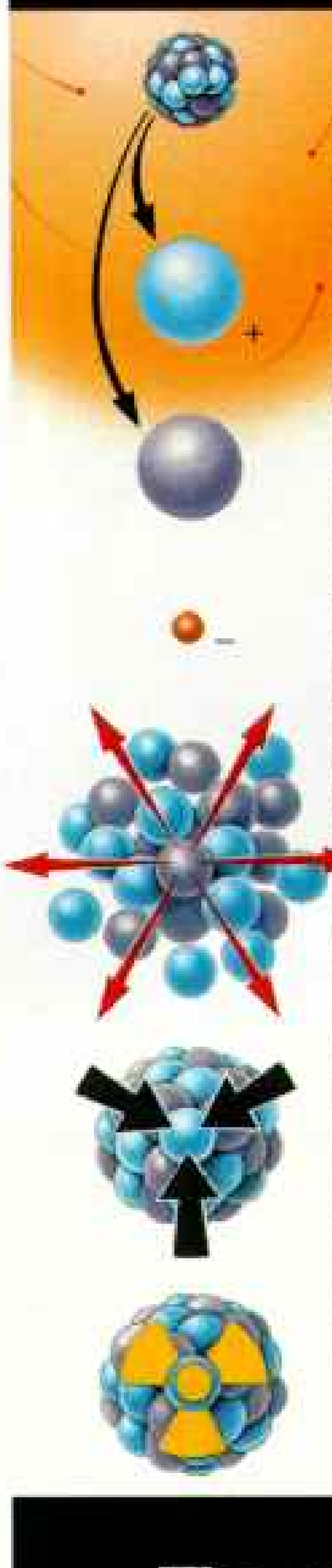
Since far back in human history, he explained, rays have been associated with gods, sometimes illuminating their image, sometimes hurled with destructive force. Death rays, as in the old Buck Rogers stories—incinerating, transforming, enslaving—have filled science-fiction novels. And the coming of nuclear weapons has reinforced the old imagery. "So long as people worry about nuclear destruction," said Dr. Weart, "radiation will cause anxiety."

Further, secrecy has shrouded many radiation projects. And with the secrecy have come suspicion and anger, particularly in matters of health and public safety.

"You go to bed with aches and pains, and the doctors can't tell you anything. Suddenly you discover you have cancer here, cancer there, and you didn't even know about it. And you wonder, 'What the hell is going on here?'" Bob Grix is one of an estimated 200,000 military veterans who participated in

Inside the atom

1 All matter is made up of atoms, and all atoms are composed of a dense nucleus surrounded by orbiting electrons.



The NUCLEUS is made up of protons and neutrons.

PROTONS have a positive charge. Atoms of a certain element always have the same number of protons. Carbon, for example, has six protons; adding one proton changes it into nitrogen.

NEUTRONS have no electrical charge. Atoms of a particular element can contain varying numbers of neutrons. These variations are called isotopes and are noted by the total number of neutrons and protons they contain (carbon 12 or carbon 14, for example).

ELECTRONS have a negative charge. The number of electrons in an atom usually matches the number of protons, making the atom electrically neutral.

Since like charges repel, the protons (+) in an atom constantly threaten to make the nucleus fly apart.

However, a powerful, localized strong force binds the nucleus together, despite the electrical repulsion of the protons. Neutrons help balance these opposing forces.

Some atoms wind up with too many or too few neutrons to maintain this balance. Such atoms are radioactive isotopes, and they seek stability by giving off energy in a process called radioactive decay.

The roots of radiation

Although scientists are still learning about this basic phenomenon, most believe that radiation has always been present in the universe. The release of energy from an atom is called radiation, and it takes two basic forms. Ionizing radiation travels in waves (X rays, gamma rays) or as particles (alpha,

The nucleus seeks stability

2 Nuclei have only a few ways to create a stable balance of protons and neutrons. Most of these ways produce radiation, in the form of subatomic particles or rays.

Types of ionizing radiation

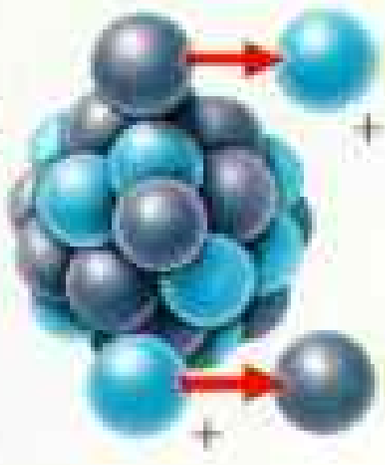
3 Ionizing radiation exists as particles, such as alpha and beta, and as waves, which are part of the electromagnetic spectrum. Their effects vary, but all can be deadly in large doses.

ALPHA

A nucleus can eject two protons and two neutrons, reducing its mass and transforming itself into a different element. The ejected foursome is called an alpha particle.

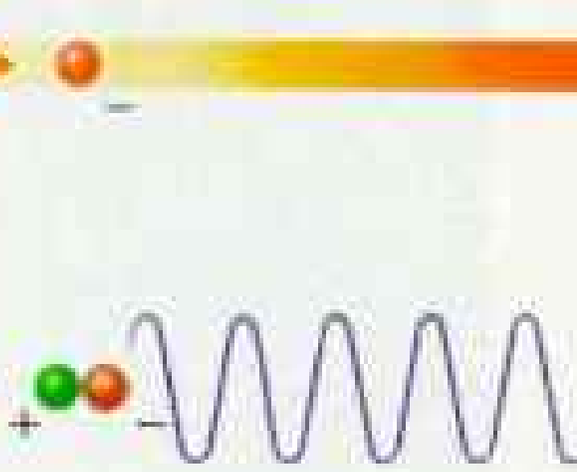
Slow-moving alpha particles carry a positive charge. They cannot penetrate a piece of paper or skin but are very dangerous when substances emitting them are ingested or inhaled.

BETA



A neutron can become a proton, emitting an electron (-) called a beta particle. A proton can also turn into a neutron, emitting a positron—a positively charged particle that can combine with an electron to produce a gamma ray.

Moving at nearly the speed of light, beta particles can penetrate paper or several millimeters of skin. Like alpha particles they can be harmful when emitted inside the body.



GAMMA

An unstable nucleus can sometimes remain agitated, even after emitting alpha or beta particles. Then it may rid itself of excess energy by emitting a gamma ray—a short, intense burst of electromagnetic energy.

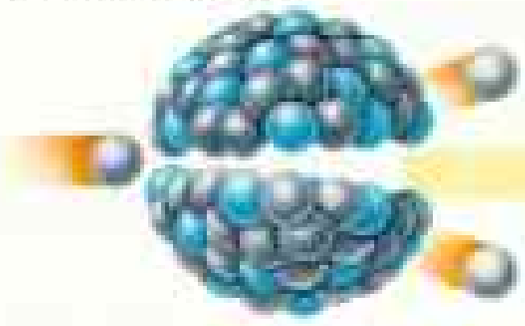
With high energy and no electrical charge, gamma rays have great penetrating power. Not even a thick piece of lead or concrete will stop all of them, and they pass easily into the human body, damaging tissue in the process.

X RAYS

X rays are not usually emitted by decaying nuclei but are a form of cosmic radiation. They can also be produced by firing electrons at a heavy metal target. When the electrons hit the metal, they release their energy as X rays.

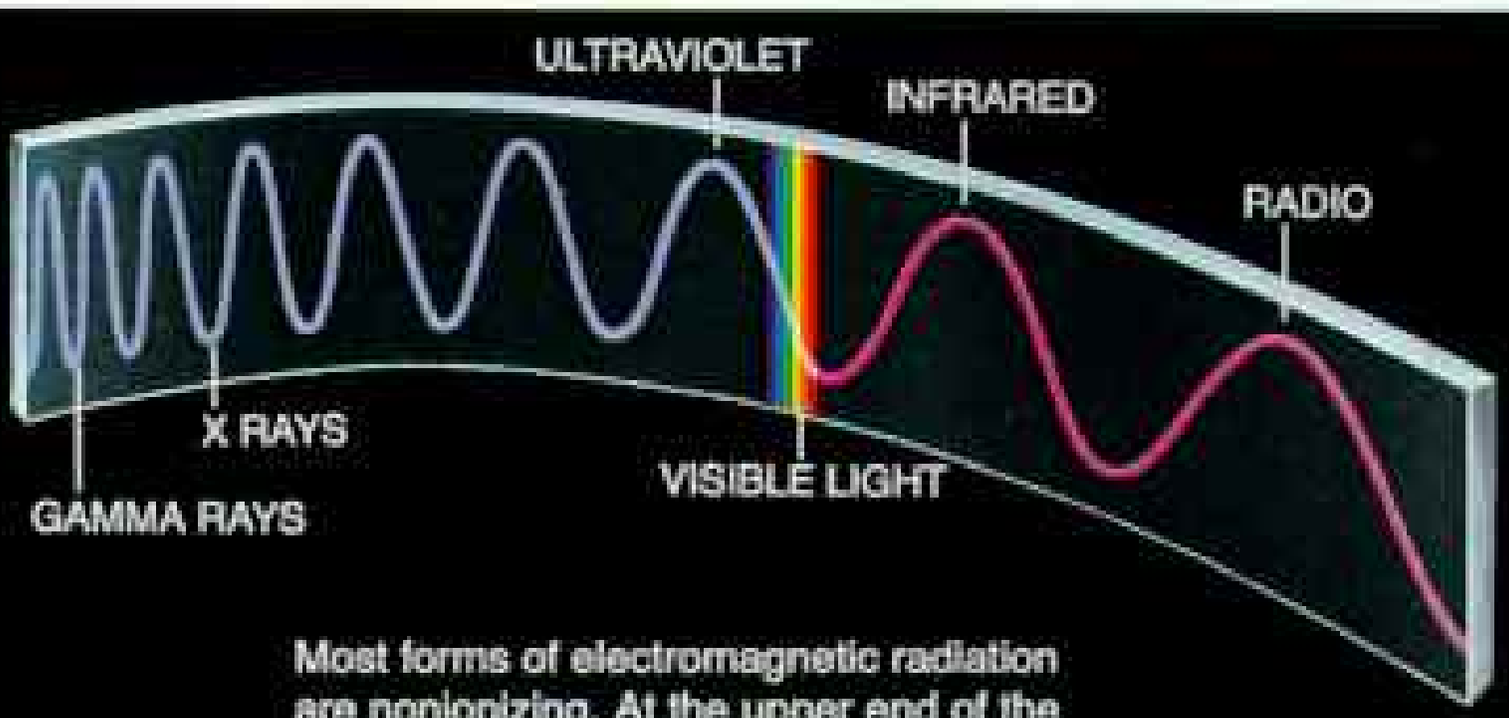
X rays are somewhat less penetrating than gamma rays, though their effects are similar. X rays too can ionize the atoms in living tissue.

NEUTRONS



Neutrons, ejected from the nucleus by nuclear fission and other processes, are emitted in great numbers during nuclear chain reactions.

When neutrons collide with an atom, they can induce radioactivity by combining with its nucleus. After an aboveground nuclear explosion, the landscape is contaminated with this radioactivity.



Most forms of electromagnetic radiation are nonionizing. At the upper end of the spectrum, however, are several types with very short wavelengths—X rays and gamma rays—that deliver bursts of energy high enough to ionize atoms.

beta) and carries energy levels so high that it can alter atoms, creating electrically charged particles, or ions. Nonionizing radiation (radio waves, heat, light) carries enough energy to excite atoms but not enough to create ions.

DIAGRAMS BY MARK SEIDLER

atmospheric nuclear testing. Some 20,000 engaged in troop maneuvers near ground zero soon after test shots. Another 160,000 "atomic veterans" were part of the U. S. occupation forces in and around Hiroshima and Nagasaki in 1945–46.

Some Americans, according to a congressional report, were used as "nuclear guinea pigs." They were deliberately injected with uranium and plutonium in experiments sponsored by predecessors of the Department of Energy. Sometimes experimenters even fed subjects fallout from an atom-bomb test, had them breathe radioactive air, had some eat radioactive fish.

In all, more than a million Americans have been exposed to greater-than-normal amounts of radiation: workers in weapons facilities, hospital technicians, "downwinders" from the Nevada Test Site, uranium miners.

In December the Department of Energy reported and ranked in terms of hazard 155 cases of contamination at 16 weapons plants and labs. In one of the worst cases, at the Idaho National Engineering Laboratory, radioactive waste has fouled the Snake River aquifer.

As doctors examined the strange burn on his leg, Ernesto Fabiano (left) told about the little cake of blue powder that had passed hand to hand through his neighborhood in Goiânia, Brazil. Like the glitter worn during Carnival, it had an irresistible glow. So he had put a piece in his pocket. Now he could hardly walk.

Elsewhere in Goiânia the luminescent powder was having equally disturbing effects. The junk dealer who had discovered it inside a steel cylinder became violently ill. So did his six-year-old niece, who had playfully rubbed it on her face, then eaten a sandwich. Soon the awful truth was known: The cylinder was part of a radiotherapy machine, scavenged from an abandoned medical clinic in 1987. And the powder was the lethal isotope cesium 137.

In all, 249 people were contaminated during the accident. Four died, including the junk man's niece. All were buried in lead-lined coffins. Their graves (below), closely monitored for radioactivity, bear witness to the need for improved regulation.

Civilians have filed many claims against the government, most of them so far unsuccessful. Of the legislation introduced in Congress on behalf of possibly exposed populations, the most important seeks to amend a law that forbids holding the federal government liable in radiation cases involving national policy.

An unresolved scientific issue lies at the root of all these cases. How much radiation is too much? The answer affects how we will live with radiation in the future.

The effects of radiation are determined by the amount, or dose, received, by the kind of radiation, and by where and how the body is irradiated.

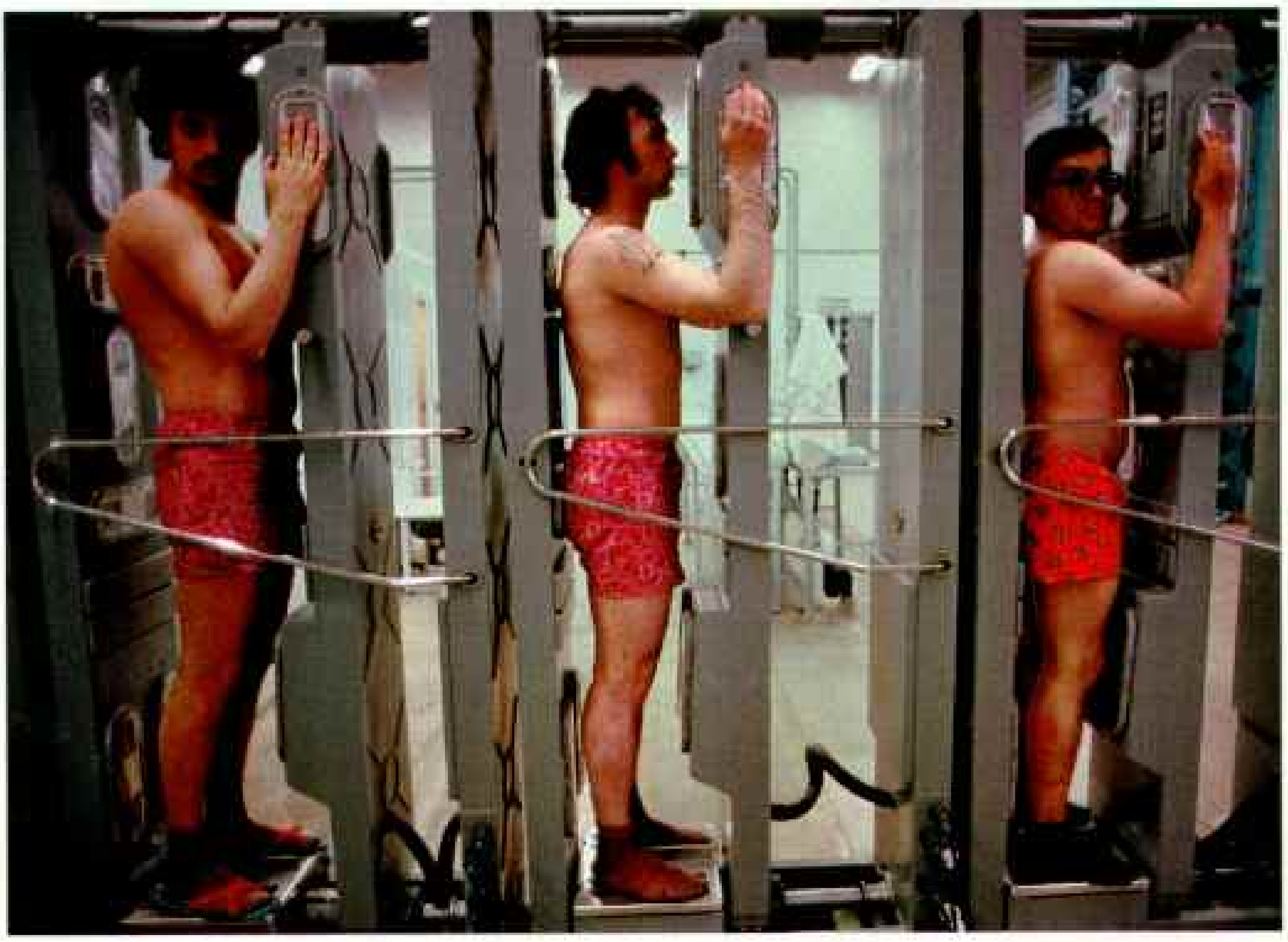
The amount of radiation absorbed per gram of body tissue is expressed in rad. That term is being replaced by a new international unit known as a gray (1 gray = 100 rad). Any dose must be weighted for damage potential. This is expressed in rem. The international unit is a sievert (1 sievert = 100 rem).

The effects of large amounts of radiation are well-known. A dose of 10,000 rem will kill quickly, through damage to the central nervous system. A dose of 300 rem delivered to the

Eerie silence accompanies a Soviet cleanup crew on the deserted streets of Pripyat (right), which once bustled with 45,000 residents, many of them workers at the Chernobyl nuclear power plant five kilometers away. That changed on April 26, 1986, when a massive explosion rocked Chernobyl's reactor number 4, spewing tons of uranium fuel; cesium and other contaminants shot skyward in a radioactive plume five kilometers high. Along with everyone else within a 30-kilometer radius, the people of Pripyat were evacuated. Today radiation levels are low enough to allow unshielded workers into Pripyat for short visits; resettlement is still decades away.

Though 30 people died in the tragedy, most citizens living nearby escaped sizable doses of radiation. Yet the accident (less severe, perhaps, than a little-known explosion of radioactive material near Chelyabinsk in 1958) has irrevocably changed the lives of people here. Workers at Chernobyl (below) routinely strip to their shorts and step through a radiation detector before heading home. And at Kiev's radiological institute sisters from Pripyat (facing page) are regularly examined for early signs of leukemia or thyroid problems. They will be monitored for life by the institute, which helps examine nearly 700,000 people, a third of them children.

Harder to measure, perhaps, is the psychological trauma of living near Chernobyl. Soviet doctors have noticed a tendency to blame any and all ills on radiation—an affliction they are calling radiophobia.

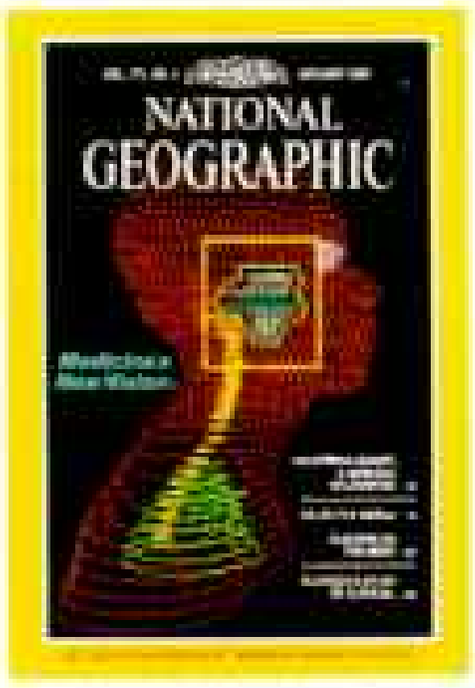


whole body is lethal about 50 percent of the time. Between 300 and 100 rem, radiation injury is probable.

RISKS are extrapolated all the way down to zero, in what scientists call a linear assumption. This assumption, however, is viewed as conservative in the sense that it may overestimate the risks of low-level radiation. Effects at below ten rem, say, are unclear, partly because they are blurred by all the other influences that affect our health. Residents of New Orleans receive only half the radiation dose of Denverites, yet the cancer death rate in New Orleans is higher than in Denver. This is the result of other "confounding factors" such as smoking, or automobiles, or even eating habits. In fact more than 300 agents besides radiation can cause cancer.

Is there a possibility that the body's mechanisms for repairing radiation damage may be more efficient at low levels? Put another way: Is there a threshold below which radiation will have no effect?

Few scientists think so any more. Said Dr. Arthur C. Upton, chairman of the New York University Medical Center Department of Environmental Medicine: "Any radioactive track can, in principle, deposit enough energy to cause a mutation." But, Dr. Upton stressed, at low levels "it would be a prodigious task to prove" what the biological effect is.



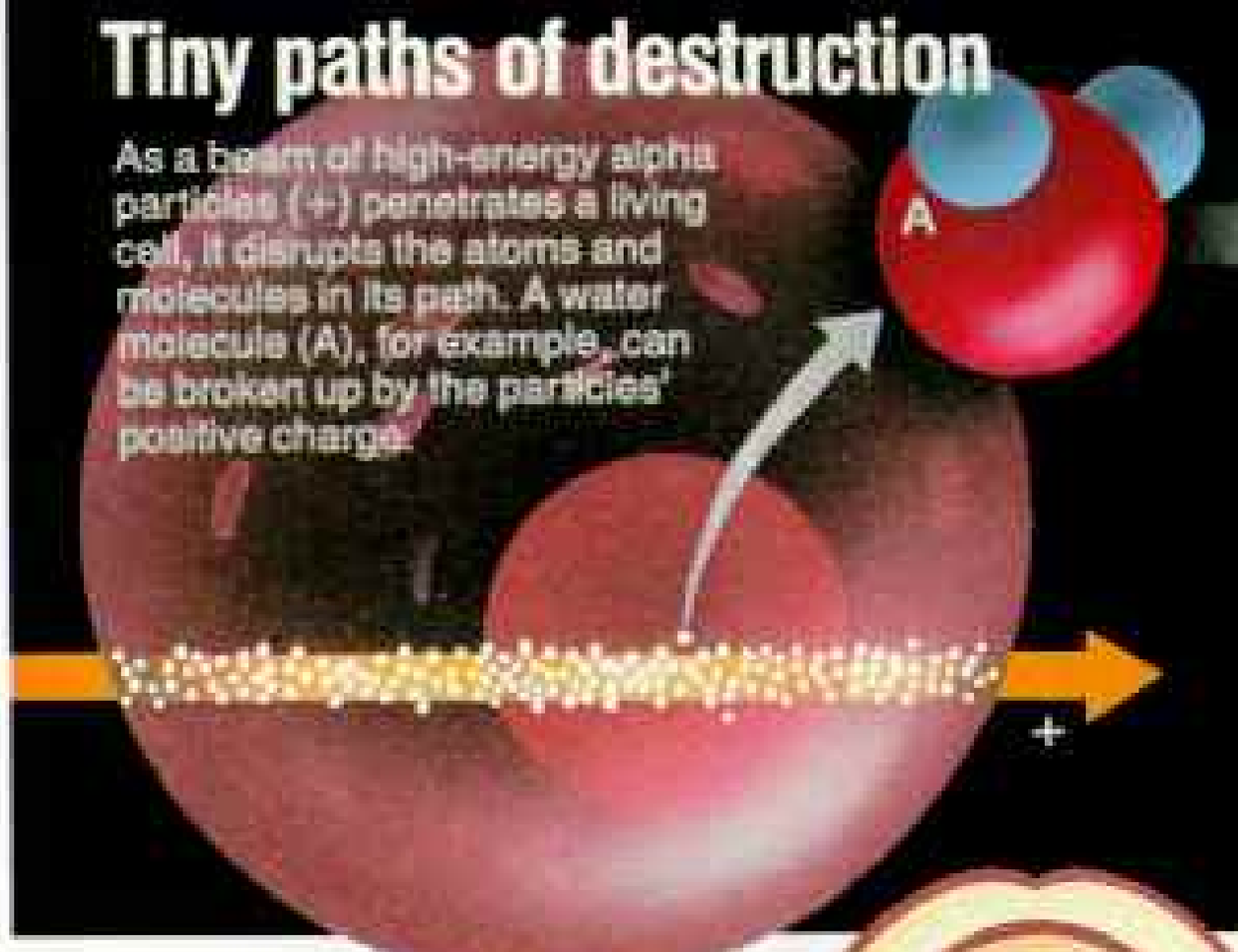
MEDICAL ASPECTS OF RADIATION WERE COVERED IN THE JANUARY 1987 ISSUE OF THE NATIONAL GEOGRAPHIC.

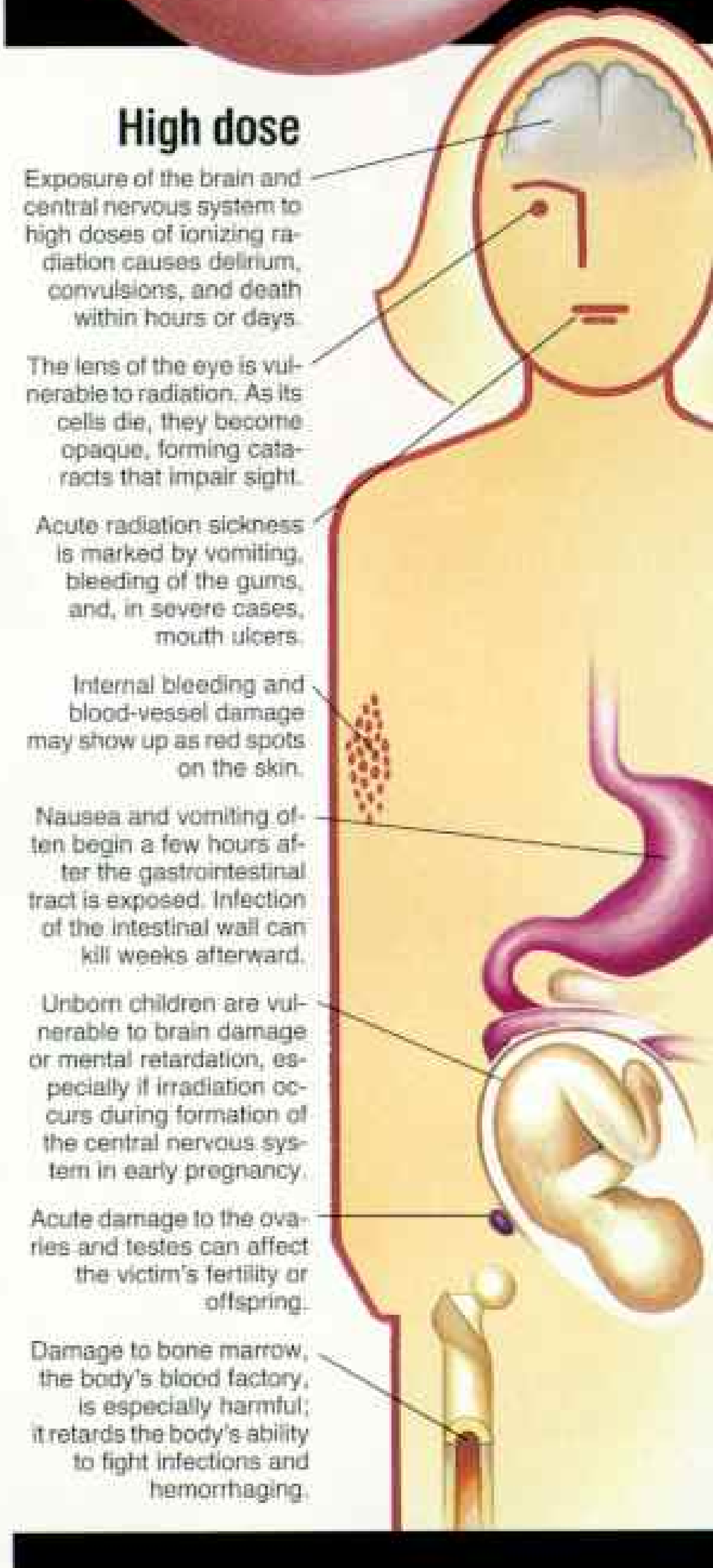
Detection at low levels, said Dr. Upton, is "like trying to listen to one violin when the whole orchestra is playing. You can't hear it."

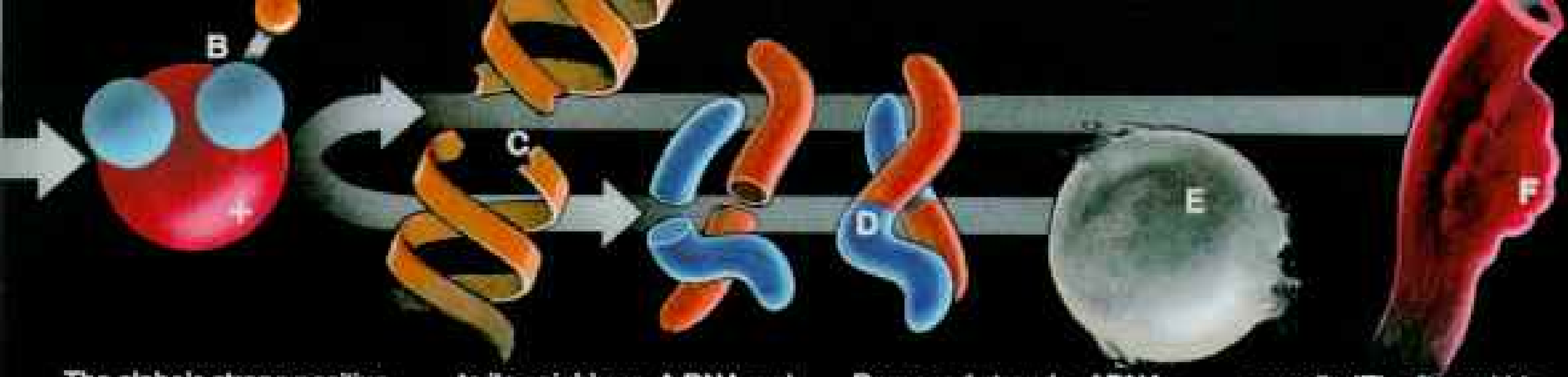
That is because the scientific establishment is not listening hard enough, argues Dr. John Gofman, one of the two scientists to isolate the world's first workable quantity of plutonium and a co-discoverer of uranium 233.

Dr. Gofman's analysis of A-bomb survivors leads him to the startling conclusion that the risk of cancer death per rem increases as the radiation dose decreases. He calls this supralinearity. "We don't know what mechanism causes it," he acknowledged, "but radiation effect is steepest at the lowest levels."

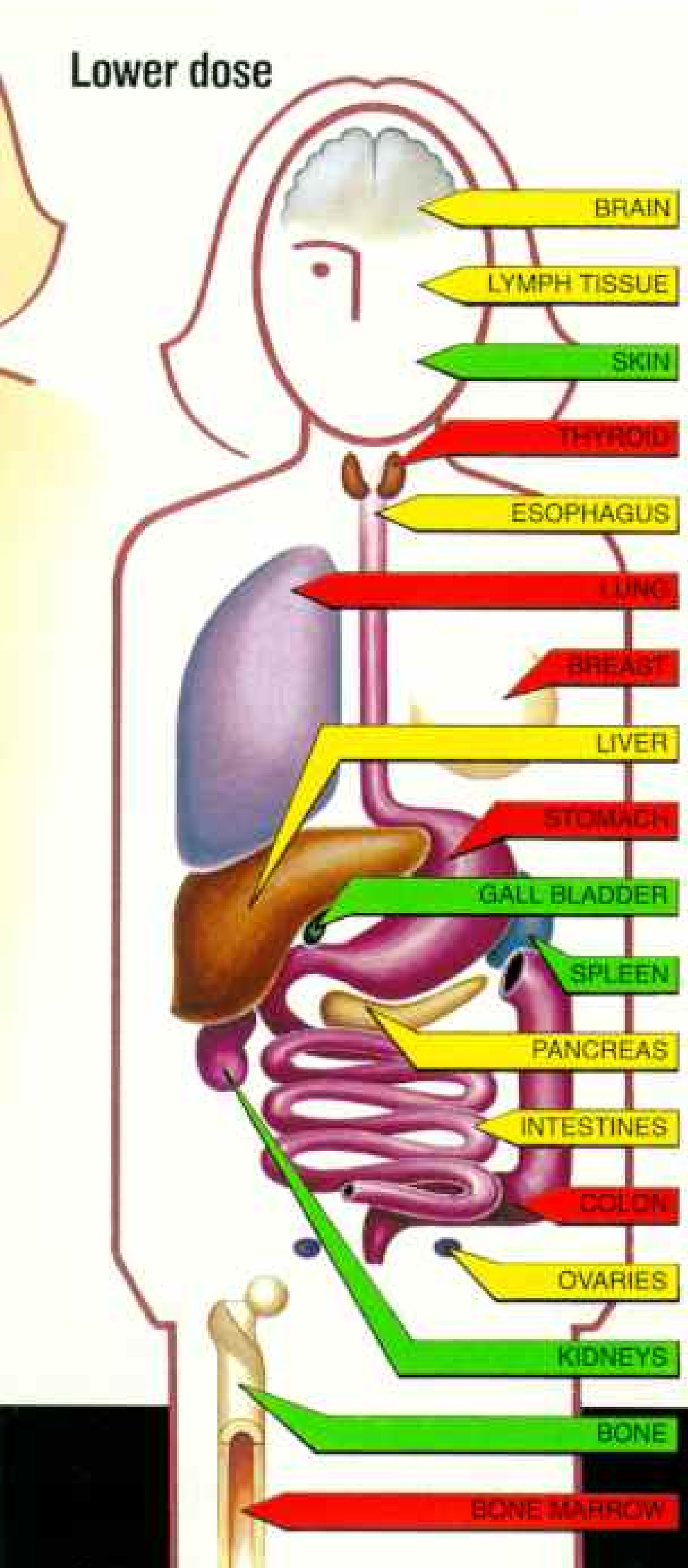
Few scientists I talked with find his theory







The alpha's strong positive charge strips the water molecule of an electron (-), forming ions (B). The water molecule's neutral charge has become a positive one, destabilizing its relationship to its neighbors. A DNA molecule (C) can also be broken apart or altered by alpha particles or ions. Sometimes the DNA's genetic code is scrambled, then reproduced in later generations. Damaged strands of DNA can cause chromosomes to break apart, then recombine in an abnormal fashion (D). Unless the body's repair system can isolate and overcome the damage, the cell may die (E), often within hours. DNA molecules altered by radiation, but not destroyed, may reproduce abnormally for years, spawning cancerous cells and, eventually, tumors (F).



Radiation's effects on the body

Think of ionizing radiation as the atomic equivalent of a bull in a china shop. When it penetrates living tissue, it wreaks havoc on the atoms and molecules in its path, setting off a chain of events that can destroy living cells or make them function abnormally. That is why large doses of ionizing radiation can kill quickly or inflict severe damage (far left)—and why nonlethal doses can initiate cancers throughout the body (left) that may prove deadly years later.

Studies of people who have received significant doses (such as atom-bomb survivors, uranium miners, and radium watch-dial painters) show that damage depends on how they were exposed, the dosage, and the type of radiation. Scientists know that human organs can repair some radiation damage, although many questions persist: How harmful is the background radiation we live in? Why are some organs more vulnerable than others? And why do some individuals seem more resistant to radiation's harmful effects?

SENSITIVITY RATING INFORMATION PROVIDED BY THE NATIONAL COUNCIL ON RADIATION PROTECTION AND THE UNITED NATIONS SCIENTIFIC COMMITTEE ON THE EFFECTS OF ATOMIC RADIATION 1988 REPORT

DIAGRAMS BY MARK SEIDLER

LOW SENSITIVITY
MODERATE SENSITIVITY
HIGH SENSITIVITY

credible. Said Dr. Upton: "There is no proof that a millirem does or does not do anything. One is in the position of making guesses."

Still, it seems unwise to completely dismiss Dr. Gofman's findings. Radiation standards are still evolving. A variety of studies hint that radiation-exposed workers may be more at risk than previously thought. And, in this inexact science, it seems that minority voices have been more right than wrong.

LIFE AND DEATH, hope and fear, known and unknown—all are tightly bound in the realities of living with radiation.

Hiroshima: Monday morning at 8:15, August 6, 1945. "It was a very fine day. Suddenly, like a flashbulb going off, a kind of blue covered the entire city," recalled Mrs. Fumie Katayama, who said she was 900 meters from the hypocenter of the bomb.

She fled toward the hills surrounding the city. As she ran, black rain fell, caused by the tremendous heat and dust clashing with the chilly atmosphere. Later Mrs. Katayama would learn that the debris blackening the rain was radioactive.

From her hillside refuge she looked across the flattened city. "Smoke and fire twisted as if reaching all the way to heaven." Then a month later: "My hair started to fall out, my eyebrows too; I had very beautiful eyebrows before the bomb."

In Hiroshima the bomb and its aftermath are an ever present frame of reference. About a third of those living before the bomb was dropped are still alive. Many, like Mrs. Katayama, think every illness is associated with the bomb. "You cannot escape from the bad effects of radiation," she told me.

Exhaustive studies conducted in Hiroshima show that heavily exposed *hibakusha*, bomb-affected people, have a 29 percent greater chance than normal of dying from cancer.

"Any person who talks about radiation will always use our data," said Dr. Jacob Thiessen of the Radiation Effects Research Foundation, which is jointly funded by the Japanese and United States governments. The RERF and its predecessor have been investigating radiation effects since 1947.

Even here not everything is clear. "We cannot say what are purely A-bomb effects," explained Dr. Akio Awa, who heads the RERF Department of Genetics. "Survivors live like the rest of us. Some smoke. Some eat broiled fish"—another suspected source of carcinogens.

Excess cases of leukemia began appearing in the late 1940s, but by the early '70s the rate leveled off nearly to that of the general population. Today the life expectancy of hibakusha may be a little *longer* than that of unexposed Japanese, perhaps because of more regular medical care.

To estimate the radiation exposure of A-bomb victims, the U. S. government in the 1960s built a test city in Nevada and exposed it to an unshielded nuclear reactor. Sensors recorded the doses at various distances and in different conditions of shielding by houses and other structures. The results provided the basis for early dosage-injury estimates.

Now the RERF realizes that the test houses were built more flimsily than the Japanese houses. Most important, the dry Nevada air filtered out fewer neutrons—a prime cause of cancer. Thus the hibakusha received less neutron radiation than originally estimated.

So did bomb-induced cancers result from lower doses? Yes, says the RERF. "The new dosimetry system has changed the doses upon which risk is calculated, resulting in an increase if we use the body-surface dose," explained Dr. Thiessen.

What about the specter of genetic deformity? Astonishingly in a sample of 16,000 children, half of whom were born to hibakusha, the frequency of chromosome damage was five in a thousand for the exposed group and six in a thousand for the control group.

Surprisingly no genetic evidence suggests generations to come are doomed. Tests on mice and fruit flies show harmful results. So why not in humans? Spontaneous abortions, perhaps, or some remedial effect of the lengthy human gestation period. Said Dr. Thiessen, "We would like to find some directly measurable effect. Right now we don't see anything."

I FOUND it easier to detect a social effect.

"Only a few people are really trying to understand the difficulties faced by the hibakusha," said Minoru Ohmuta of *Chugoku Shimbun* newspaper. "There is an invisible point that does not get made. Family relations get quite broken. There is loneliness. In the Japanese mentality there is hesitancy in contact with mentally handicapped people. People are reluctant to talk about them."

In Iwakuni, about 35 kilometers from Hiroshima, Kuniso Hatanaka drew the window curtains together and shut the door of his barbershop. His daughter, 43-year-old Yuriko, settled into a chair.

In 1945 Mr. Hatanaka's wife, Yoshie, was standing next to a small hut in Hiroshima when the bomb fell. Six months later Yuriko was born—"too small to my eyes."

At age five Yuriko was diagnosed as microcephalic. "She could not do anything for herself, not even wash her own body." Yuriko sensed we were talking about her. She threw a shy smile my way, brushed her hair back, and straightened up from her slouch.

I asked Mr. Hatanaka if the social rejection mentioned by Mr. Ohmuta had been his experience. Yes, he replied, "I have no hope for her future happiness. People do not treat her badly, but they cannot treat her properly."

Dr. Kiyoshi Shimizu, retired from Hiroshima University's Research Institute for Nuclear Medicine and Biology, told me that almost half of the 700 hibakusha he studied have considered suicide at least once. "They have so many diseases for which the exact cause is unknown, it causes mental depression. They think their problems are caused by radiation, but the doctors cannot say so, and they think the doctors do not believe them."

It seems ironic that a portion of Hiroshima's electricity comes from nuclear reactors. Japan, like many other countries, is turning to nuclear power to meet its energy needs.

Even here in the United States, where nuclear power seems stalled, it is second only to coal as a source of electrical energy, supplying 18 percent. Thirteen nations depend more heavily than the U. S. on nuclear energy. France heads the list with reactors producing 70 percent of its electricity.

Clearly electrical uses and power needs are rising. Fossil fuels are in finite supply, and concern is mounting over the greenhouse effect. Is nuclear the answer?

"Without coal it's the only option we have today for large quantities of electricity," said John Graham of the American Nuclear Society. "There are better alternatives," countered Ken Bossong, director of Public Citizen's Critical Mass Energy Project, established in 1974 to oppose nuclear power. "Energy efficiency and renewable systems such as solar and wind make more sense."

Radioactivity is at the center of the debate, explained Dr. Spencer Weart. "Opposition came up from the grass roots, beginning with the battles over fallout from atom-bomb testing. The nuclear industry, associated with atomic energy and therefore the bomb, became regarded as a dangerous, polluting industry." The Three Mile Island (TMI) meltdown in 1979 crystallized nuclear fears.

There are 110 licensed nuclear plants in the U. S. But perhaps the most significant number is the 53 nuclear power plants canceled between 1980 and 1984. None has been ordered since 1978.

Water-cooled reactors such as those at TMI dominate the industry. They are costly, complicated, and, like all reactors, cannot be made absolutely safe. Inside a thick-walled reactor vessel filled with water, zirconium-alloy-clad fuel rods hold uranium oxide fuel pellets. When the uranium fissions, energy heats the water to steam, driving generators that in turn

Designed for disaster, this French railway car was built to rush emergency medical aid and radiation detectors to nuclear-accident sites. The 3.5-million-dollar railcar can be anywhere in France in 12 hours, anywhere in Europe in 24, and can examine 5,000 people a day.

produce electricity. The water also keeps the alloy surrounding the uranium from melting.

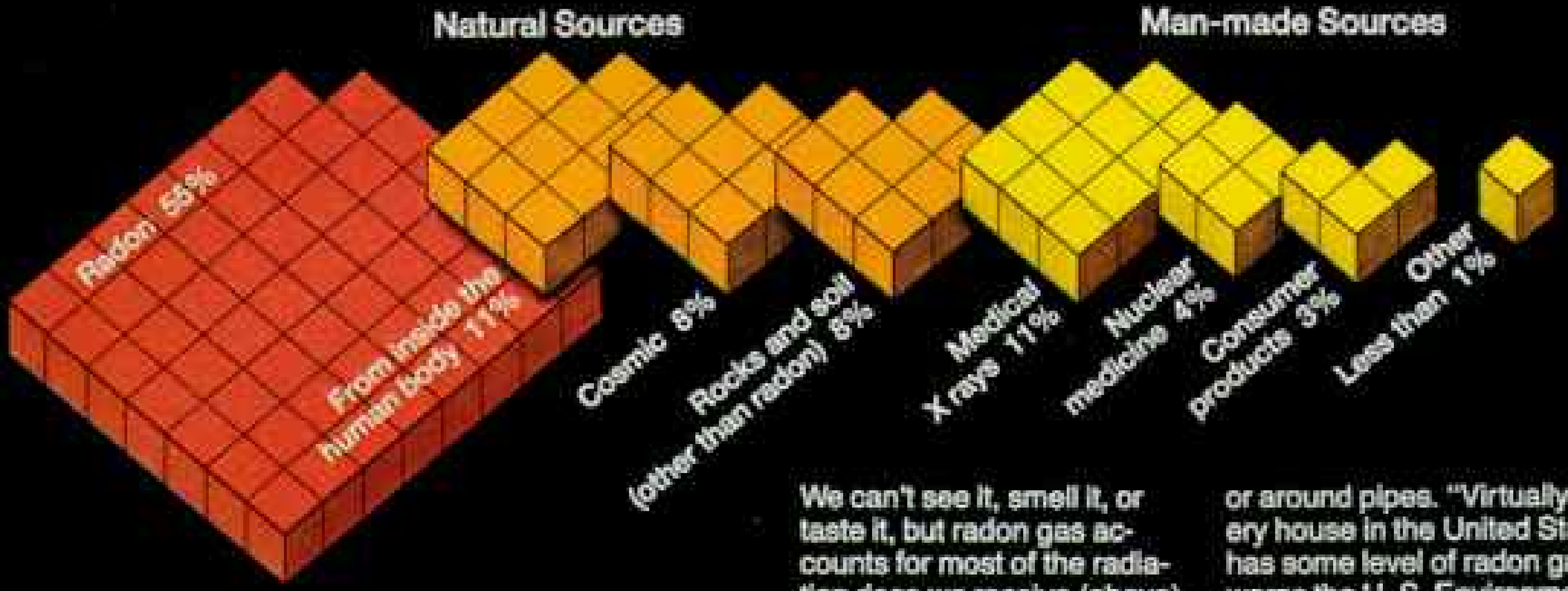
Safety in water-cooled reactors is built around the concept of "defense in depth." If something goes wrong, various engineered systems kick in to shut the system down—unless overridden by human commands, as occurred at Three Mile Island.

There are, however, newer designs that proponents claim are inherently safe. "Passive" safety features, they argue, offer greater protection than engineered defense in depth.

ONE CANDIDATE is a gas-cooled reactor now under development. The active components of water-cooled reactors—pumps for instance—can break down. A gas-cooled reactor has "no pumps, no diesel generators, not anything that breaks down in the emergency system," boasted Dr. Richard Dean, in charge of reactor development for General Atomics. "We made it simple."

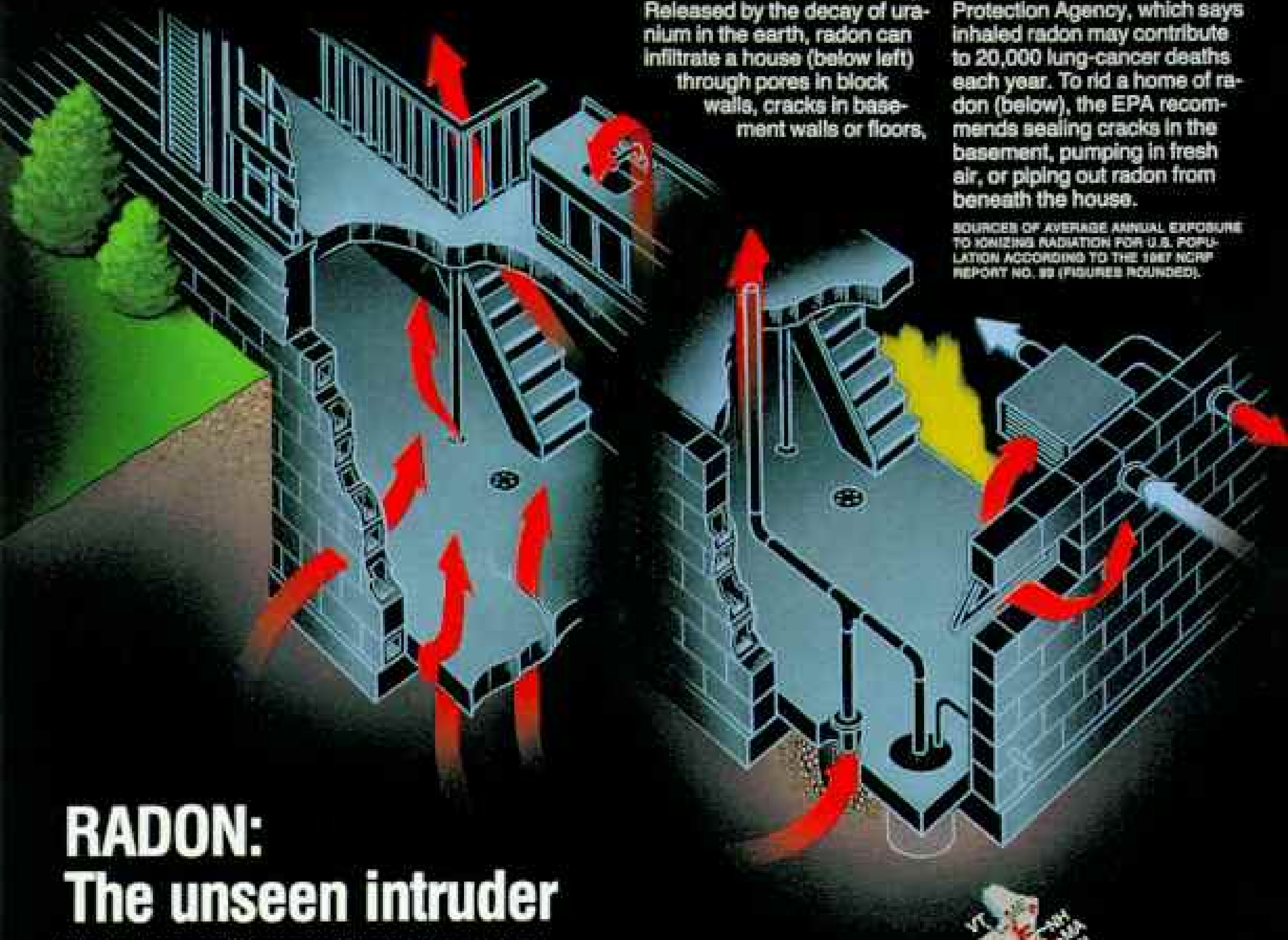
Because the reactor is underground, he said, in an accident the earth itself would keep

Radiation on the hoof, the reindeer herds of Sweden and Norway were showered with radioactive rain for days after the Chernobyl accident. Today the lichens they eat—and the reindeer themselves—still show high levels of cesium 137. To protect consumers, both countries monitor reindeer sold commercially. A Norwegian inspector (left) checks reindeer in the field. The herd at top was judged too radioactive for human consumption. Its albinos are natural mutants.



We can't see it, smell it, or taste it, but radon gas accounts for most of the radiation dose we receive (above). Released by the decay of uranium in the earth, radon can infiltrate a house (below left) through pores in block walls, cracks in basement walls or floors, or around pipes. "Virtually every house in the United States has some level of radon gas," warns the U. S. Environmental Protection Agency, which says inhaled radon may contribute to 20,000 lung-cancer deaths each year. To rid a home of radon (below), the EPA recommends sealing cracks in the basement, pumping in fresh air, or piping out radon from beneath the house.

SOURCES OF AVERAGE ANNUAL EXPOSURE TO IONIZING RADIATION FOR U.S. POPULATION ACCORDING TO THE 1987 NCRP REPORT NO. 93 (FIGURES ROUNDED).



RADON: The unseen intruder

Shaded regions indicate uranium-bearing geology—native granitic rocks, phosphatic rocks, coals, and shales, and similar rocks transported by glaciers—in which high radon levels might be expected.

DIAGRAMS BY MARK SEIDLER

Few people had even heard of radon back in December 1984, when the Watras family of Boyertown, Pennsylvania (above), got a houseful of bad news for Christmas. For weeks a puzzled Stanley Watras had been setting off radiation detectors at Limerick Nuclear Power Plant, where he works as a construction engineer—far from any radioactive materials. Then technicians from the plant tested his house and found levels of cancer-causing radon a thousand times higher than the four picocuries a liter the EPA uses as a threshold for concern.

"That's when the horror really set in," he recalls. "My family had been living in a radioactive cloud."

The family promptly moved into a motel. Then the Philadelphia Electric Company offered to radon-proof the house as part of its research on the radioactive gas. Investigators discovered the house was built above a block of granite containing uranium, which decays into radium, then into radon gas. Concerned neighbors tested their homes and discovered another of radon's quirks: So site specific is the gas that many registered insignificant levels. After the investment of $32,000 in radon-reducing membranes, sub-slab ventilation, turbines, and monitors, the Watras house was given a clean bill of health—and the family moved back in.

Today the Watrases worry about the year they spent breathing the alpha and beta particles emitted by radon as it decays. "We assume the worst and pray for the best," they say. They urge others not to take the gas lightly. "Even in our so-called fixed house, the radon levels change every single day," cautions Stanley. "The word is test, period. Exclamation point."

At a home in Great Falls, Virginia, holes were drilled in the basement floor (left); test smoke revealed negative pressure inside the house, which may have sucked in radon.

the reactor cool enough to prevent meltdown. "The public could walk right up to the fence and watch us cope," claimed Dr. Dean.

Dr. A. David Rossin, former Department of Energy assistant secretary for nuclear energy, says, "I don't call any reactor 'inherently safe.' In fact, we are still waiting to hear whether the Nuclear Regulatory Commission will even approve reactors that lack the containment domes of our conventional plants." But such walls would force a redesign of the gas-cooled reactor's passive cooling system. The small size makes self-cooling possible, but it would take a dozen modules to match the original 1,700 megawatts at TMI. It would be better, Dr. Rossin believes, to incorporate passive safety features and less complicated engineering into established water-cooled technology—a process that already has begun.

Passive safety might have eliminated the human error that compounded the TMI accident, in which much of the defense in depth collapsed at the unit 2 reactor. More than half the unit's core melted during the 200 minutes when it lost most of its cooling water. Only the last lines of defense, the vessel walls and the containment building, held.

I would have preferred to spend my time enjoying the Amish countryside not far from Three Mile Island; I felt the Susquehanna River beckon me to come fishing. But just outside Middletown I headed toward the concrete towers of TMI, where the river's water cools reactor rods. I had come to visit men who are placing themselves as close as they can to a radioactive volcano, defueling the core of unit 2. They called it "working in the pot."

"We're pretty much flying by instruments," said George Knetz in the command center. Workmen stood on a bridge above the reactor core, sweltering in protective garb.

Guided by computer, video cameras, and monitors, they manipulated a 50,000-degree plasma-arc torch through an 18-inch slot into 35 feet of water to cut through radioactive steel plates of the reactor's lower core-support assembly. Fuel rods were seated on this assembly. Once the plates are removed, the men can begin taking out more of the melted fuel.

Debris dirtied the water, and the men could see little. A pilot arc used to light the torch balked at starting. Jokes and camaraderie cut through the strain of intense concentration. "Have a seat," someone suggested to defueling director Sandy Levin. "No thanks," he said. "I'm giving birth here; can't sit down."

They made two good cuts before the torch failed, then fished for radioactive material with 40-foot pliers. "It's like plucking your eyebrows in the dark," said senior reactor operator Tom Osterhoudt.

I wondered about risk to workers. The average hourly exposure on the platform is about 15 millirem. That is like getting a chest X ray every hour. Shifts are three to four hours.

Defueling crews work in the pot for one week and elsewhere for five, said Dr. Hans Behling, manager of radiological health. Federal law limits a worker to a maximum of 12 rem a year. "We don't allow a person to exceed a yearly dose of five rem," Dr. Behling said. "At any time we can call up a worker's monthly, quarterly, or yearly exposure. We have the best computer tracking system in the world." On average, unit 2 workers received 710 millirem in 1987, far below federal limits but also equaling about 50 X-ray exams.

EVEN MORE than Three Mile Island, the explosion at the Chernobyl power plant in Soviet Ukraine confirmed the worst nuclear fears. Poor design magnified operator negligence to cause disaster.

In April 1986 operators ignored warnings from various sensors and even disconnected the emergency core-cooling system. Neutrons went out of control; steam built up in pipes. The ensuing explosion sent the graphite slabs of the reactor core through the roof, setting it afire and spewing radioactive materials around the world. Twenty percent of the plant's radioactive iodine escaped, along with 10 to 20 percent of its radioactive cesium and a mix of other radioisotopes including plutonium. Thirty persons died; 237 suffered severe radiation injury.

The air was frosty when I made my way to Chernobyl, but bursts of wildflowers along the roads reflected the start of spring.

It was no ordinary spring at the "zone." One hundred seventy-nine villages—135,000 people—had been evacuated in a 30-kilometer (18-mile) radius. Radioactive topsoil had been bulldozed away, trees cut down.

I boarded a "dirty" bus, one allowed to travel only in the zone. Trucks driven by white-masked workers watered the road to keep down radioactive dust.

"From a technical point of view the accident could not happen again," chief engineer

Gennadi Yaroslavtsev told me at the plant. Among the changes made since the accident: New rules on the withdrawal of control rods, more neutron-absorber rods, higher fuel enrichment to limit rapid power increases, and additional training for operators.

Nonetheless the plant was under political fire. Just before my visit the Communist Party paper, *Pravda*, accused Chernobyl officials and Kombinat, the organization overseeing the plant and cleanup, of mismanagement, nepotism, and safety abuses.

Like Japan's hibakusha, Soviet citizens exposed to Chernobyl radiation were showing surprising resilience. But it is far too early to know what the health effects will be. Scientists are watching carefully.

Dr. Angelina Guskova, director of medical science at Moscow's Institute of Biophysics, described results of studying 696,000 people. A third were children. "Basically we find no effect so far," she said.

Of more than 2,000 children born to women living within the zone when the accident occurred, all seem healthy, according to Professor Ilya Likhtaryov. He expressed surprise. "We thought there would be thyroid abnormalities, but it does not seem to be the case. And no effects are showing up in mothers. Of course, we will follow them all their lives."

I asked Professor Likhtaryov his prognosis for cancer increase in the U.S.S.R. "In 20 years' time I think we will see about a 0.04 percent increase of cancer." Dr. Leonid Ilyin, who heads the Institute of Biophysics, told the daily *Soviet Russia*, "The danger that is implied is more theoretical than practical."

I wondered how Chernobyl plant workers felt. In Slavutych, outside the zone about 40 kilometers from the now abandoned workers' town of Pripyat, roaring bulldozers, cement mixers, and passing trucks announced a new community going up. Fifty-two families had already moved in, with 3,000 more expected by the end of the year.

I talked with townspeople, but always through government translators and usually accompanied by officials. It was often difficult to know whether I was getting genuine opinion. Sometimes lengthy expressions in Russian were translated in a few words. I sensed nuance I was not getting.

At one new home in Slavutych, Svetlana Stanislaw was kissing her husband, Valentine, good-bye as he left for his first day at the plant. She was a little embarrassed at my sudden visit. Unpacked boxes were piled up in one room. She was trying to get her two children, age two and ten, fed.

"Valentine wanted to come; I was against," she told me. "He finally convinced me." Are you really convinced? I asked. "Well, naturally all parents worry about their children," she replied, somewhat obliquely, I thought, casting a quick glance at the children who were shyly casting their own glances at me.

THE OPTIMISM of scientists and plant workers did not appear to prevail in much of Ukraine or in Moscow. Fear of radiation has grown because of Chernobyl and is persistent. "Radiophobia," Soviet scientists call it.

"Someone sneezes in Kiev, and they think it's a radiation sickness from Chernobyl," Dr. Likhtaryov complained. "In the first month

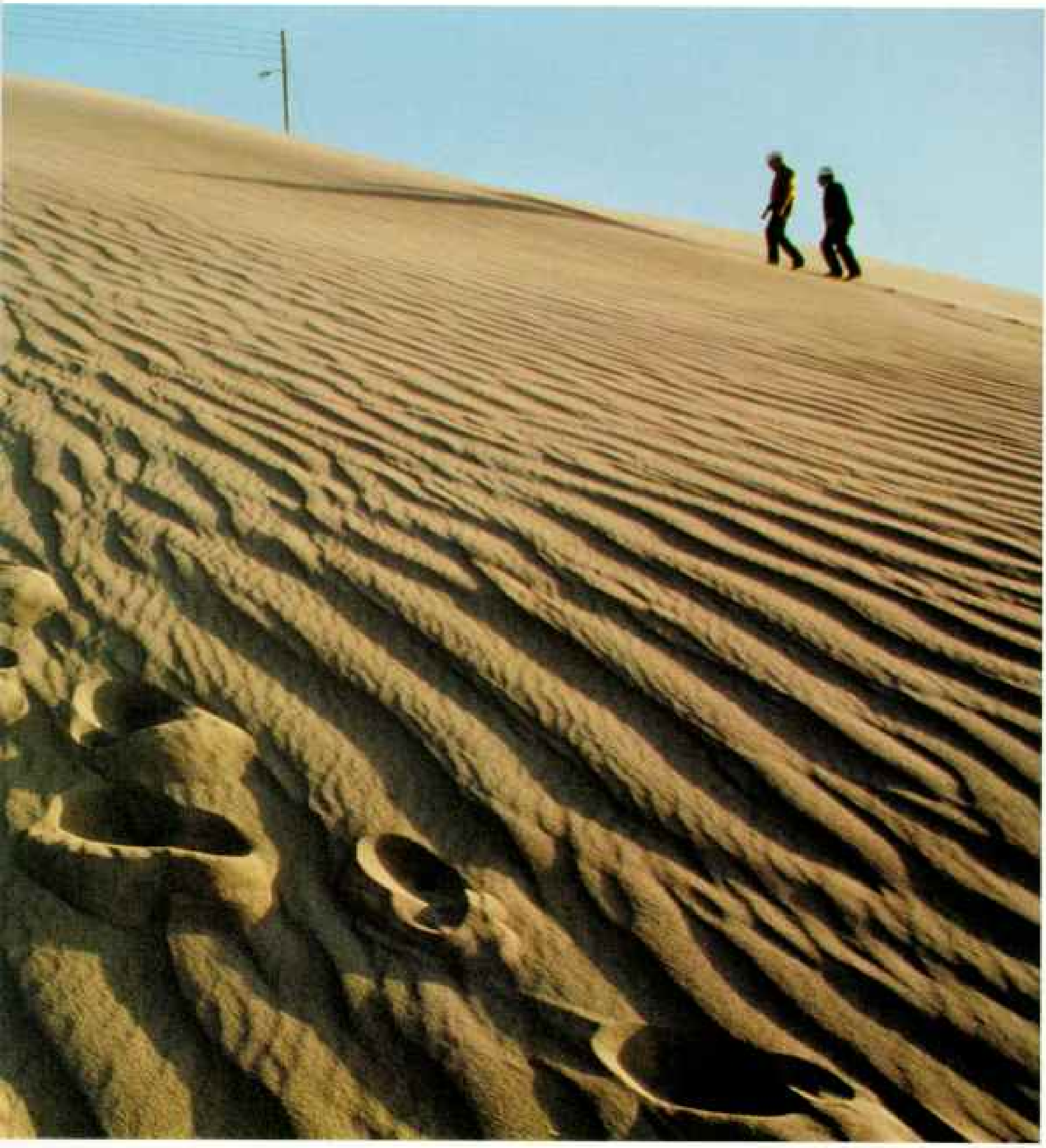
A "radon spa" in Misasa, Japan, offers radioactive hot springs for those who believe radon vapors promote healing. Most scientists consider radon's alpha, beta, and gamma emissions harmful. Misasa honors a radiation pioneer with its annual Madame Curie Festival.

[after the accident] it was acute; now it's chronic." He looked at me sharply, then smiled. "You could have picked something else to write about here, but you have to write about Chernobyl!"

Chernobyl also left its fingerprints on Europe: A study by the European Community estimates a thousand extra cancer deaths in the next 50 years. But that number, and even higher estimates by others, disappears against the expectation of 30 million deaths from "natural" cancers over the same time period.

Nevertheless the Chernobyl accident has exacted a price. Until recently thousands of sheep in northern Britain could not be slaughtered for food because of radiation; herds of reindeer in Sweden still must be steered away from contaminated lichens. If anyone benefited after Chernobyl, it was northern Europe's frozen food industry; sales soared.

Much of the nuclear world, from bombs to power plants to medicine, converges at the Hanford Site in southeastern Washington State. Here as well are all of the questions.



Radioactive dunes at New Mexico's Homestake uranium mill are composed of tailings—leftovers produced when uranium yellowcake is extracted from the ore. More than 200 million tons of this waste, which emits low levels of radon and gamma rays, are piled in the open across the western U. S., prompting calls for a monumental cleanup.

Hanford is part of a network of weapons facilities operated by the Department of Energy. Few communities have been shaped as much by the atomic age.

Hanford spreads over 560 square miles of sagebrush country on a bend in the Columbia River. Its isolation made it ideal for plutonium production, and from it came the guts of the bomb that leveled Nagasaki. Since then its expanded activities include defense projects, reactor research, waste management, robotics, and biomedical and life sciences research. The

Washington Public Power Supply System, known as "Whoops," operates a 1,100-megawatt nuclear reactor on Hanford land leased from the Energy Department.

In a very real sense, to look at Hanford is to look at a nuclear culture. The onetime tiny village of Richland has become a small city, its economy fueled by Hanford's atomic energy.

DRIVING around Richland, I might have been anywhere in Smalltown, U.S.A. I passed the usual stores, shops, and gas stations, the bowling alley. But wait: It's called the Atomic Lanes. And there is Atomic Body Shop and Towing, also Proton Lane and Nuclear Lane. The high-school football team is the Bombers. Their emblem is a mushroom cloud; the cheerleaders wear the cloud too.

"We were always held up for ridicule because of our support for the industry," said Dr. Michael Fox, a Hanford engineer. "We have scientists and engineers who are community leaders. We're pretty decent people and proud of it." Cliff Groff, vice president of Hanford Family, formed in 1986 to combat negative opinion about the area, was more emphatic: "There is nothing wrong with being a part of the defense industry. That is a part of our heritage, our history. We helped end World War II, and I am proud of it."

Pride defines this community's attitude. Pride of past, pride in current work.

Dr. Darrell Fisher is project manager for a new cancer treatment involving the injection of radioactive antibodies into the body to destroy cancer cells. "We compare the effectiveness of different radionuclides," he explained. "Alpha emitters may be better against diffuse tumors, beta emitters against solid tumors. Tumors disappeared in three to six weeks from five patients terminally ill with cancer of the lymph glands."

Bone-crippling osteoporosis, a painful disease that afflicts millions of elderly women, was the isotope target of Dr. Robert Schenter. His promising program uses the diagnostic properties of gadolinium 153, a radioactive product of Hanford's fast-flux reactor. It produces gadolinium and other isotopes more efficiently than other reactors. The reactor is also a source of concern to those who fear its role in the development of breeder reactors.

For years Hanford has also symbolized a dark side of the atomic age. Critics charge inadequate safety measures, old equipment, and poor supervision. I sought out those voices too.

"Pushing safety measures is a sure way to become unpopular here," said Ed Bricker, an operator at the tank farms where underground waste is stored and monitored. The Richland native is a third-generation Hanfordite.

Ed began complaining five years ago when he worked at the plutonium finishing plant. He was concerned about careless handling of plutonium, lax safety procedures, uncertified operators in the control room, and engineering blueprints that didn't always represent the equipment actually in place.

"I was asked, 'What are you, some kind of troublemaker?' I said, 'No, I'm a safe worker.'" For a time the Energy Department shut down the plant. "We have some of the best

Preparing to fight an invisible foe, a technician involved in the billion-dollar cleanup of Three Mile Island suits up to enter the unit 2 reactor building, scene of the 1979 meltdown. To block radioactive particles, workers breathe through a respirator, wear paper coveralls, and seal their outer suit with tape. Exposure to gamma rays is closely monitored. Using 40-foot tools and TV cameras, workers dismantle the water-filled reactor, then pack the debris in stainless-steel canisters (above) for shipment to an Idaho storage site.

Deadly by-products of the bomb

It's the problem that won't go away—at least not for the millennia it will take certain radioactive isotopes to decay. With poisonous wastes piling up at weapons plants across the U. S. (map above), the search is on for safe ways to dispose of millions of tons of spent fuel, high-level wastes, and other radioactive by-products. Permanent waste-disposal sites may take decades to prepare. In the meantime cleanup is needed for some 40 years' worth of waste stored improperly due to lax safety practices or obsolete facilities.

Expanded hurriedly to produce the atom bomb dropped on Nagasaki, the Hanford Site in Washington (above right) is currently the nation's largest repository of nuclear waste.

But corrosive, highly radioactive liquids have eaten through Hanford's World War II-era storage tanks and are being moved, at a cost of millions of dollars, to Hanford's tank farms of computer-monitored carbon-steel storage tanks (below). Nationwide the cleanup of military wastes may take decades and cost more than a hundred billion dollars.

brains in the country," said Ed. "At least some of the problems here can be solved. Whether we have the leadership to do it, I don't know."

Nuclear waste at Hanford is a huge problem. More than four decades of it have accumulated, and the cost of cleanup will be enormous. A maximum cleanup could cost as much as 57 billion dollars. Even a minimal cleanup, leaving waste where it is and stabilizing the ground in which it lies, would cost between two and three billion dollars.

"We are victims of this mismanagement," said farmer Tom Bailie angrily. He was especially angered by revelations under the Freedom of Information Act of an event that exposed thousands of citizens to radiation.

In the 1940s and '50s massive doses of radioactive iodine 131 were deliberately released across the Pacific Northwest. They dwarfed by tens of thousands of times the severity of Three Mile Island's release of 15 curies.

The releases came without warning, and many other details are still classified. They seem to have been part of a mysterious Cold War effort to locate plutonium plants inside the Soviet Union; Hanford's emissions would serve as indicators of what to look for.

A preliminary study estimated that some infants in Spokane, Washington, may have received as much as 256 rem to the thyroid in 1945, and some living next door to Hanford a huge 2,295 rem. Exactly how much radiation residents absorbed, according to Dr. Jim Ruttenber of the Centers for Disease Control, depends on amounts of local vegetables and milk each consumed. Last September Congress appropriated 1.4 million dollars to establish such a study. The states of Washington and Oregon and area Indian tribes agreed in 1987 to begin a 15-million-dollar, five-year study as well.

"I really think someone should go to jail for manslaughter," said Tom Bailie. Although radiation may not be the cause of his family's ailments, he thinks it is; but that can't be proved now. A cousin was born with a cleft palate. "I was born with birth defects; I'm on thyroid medicine." According to Tom, 25 of 27 households around him have been afflicted with cancer, birth defects, or heart problems.

"The challenge," said Dr. Ruttenber, "is to relate disease to exposure." Local doctors, Tom Bailie said, doubt that Hanford is the culprit. "They say, 'You don't believe that anti-nuclear stuff, do you?' "

IT IS BECOMING increasingly difficult not to believe "that antinuclear stuff." Last October, amid revelations of mismanagement, safety violations, and possible danger to public health, the federal government shut down three reactors and a plant at major nuclear-weapons sites. A study prepared for the Energy Department concluded that there were numerous "significant deficiencies" in operation and management.

Other reports suggest that workers at weapons plants may be developing unusually high rates of radiation-related cancers. At the Rocky Flats plant near Golden, Colorado, where bomb parts are made, one study found the death rate from brain tumors among white male workers to be twice that of a similar group not exposed to such radiation.

Even the Department of Energy said in court papers that "any amount of unnecessary radiation exposure, however small," has some increased risk of adverse health effects.

Its December report, DOE says, will assist in setting priorities for cleaning up weapons facilities. Cost estimates for this undertaking well exceed a hundred billion dollars, and

Atomic casualty Yuriko Hatanaka (far left) is one of dozens of mentally retarded children born near Hiroshima and Nagasaki in the months after the bomb. Visiting the site of the blast ten years after (above), Yuriko holds the hand of her mother, who later died of bone cancer. Dr. Kaichi Fukazawa of Hiroshima University (below) cradles a seven-month-old fetus aborted after the bomb. Experts say fetuses 8 to 15 weeks old are most vulnerable to radiation.

KUNIYO KATAHARA (ABOVE)

the work is certain to continue for decades.

Even if safety and management issues are resolved at weapons plants, what to do with the nation's nuclear waste remains a plaguing problem, as political as technological. Nobody wants it. And there is a lot of it: Low level, high level, from commercial nuclear power plants, defense facilities, hospitals, and old watches. It is stored in hundreds of places.

"Salt is a good medium for storage," said Arlen Hunt, deputy manager at the Waste Isolation Pilot Plant (WIPP) in New Mexico. "If salt develops cracks, as from an earthquake, its plastic nature will seal up those cracks."

WIPP is an enormous complex of mile-long corridors and ventilation shafts excavated from salt deposits more than 2,000 feet beneath the desert near Carlsbad. It is being studied as a site for permanent storage of transuranic waste generated by defense production facilities—metal tools and laboratory coats, for instance.

Escorted by Bill Chiquelin and Wendell Weart, I entered an elevator and slowly dropped 2,100 feet. It was chilly at the bottom; air rushed in from a ventilation shaft. The thin

red beam of a laser guided workmen trimming rock-hard walls of an access tunnel.

Wendell explained some of the experiments taking place in the tunnel. "We have to measure the amount of moisture in the salt to determine corrosion rates and whether water will transport the wastes"—serious concerns of WIPP's critics. "We also need to know the rate the salt walls creep in. Safe storage relies on salt encapsulation of the wastes." Since my visit, questions concerning the design and construction of WIPP have caused the Energy Department to delay opening the repository.

In addition to defense waste, used fuel rods from commercial reactors number in the millions and are stored in ponds at reactor sites. Somewhat misleadingly called "spent" fuel, they contain the accumulated products of fissioning and are lethal because of their high-level radioactivity.

Near Buffalo, New York, the Energy Department is piloting the incorporation of high-level liquid nuclear waste into borosilicate glass—a stable solid that will be kept in

Remembering the day the bomb fell, mourners in Hiroshima launch lanterns for its victims on a branch of the Ota River, where many sought escape from the heat burning their bodies. Memories are revived during annual ceremonies at the A-Bomb Dome, center, near ground zero. It was one of the few buildings left standing on that bright and terrible day when the world first saw the power of the atom.

drums. It is hoped that such waste can be permanently stored at Yucca Mountain in Nevada early in the next century. Nuclear waste also fuels the debate over nuclear power. Said Marvin Resnikoff, staff scientist for the Radioactive Waste Campaign: "If you can't dispose of it, I want production closed."

Given the huge problems of disposing of nuclear waste, there is at least a little irony in the fact that a troubling radiation problem is not man-made but natural: radon.

Produced by radium decay in the soil, radon cannot be seen, smelled, or felt. The gas is sucked up through basement cracks, and once inside today's energy-efficient houses, it does not escape. After inhalation, radon continues to decay, producing alpha radiation that can cause cancer of the lungs.

A federal survey of 20,000 houses in 17 states found more than 25 percent with potentially hazardous radon levels. It is "the largest environmental radiation health problem affecting Americans," said the Environmental Protection Agency's Richard Guimond.

Added Dr. Anthony Nero at Lawrence Berkeley Laboratory: "You're talking about huge doses in comparison with all other background radiation. Radon is like having two or three Chernobyls every year."

Fortunately radon is neither difficult to test for nor costly to correct. Products for testing are available through the mail and cost from $10 to $50 apiece. The simplest corrective measure is natural ventilation: Open basement windows. Since radon passes through any opening to the soil, seal tiny cracks, openings around pipes, and joints between floors and walls. Soil-ventilation systems to pump radon-laden air from beneath the house cost from $700 to $2,500. From $1,200 to $2,500 buys a heat-recovery ventilation system.

As the radon problem emerged, I discovered I had come full circle back to the obvious: Radiation is a fact of life.

Voices will continue to clash over risk versus benefit, but even in controversy I like to think we will gain. Perhaps there will be newer, safer nuclear reactors. Perhaps too we will clean up the dangerous radioactive waste scattered throughout the country and around the world. Certainly radioisotopes will make new contributions to medical diagnosis and treatment. I also think we will learn about the danger of low-level radiation. And let us all pray there is no nuclear war.

Living with radiation raises questions, difficulties. But live with it we must. □

KRONAN

Remnants of a Warship's Past

THREE HUNDRED YEARS after catastrophe struck Sweden's magnificent warship *Kronan*, an archaeologist's dream came true: In 1980 the author and his team discovered the wreck of the man-of-war that had led the Swedish fleet against Danish and Dutch forces in the Battle of Öland on June 1, 1676. Mightily armed and woefully top-heavy, she turned too fast, heeled, capsized, exploded, and sank, taking with her most of her crew. The remains of the warship represent a veritable microcosm of 17th-century Swedish society, from the gilded hilt of an officer's sword to the buttons of a lowly seaman. The skull of one of the tragedy's 800 victims lies near one of the ship's cannon.

By ANDERS FRANZÉN

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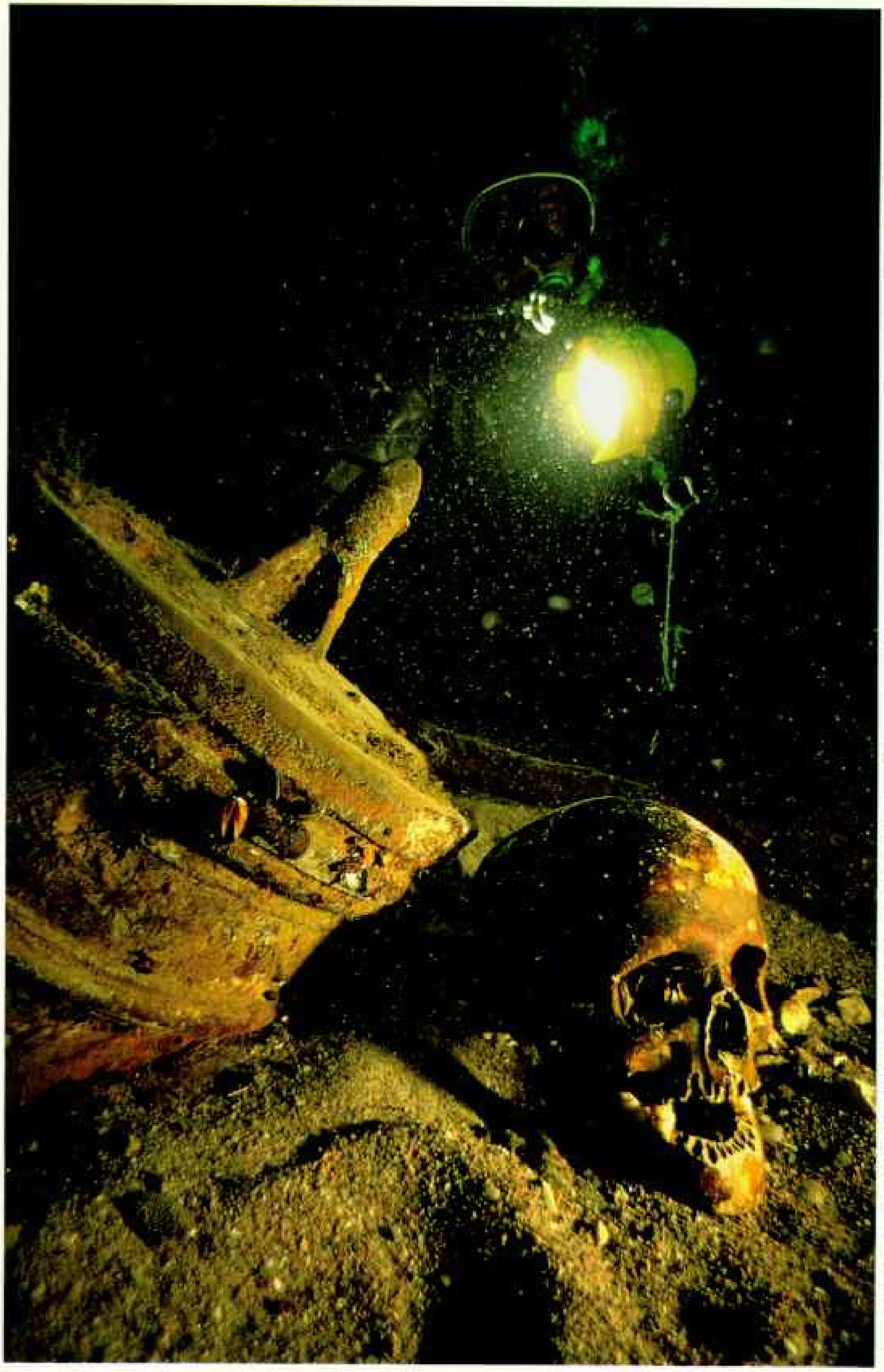


Royal flagship of the Swedish fleet, Kronan *hosted a splendid reception in the summer of 1674 for King Karl XI. Spectacularly embellished with wooden carvings, the 197-foot-long*

ship was one of the largest of her time. Since no contemporary drawings or model of the ship exist, the artist based his vision of Kronan *in her heyday largely on excavated remains.*

Surreal through unusually clear Baltic waters, wreckage of Kronan's upper gun deck includes a 12-pounder—a cannon so named for the weight of its shot—still in its original gunport.

Kronan came to rest on her port beam and has been slowly subsiding into glacial clay on the seafloor. Divers are at work on the ship's side, seen here in a view toward the bow.

NINETY FEET DOWN on the floor of the Baltic Sea the bronze cannon lay scattered like giant jackstraws. As our remote-control television camera panned across them, I wished silently for some evidence that my 30-year search had come to an end. We soon found it in a raised inscription on one of the six-pounders: VIVE LE ROI—1628.

The date of our discovery was August 8, 1980, and the site an area four miles east of the Swedish island of Öland. The guns belonged to one of the most famous ships in Swedish history—*Kronan*, or *The Crown*, which sank on June 1, 1676.

In her day *Kronan* was the largest vessel in all of Sweden—nearly 200 feet long overall, weighing 2,350 tons, and carrying 126 guns. She was the pride of Sweden's King Karl XI and the most powerful warship afloat. She took seven years to build and less than a minute to destroy. Her story is one of the great epics of seafaring history.

The saga of *Kronan* is well-known in Sweden—launched in 1668 and commissioned in 1672, she was sent into action in the Baltic four years later with some 60 other Swedish warships. The Danes had vowed to win back Baltic provinces seized by Sweden nearly two decades earlier, and the Dutch had joined them in a declaration of war.

In early action against the combined Dutch and Danish fleet *Kronan* fought well. Maneuvering astern of the Dutch admiral's flagship, she loosed a broadside and tore such a gaping hole in the Dutchman's sterncastle that, in the words of a Swedish gunner, "You could drive a coach-and-four through it."

It was to be *Kronan*'s only success. A week later the fleets met again off Öland. While under full sail in a gusting wind *Kronan* made a sharp turn to face the enemy. The maneuver was fatal; the great ship simply capsized on her port beam. As her masts and sails touched the water, a violent explosion ripped her amidships and she sank within minutes, carrying some 800 men to their death. It remains one of the greatest disasters in Swedish naval history.

As a naval historian and engineer I have long been fascinated by *Kronan*'s story. In the 1950s I made an initial search for the wreck in the area where she was said to have gone down. Then my interest turned to the waters of Stockholm Harbor. There in 1956 I discovered an equally famous casualty

Kronan's disastrous last battle was patriotically, if inaccurately, commemorated in the 1680s by a Danish artist celebrating the victory of Danish and Dutch allies, who pushed the Swedish fleet back to Dalarö. The painting compresses the events of the battle into one scene. Contemporary accounts tell the dramatic tale of Anders Sparrfelt, one of Kronan's survivors: Blown sky-high by the explosion, he flew over two enemy ships before landing safely in the sail of a Swedish vessel.

among 17th-century warships, the *Vasa*.*

Like *Kronan*, *Vasa* wasn't designed to carry the heavy armament placed aboard her. As a result she was dangerously top-heavy, and she capsized and sank on her maiden voyage out of Stockholm in 1628. More than three centuries later we raised *Vasa* intact and put her on permanent display beside Stockholm Harbor. Then in 1979 I resumed my search for *Kronan* in the waters east of Öland.

Despite similarities in the way they were lost, *Vasa* and *Kronan* were vastly different ships. *Kronan* was nearly twice the size of *Vasa* and carried three times her weight of guns—240 tons compared with 80 tons. *Vasa* sank on a trial voyage with a minimal crew at a cost of only 50 lives. *Kronan* went down with a full battle crew of 550 plus 300 troops in an action that cost Sweden control of the southern Baltic.

*See "Ghost From the Depths: the Warship *Vasa*," by Anders Franzén, in the January 1962 NATIONAL GEOGRAPHIC.

FREDERIKSBORG CASTLE, DENMARK

Massive timber of Kronan's sternpost is flooded with light from a 30,000-watt parabolic lamp built and designed by engineer Bengt Grisell (right), who helped discover the wreck. Lars Einarsson—director of Kronan's excavation—studies a wooden rammer (above) used to compress wad and powder in this 30-pounder.

The sinking of *Vasa* was a blow to Swedish pride; the loss of *Kronan* was a national disaster.

JUST WHERE that disaster occurred has long been a question. Contemporary accounts place the battle some miles east of the coastal village of Hulterstad, where the bodies of *Kronan's* crew washed ashore for days afterward. But the actual search area was enormous, involving many square miles of seafloor. The target was not only comparatively small, it may well have been blown to pieces by the explosion.

In my search for *Vasa* I had worked entirely alone, but *Kronan* obviously called for a team effort. Three friends and fellow engineers—Bengt Grisell, Sten Ahlberg, and Bengt Börjesson—and I equipped a small research vessel with side-scan sonar and set out in July of 1979 in search of *Kronan*.

From the outset we were hampered by a frequent phenomenon in the Baltic—thermoclines, or different levels of water with abrupt changes in temperature. These changes serve as a barrier to sonar—a fact that foreign submarines have taken advantage of for years in their spying on Swedish naval bases.

By contrast, the magnetometer we later added to our search equipment was sometimes *too* sensitive. One day as we towed the device far below the surface, it registered an electrical storm at least 80 miles away on the Soviet Union's side of the Baltic!

To our disappointment the first season yielded nothing conclusive. In all we explored more than 13 square miles of seafloor without making a single find. It seemed not

only that *Kronan* may have been blown to bits but also that the pieces may have been buried deep beneath the floor of the Baltic Sea. Nonetheless we determined to try again.

OUR LUCK changed abruptly on an afternoon in August of the following year. As we towed the magnetometer over an area due east of Hulterstad, the needles on the shipboard instrument panel suddenly began to fluctuate, indicating a sizable amount of iron below. In this same area nine years earlier a Swedish Navy diving and rescue ship had found some oak planks that obviously had been underwater a long time. Talking it over, we decided to lower the TV camera for a look.

None of us, I think, will ever forget the first view of *Kronan*. Cannon lay scattered across the seabed among a jumble of ship's timbers—more than half a dozen beautiful bronze gun barrels. Like most flagships of her day *Kronan* was a floating trophy hall. Her armament came from countries all over Europe, either captured in battle or purchased from foundries. The oldest gun we eventually salvaged was a German cannon cast in 1514—a full century and a half before *Kronan* was even launched. The gun may well have been carried aboard half a dozen different warships before it went down with *Kronan*. Other cannon we salvaged were cast in Sweden, Denmark, Austria, and possibly France.

Within hours after the discovery we began diving on *Kronan* with scuba gear. We soon found that although the ship had been badly damaged by the explosion, parts of her were

still intact. The massive stern timbers stood joined together like a giant tripod rising 12 feet above the seafloor.

Though the upper section of the starboard hull had been blown away, the lower portions remained. We were later to discover that much of the ship's portside hull section also remained, buried beneath the sand and clay of the seabed. The section was so well preserved that some of the cannon still protruded from their ports. *Kronan*'s bow section is missing entirely, and my guess is that it broke loose during the explosion and simply floated away.

But the ship itself was nothing compared with the enormous wealth of artifacts it was soon to yield. Swedish salvors in the decade following the wreck were interested primarily in *Kronan*'s valuable guns, and they managed to recover nearly half of them. But fortunately for us they ignored the tens of thousands of everyday articles that went down with *Kronan* and her crew. To the archaeologist these are far more valuable than guns, for they provide a detailed portrait of the ship and the men who sailed her. None is more fascinating than Baron Lorentz Creutz, the admiral who sailed *Kronan* to her death.

LARS ERIKSSON

INCREDIBLY this was the 60-year-old Creutz's first sea duty. He was appointed commanding admiral of the Swedish Navy from a post as civil adviser to King Karl XI. The career admirals under Creutz resented him bitterly and often ignored or disobeyed his orders at sea.

In all fairness to Creutz he was the commander of the entire Swedish fleet, not the captain of *Kronan*. In fact, the ship is reported to have had three working captains, all career men—and they would have had no excuse for mishandling their ship.

Through the artifacts we have recovered from *Kronan*, we have come to know Creutz and some of his fellow officers almost as personal friends. One of the most touching items among some 17,000 objects we have so far recovered is a gold ring with the initials LCD engraved on the inside. The letters stand for Lorentz Creutz Duvall, the last name being that of Creutz's wife, who came from an equally noble family.

Elsa Duvall had died the year before the battle, and the ring had obviously been hers. It had been cut through and enlarged, apparently so that Creutz himself could wear it. Although his body washed ashore near Hulterstad without it, Creutz plainly treasured the ring and kept it with him at sea.

He was a man of elegant tastes, as indicated by another find, a leather chair with the initials LCED—probably for Lorentz Creutz and Elsa Duvall—stamped into the back panel (page 451). On 17th-century ships, chairs were relatively rare; officers and crew alike sat on wooden benches or chests. Chairs were found only in such elegant surroundings as the royal palace where Creutz had worked for years, and he obviously had no intention of roughing it at sea.

For all his inexperience Creutz was an aggressive commander. In early action against the Danes and the Dutch he constantly urged his admirals to attack, often in vain. But on the fateful day of June 1 off Öland, the Swedish fleet went into action prematurely, a fact that may have cost *Kronan* her life.

As the ship began her swing to confront the enemy, Creutz's thoughts clearly turned to *Vasa*, for he is said to have shouted, "In the name of Jesus, make sure that the cannon ports are *(Continued on page 454)*

Several hundred coins—mostly gold—found on Kronan include two rare ten-ducat pieces and a copper daler, a huge square coin common in 17th-century Sweden. Found in the hull, the royal coat of arms (above) shows Sweden's three crowns and the symbols of four German provinces once ruled by the king.

ADMIRAL *Lorentz Creutz's coat of arms, embossed on the leather back of his chair (left), bears his initials and those of his wife. A controversial appointment by the king, Creutz had never before served at sea and was blamed by many for Kronan's tragic end. When his body washed up on Öland's shores, villagers found his seal (below, at center) in his pocket.*

Other seals recovered include a mystery one marked PAW (below right) and one initialed LMST, probably belonging to Lars Månsson Torsk, the ship's artillery captain.

SHINING BREASTPLATE *engraved with King Karl XI's crest was found in 1986, sealed inside a wooden medicine chest (left). Almost certainly the property of Peter Schallerus Gripenflycht, the Swedish Navy's highest ranking doctor at that time, the breastplate would have been worn on ceremonial occasions. The compartmented chest also contained a number of jars and vessels made of ceramic, glass, and pewter; a brass spoon; a handful of juniper berries; tin bottle lids, at front left; and a few objects that Kronan's archaeologists are still trying to identify.*

Two leather-covered notebooks that survived the seawater (right) were designed to hold blocks of wax—easily erased and reused—rather than paper. The volume that lies open, below the inkwell, is thought to have been a book of psalms; nearby are a pen and a stick of sealing wax.

Staring death in the face, Kronan's terrified crew cowered against the overhead and side of the rat-infested lower gun deck as the ship heeled over and water flooded through the

gunports. Cannon burst loose from their tackles, and ammunition rained down on the helpless men. Of the 850 aboard, 41 escaped drowning by clinging to pieces of wreckage.

closed and the cannon made fast, so that . . . we don't suffer the same accident as befell the *Vasa*."

But another account maintains that Creutz wasn't even on deck, having suffered a heart attack the morning of the battle. The account may well be false, however, for Creutz did not lack enemies aboard *Kronan*.

In any case the order to close the gunports came too late. As Anders Gyllenspak, *Kronan*'s master gunner, hurried below to see the command carried out, he found that "all the cannon had their muzzles in the water. . . . it was impossible to get them inboard: the ship was heeling so much that the cannon needed to be hauled almost straight up."

At that point a sudden squall caught *Kronan* and blew her completely flat so that her masts and sails touched the water. A massive explosion followed within seconds. No one knows what caused the explosion, but most likely a linstock—a wooden staff used to hold lighted fuses for the guns—fell into the ship's main magazine. *Kronan* and all but 42 of those aboard vanished in a giant fireball.

One of the 42 survivors was Anders Sparrfelt, whose story is the stuff of legend. Sparrfelt, a 31-year-old major in the Swedish Army, was standing on the main deck at the time of the explosion. As *Kronan* went up, so did Sparrfelt—straight into the air to a height of 160 feet. He cleared the masts of two neighboring enemy ships and landed unharmed in one of the sails of the Swedish man-of-war *Draken (The Dragon)*.

A contemporary account of the battle attributed Sparrfelt's survival to "a peculiar grace of God." But God's graces were far from over for Anders Sparrfelt. He not only survived the battle but rose to the rank of major general. In 1708 he was appointed governor of the Swedish island of Gotland in the Baltic, where he served with great distinction. He died a natural death at 85.

MIRACLES were rare aboard *Kronan* that day, and most of the artifacts we have recovered speak of violence and sudden death. Among the most poignant are the remains and personal possessions of a man we came to know affectionately as the Giant.

We found only the lower half of his skeleton, with his stockings and leather shoes still

Plucking history from clay, a diver raises the carved wooden bust of a young woman. The frontal view suggests that she occupied a central position, probably on the ship's sterncastle. An officer's sea chest (facing page) held bullets, spices, a powder horn, liquor jar, and leather mittens.

attached. Forensic study of the leg bones tells us that he was unusually tall for his day—six feet four inches, compared with the average of about five feet four inches for Swedish men in the 17th century.

The Giant was not only tall, he was also obviously wealthy. Among his remains we found a watch, a large brass belt buckle, a gold ring, gold enameled cuff links, and an elaborately gilded sword handle (page 438).

Who was he? We will never know with certainty, but he may have been Creutz's 26-year-old son, Gustav. Gustav was reported to have been on board *Kronan*, and eyewitness accounts say he drowned in the sinking. Unlike his father's body, that of Gustav never washed ashore.

Another clue points to Gustav. Laboratory examination of the Giant's bones revealed that one of his ankles had been badly broken and eventually mended. The injury was common in Gustav's branch of the service: He was a career officer in the Swedish cavalry.

Whoever he was, the Giant was destined to die, and neither courage nor faith could save him. Among his possessions we found a tiny gold pendant in the shape of a human skull, a popular charm in 17th-century Europe. The talisman probably was sewn to the owner's tunic; it symbolized the frailty of human life.

ANOTHER father-and-son team sailed aboard *Kronan* and met the same fate as the two Creutzes. Sven Olofsson Ram was a naval trumpeter, a position of such rank and importance that only warships with an admiral on board were entitled to one. Trumpeters not only relayed orders to their fellow crew members but also transmitted signals to other ships within hearing range. Among the artifacts we recovered was a battered brass trumpet that may well have belonged to Sven Ram.

As the flagship of the fleet, *Kronan* carried not one trumpeter but five. Tragically for the Ram family one of the other trumpeters was Sven Ram's own son, Olof Svensson Ram. Worse still, the kettledrummer on board was Sven's other son, Hans.

The loss of the three men was a staggering blow to the Ram family, and Olof's widow later wrote a pathetic letter to a senior admiral in Stockholm:

"Though I feel great shame to approach Your Excellency with a feeble matter like

this, God is my witness that I am in desperate need of help. Ever since my dear husband, the trumpeteer Olof Svensson Ram on 'Great Cronan' passed away, I have been alone with four defenseless little children, and have had not a single crumb of bread to feed them. . . ."

There is no record of a reply, but in any event the navy's help would have been minimal. As in the case of so many military defeats, *Kronan*'s dead and missing were accorded little thanks or honor by their countrymen. As the bodies of the crew washed ashore at Hulterstad, they were dumped into a common grave in a corner of the village churchyard. No stone was raised to their memory.

Miraculously intact, a silk ribbon and woven fabric are among the 17,000 finds salvaged from the wreckage so far. Also found: parts of a sewing kit—brass thimbles, buttons, and hooks and eyes—along with buckles, rings, and a lion brooch. Below a fiddle block (above) lie parts of two muskets and a pistol, lead shot, and a powder horn. One musket bears its owner's initials, APS, and the date 1676.

FROM THE REMAINS of those who went down with *Kronan* we have learned a good deal about 17th-century shipboard life. So far we have recovered partial skeletons of 80 individuals, mostly men in their late 30s. Obviously there were older men on board, and we may find some of them as we dig deeper under the seafloor.

The remains have been examined by Jan Lindberg, one of Sweden's leading forensic pathologists. Dr. Lindberg found that most of the individuals had been in good health, probably because *Kronan* had been at sea only a short while. On 17th-century warships crewmen were lucky to get one full meal a day, and extended voyages led to malnutrition and related health problems.

Most of the teeth we found were badly worn, attesting to the seaman's traditional fare of hardtack, dried beef, and other coarse foods. One fascinating discovery was a skull whose shape and structure bear certain feminine characteristics. Dr. Lindberg will not say the skull is definitely female, and certainly there is no record of a woman aboard *Kronan*. On the other hand it would not be the first time in history that a woman was smuggled aboard a warship for illicit purposes.

Someone on board *Kronan*, probably Admiral Creutz, carried a sizable treasure to sea. During the third season of excavation Lars Einarsson, our director of marine archaeology, was exploring the area astern where Creutz and his senior officers had been quartered. There Lars found 105 gold coins, one of them a rare ducat from the reign of Sweden's King Karl IX. The following season we found another 150 gold coins, bringing the total to 255—the largest single hoard of minted gold ever found in

UNSURPASSED in armament, Kronan carried 126 cannon, weighing a hefty 240 tons. (Sweden's famous warship Vasa—discovered by the author in 1956—carried only 80 tons.) A mud cloud billows from a 36-pounder (opposite), which was accidentally pulled upright in 1980 by a ship's anchor cable.

A trophy from Europe's Thirty Years' War, a bronze 30-pounder (below) was cast in Austria in 1627. Records show that the Swedes captured it from the Germans in 1631 and deployed it against its former owners in the 1660s. It bears the initials of Holy Roman Emperor Ferdinand II and the name of his master of ordnance, Rudolph von Teuffenbach.

Corroded copper on one of Kronan's 24-pounders is examined by chemist Tommy Wadsten (left), who hopes to establish whether copper containers might be used for long-term storage of nuclear waste.

To chart their course, Kronan's crew relied on navigational instruments such as compasses, protractors, and proportional dividers. Sand glasses were used to time the ship's watches. A device called a nocturnal (below, background) permitted the user to tell time at night: The North Star was sighted through the center hole and a movable arm lined up

with a pair of circumpolar stars; the time was then read off a scale, since eroded.

A small cabinet (opposite) with drawers swollen tightly shut was discovered on the site in 1981. The find was X-rayed to determine its contents—more navigational equipment, including a sundial, second from right. The back panel was then carefully removed and the nine compartments gently pushed open so as not to strain the fragile drawer pulls.

Sweden. Like many other artifacts from *Kronan*, the coins are now on display at the Kalmar County Museum, where Lars is a curator.

Rich and poor, noble and commoner, all were thrown together aboard *Kronan*. They came from every corner of Sweden and from all levels of society, a complete cross section of the country. Most would never have associated ashore, yet they shared life, and ultimately death, together. In a real sense they formed a working Swedish community with all its color and variety. Therein lies *Kronan's* unique value, for life in that community ceased abruptly on June 1, 1676, and virtually nothing in it changed over the next 300 years. It is indeed a priceless time capsule of 17th-century Sweden.

Consider, for example, the fleet surgeon's medical chest (page 450), which we found intact with an assortment of cups and bottles neatly arranged inside. Some of the bottles still hold remnants of their original contents, and we hope to analyze them soon. We know the surgeon's name—Peter Schallerus Gripenflycht—and next to the bottles we found his badge of office, a brass breastplate with the Swedish royal crest on it. The breastplate was strictly ceremonial, and in any case it would hardly have saved Peter Gripenflycht's life; he drowned or was killed in the explosion.

Still another chest held a set of navigator's instruments, including dividers, a protractor, ruler, adjustable pencil, and a heavy lead inkwell.

A third chest was more commonplace, and thus in some ways more revealing. It was a wooden sea chest, and, judging from the contents, it had belonged to an officer rather than a seaman. There was a heavy glass liquor bottle—something a seaman would not have had aboard ship—a handsome belt

fashioned of silk and leather, and a pair of good quality mittens (page 454). We also found garlic cloves, peppercorns, and ginger-root, all lying loose in the chest. The man was not a cook; he was simply wise in the ways of the sea. He knew the mariner's age-old remedies, still in use today: garlic and pepper to treat a cold, ginger as a cure for seasickness.

The owner had a romantic side as well. Tucked in a corner of the chest was a length of silk ribbon once adorned with a flower, surely a memento from some lady ashore.

master gunner. The term *spak* means "tiller" in Swedish, but shortly before *Kronan* sailed, Spak had been knighted and the prefix "Gyllen" added to his name, rendering it Golden Tiller.

OVER THE YEARS we have recovered nearly 40 of *Kronan*'s beautiful bronze guns, including the six-pounder with the VIVE LE ROI inscription on it. A much larger 30-pounder bears an even more personal

Whoever she was—sweetheart, wife, or simply a friend—he had cared for her and treasured the keepsake. One hopes he survived and was reunited with her, but the odds were heavily against him.

Such personal items add a human dimension to *Kronan*—a clay pipe with the owner's teeth marks on the stem, an hourglass with the sand run halfway through and frozen in time, a small pair of dividers bearing the initials AES. Very likely the dividers had belonged to Anders Eriksson Spak, *Kronan*'s

message, this one in German: JACOB SCHULTES IN WIEN GOSS MICH—1627 (Jacob Schultes cast me in Vienna in 1627). Schultes was one of Europe's leading gun founders and his cannon is now on display at the Kalmar Museum.

Considering the primitive equipment they had, one wonders how *Kronan*'s 17th-century salvors were able to retrieve nearly half her guns, some 60 out of 126. The answer lies in a single name—Hans Albrecht von Treileben.

"IT WAS a little frightening," concedes Bengt Grisell of his descent (opposite) to the ocean floor under a 3,000-pound replica of a 17th-century diving bell. Without the benefit of air tanks, divers of that period relied on air trapped in the top of such bells to breathe underwater. This allowed them to salvage cannon and other valuable items from ships downed in battle. Between 1682 and 1686 they managed to retrieve 60 of Kronan's cannon.

In 1986 Grisell tested their method, using a bell he designed and had built based on extensive archival research. Under the watchful eye of the Swedish Coast Guard, he mounted the bell's platform (above) and braced himself for the descent to 85 feet. After swimming from under the bell (right), he successfully lassoed a cannon before returning to the bell for more air and resurfacing. The entire operation took 15 minutes; the bell holds 20 minutes' worth of air. Grisell's dry suit protected him from the frigid waters. His less fortunate predecessors probably had to knock back shots of liquor in order to feel warm.

BRITISH BROADCASTING CORPORATION (ABOVE AND BELOW)

A Swedish nobleman of German ancestry, Von Treileben was a genius when it came to organizing underwater salvage. He had engineers design a diving bell in the form of a huge lead cone, open at the bottom and large enough to carry a single diver.

The diver could work from inside the bell, using a long-handled hook to attach ropes from the surface to guns on the bottom, or he could take a breath and work outside the bell for as long as two minutes at a time. The major obstacles were cold and buildup of carbon dioxide in the bell from the diver's own breath. Von Treileben was well aware of the latter, even though oxygen would not be discovered for another hundred years! It is a testament to his skill and judgment that none of his divers were killed or suffered serious injury.

Von Treileben managed to recover some 50 of *Vasa*'s 64 guns from a depth of 110 feet in Stockholm Harbor in only two years, 1663-64. Although he did not salvage *Kronan*'s guns, some of his divers worked on the wreck in a replica of his bell. They recovered 60 cannon in a period of four years, from 1682 to 1686.

Some of those cannon weighed as much as two tons out of water, too much for the lifting gear aboard the salvage ships to raise above the surface. So the salvors brought the cannon up to a point just below the surface, then towed them to shore.

Bengt Grisell, an old friend and colleague at the Royal Institute of Technology, built a replica of von Treileben's bell and made several dives on *Kronan* with it (preceding pages). Some experts doubted that the bell could function below 60 feet, but Bengt went to 85 feet and even worked outside the bell with no trouble.

Our recovery of the cannon has led to a fascinating discovery relating to the nuclear age. One of the critical problems man faces today is that of safe storage for nuclear waste, whose lethal properties can endure for millennia. Where to store it, and in what sort of containers?

The cannon we have recovered are bronze—an alloy of copper and tin. All have been underwater for more than three centuries; some have been completely buried during that time in the clay of the Baltic seafloor. Most of the cannon show virtually no deterioration—once cleaned they look almost as new and perfect as they did on the day they were cast.

In their search for an ideal method of nuclear-waste disposal, Swedish nuclear chemists ran a number of tests on our guns. They were especially interested in one with an unusually high copper content—98.5 percent. Their conclusion: Nuclear waste stored in copper tanks, then surrounded by clay and buried in bedrock, would be safely contained for at least 100,000 years.

We are still learning from *Kronan* and will continue to do so. We have excavated only about a quarter of the wreck site and estimate that it will take at least ten more years to finish the job.

The work is endlessly fascinating and rewarding. At the opening of the Kalmar Museum two years ago the guest of honor, Carl XVI Gustaf, King of Sweden, who is a patron of the *Kronan* project and who has dived on the ship himself, declared:

"The recovery of *Kronan* off Hulterstad . . . is a major event and one of great significance even far outside the realm of marine archaeology. . . . This work and these fateful human events will remind us—despite everything—of our close contact with times past."

There could be no finer epitaph for *Kronan*. □

Portly survivor of Kronan's last voyage, this Roman warrior (right) was found 15 feet from the stern he once adorned. Low salinity in Baltic waters repels the wood-eating shipworms that attack wrecks in other seas. Traces of gilt on many of the recovered carvings (including the iron-spiked head above) recall the long-vanished glory of the crown of Sweden's fleet.

THE JOHN MUIR TRAIL

Along the High, Wild Sierra

ARTICLE AND PHOTOGRAPHS BY
GALEN ROWELL

THE SOUTHERN TERMINUS of the John Muir Trail is at a most unlikely spot: the summit of California's 14,494-foot Mount Whitney, the highest point in the contiguous 48 states. On an equally unlikely date—February 2, 1988—I started out with Rob Mackinlay and David Wilson to climb Whitney by an 11-mile-long trail from the east. From there we would begin skiing the entire Muir Trail, northward for 212 miles, through three national parks, one national monument, and four national wilderness areas (map, pages 470-71).

After our first, long day the temperature dropped below zero as we made camp a thousand feet short of the summit, on a ridge so narrow that the edges of our tent overhung cliffs that dropped away on either side. The payoff came at sunset. A rose-purple glow slowly filled the eastern sky, and the full moon appeared over an empty landscape that looked more like the Himalaya than the *(Continued on page 475)*

"One smooth, pure, wild glow," exulted mountain sage John Muir of June in his beloved Sierra Nevada. A hiker finds a dazzling echo of these words in Yosemite National Park, northern terminus of a 212-mile trail named for Muir, where solitude is easy to come by.

Coming into the country on his first wilderness hike, 16-year-old Jim Jackson passes an alpine pond, with Thousand Island Lake beyond. He has just climbed 12,945-foot

Banner Peak. "He fell in love with the region the same way I did," says the author, who was about Jim's age when he first camped near here on one Sierra Club outing.

John Muir Trail

"*Drinking this champagne water is pure pleasure,*" *Muir reveled while exploring the Sierra in 1869 as a shepherd of a flock of sheep he called "hoofed locusts." Here, 40 years later, he surveys the Merced River in Yosemite Valley, by then part of the national park. Muir had helped found the conservationist Sierra Club in 1892. He lost a heartrending battle in 1913 when a dam for Yosemite's Hetch Hetchy Valley was approved to provide fresh water for San Francisco.*

Conceived by Sierra Club charter member Theodore S. Solomons and begun a year after Muir's death in 1914, the trail ascends from Yosemite Valley, hugs the Sierra crest, and ends on 14,494-foot Mount Whitney. En route nearly a dozen peaks exceed 14,000 feet.

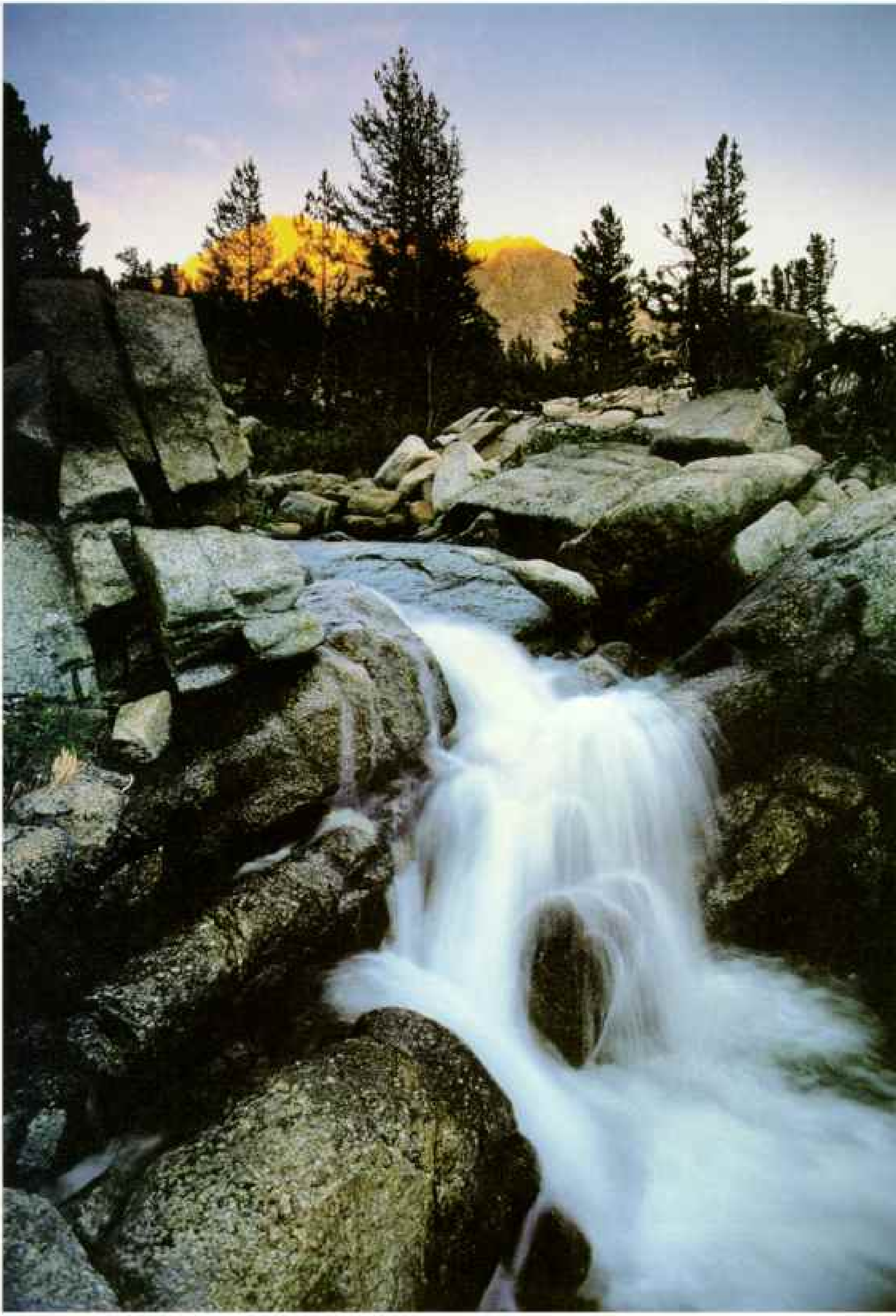
OLIVER KEHRLEIN, COURTESY SIERRA CLUB

Even before the trail was completed in 1938, hikers had begun to take to the wilderness en masse, a tradition continued by this 1951 Sierra Club group. "The people had become Muir's sheep," says the author. Mules packed wood-burning stoves and iceboxes, later filled with snow in camp. This site became part of the Minarets (now Ansel Adams) Wilderness after the Wilderness Act of 1964, which protected places "where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain."

Today the trail passes through three national parks, one national monument, and four wilderness areas. But backpacking no longer holds as much magic for the young generation, and only a few hundred people a year hike the entire trail.

Amid shadow and a great deal of substance, hikers drink in a powerful landscape that includes a rugged ridge near the summit of Mount Whitney. The southern

end of the John Muir Trail winds through this basin, looping westward for a few miles before swinging north along the Sierra crest.



(Continued from page 467) gentle wilderness that naturalist and explorer John Muir roamed so long ago. Though the trail was created after Muir's death, his love of California's Yosemite and High Sierra helped inspire the trail that bears his name.

We slept fitfully that night on the ridge, all too aware of the danger of rolling over. At dawn the light show repeated itself with the sun and moon in reverse positions as we scrambled our way up to the summit. By mid-morning we were skiing down the Muir Trail, our uphill effort now rewarded by a long glide from barren heights through a mystical timberline forest of foxtail pines. Here we set up a second camp amid dead limbs poking out of the snow; they were burnished and twisted by the elements. We were cold and sweaty, but we hesitated before the next obvious step, as David expressed all our thoughts: "Let's not build a fire; this forest is too beautiful."

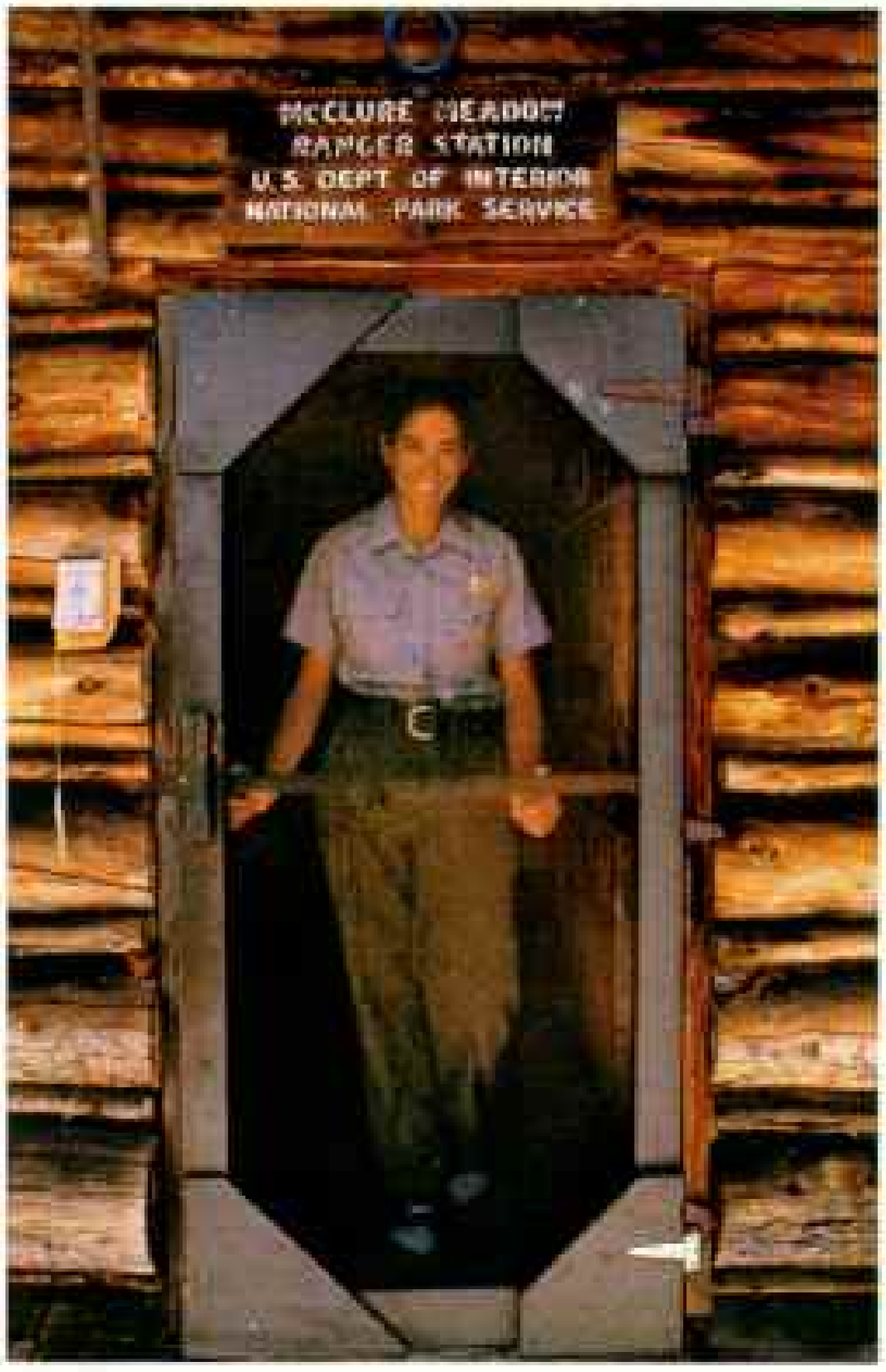
That winter expedition was the beginning of my quest to explore the trail in all seasons. For the first 160 miles David, Rob, and I saw no one. Maps and tree blazes in the forests helped us stay near an invisible path buried beneath three to six feet of snow.

On our 17th day, as we glided the last miles into Yosemite Valley, I recalled a favorite John Muir quote, written in 1873 after his fifth Yosemite season: "The last days of this glacial winter are not yet past, so young is our world. I used to envy the father of our race, dwelling as he did . . . with the new-made fields and plants of Eden; but I do so no more, because I have discovered that I also live in 'creation's dawn.' The morning stars still sing together, and the world, not yet half made, becomes more beautiful every day."

JOHN MUIR'S LIFE defies quick definition. Born in Dunbar, Scotland, in 1838, he grew up in Wisconsin, then walked from the Ohio River a thousand miles to the Gulf of Mexico, signing his travel journal "John Muir, Earth-planet, Universe." He planned to continue south to explore the jungles of the Amazon, but a bout of malaria turned his sights west to California, where he arrived in 1868 and immediately fell in love with the land.

Over the next decade Muir became well-known as a Sierra mountaineer, explorer, and naturalist. He often wandered near the trail's present course, believing that "only by going alone in silence, without baggage, can one truly get into the heart of the wilderness."

In later life Muir built another, more significant career upon his first. He became the nation's foremost conservationist. Yosemite National Park was established in 1890 essentially to Muir's recommendations.



"I am well again, I came to life in the cool winds and crystal waters," Muir wrote, invigorated by Sierra treasures like this cascading stream (facing page). Em Scattaregia (above) has sought such rewards during nine seasons as a ranger. The National Park Service and U. S. Forest Service share the trail but often take separate forks on policy. Helicopters, used by the Forest Service only for emergencies, ferry park rangers and trail crews into the backcountry and sometimes relocate problem bears.

An expert mountaineer, GALEN ROWELL climbed Yosemite's Half Dome in 1973 for his first GEOGRAPHIC assignment. His photographs most recently appeared in the November 1988 magazine.

Two years later he helped found the Sierra Club, which originally limited its conservation activities to "preserving the forests and other natural features of the Sierra Nevada Mountains," before it branched out in recent years to tackle global issues.

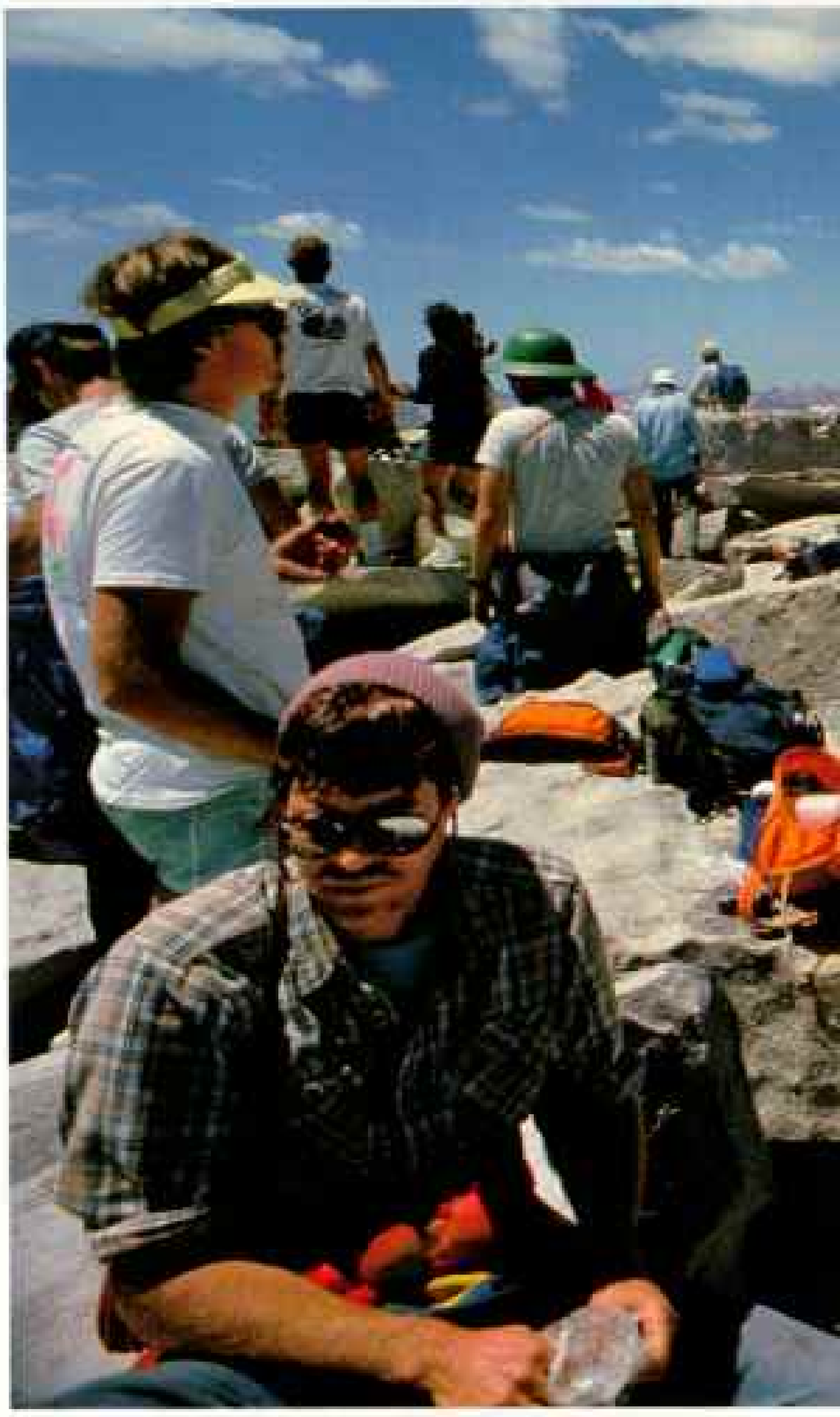
In 1903 Muir lured Theodore Roosevelt away from his presidential entourage to spend three nights in Yosemite. Later the President remarked to his party that the time he spent talking conservation with Muir was "the grandest day of my life!" His administration was to make the most sweeping conservation effort in the nation's history.

John Muir died on Christmas Eve in 1914. Soon afterward the Sierra Club helped persuade California to appropriate $10,000 to begin construction of a memorial John Muir Trail, from the summit of Mount Whitney to Yosemite Valley. Not until 1938 was the last section, called the Golden Staircase, finished.

I HAD SPENT MANY YEARS trekking and climbing in the High Sierra of California without following the whole John Muir Trail, assuming it was too crowded for real pleasure. Only after seeing its present state for myself and studying its history did I discover that mine was just one of several widespread misconceptions about a trail that has become *less* crowded since the mid-1970s.

Before I set off in the summer of 1988 to retrace the trail on foot, I visited someone who had been there before it was completed, a very special woman who traveled major parts of it during the summers of 1923, 1924, and 1925. Margaret Avery trekked as much of the present route as possible with her sister Marion and several friends. When they reached Evolution Valley, a point about midway along the trail, they made the first ascent of a sharp rock peak called The Hermit.

As we looked through her worn scrapbook crammed with photographs of lakes, mountains, and mule trains, I felt her youthful exuberance return. She spoke in the present tense about "summers that mean more to me than anything in my whole life," and I wondered if anything else in the life of a woman born in the first year of this century could have remained as much the same. Had her album contained pictures of school years, friends, relatives, or hometown scenes, she would now be thinking about them in the past tense, but the wilderness landscape in her scrapbook exists largely



Calm or chaos—either can reign atop Mount Whitney. On holiday weekends in the early 1970s more than a thousand visitors a day hiked an 11-mile route to the summit. To limit access, Inyo National Forest in 1974 instituted an annual lottery to fill a quota, now set at 50 campers a day. Thus on Labor Day evening of 1987 permit-holding campers atop Whitney enjoy a quiet moonrise over Owens Valley (right), in contrast to a sprawling scene hours earlier created in part by day hikers.

unchanged from the day she first set eyes on it.

Such is the legacy of John Muir. By using the weight of his fame and the muscle of his prose to help legislate protection for his favorite Sierra wildlands, he gained a kind of immortality that few human beings ever achieve. The physical world of his writings, unlike that of many of his contemporaries in the American West, is alive and well today, not only in his many books that remain in print but also in an elderly woman's memories and in my own fresh experience.

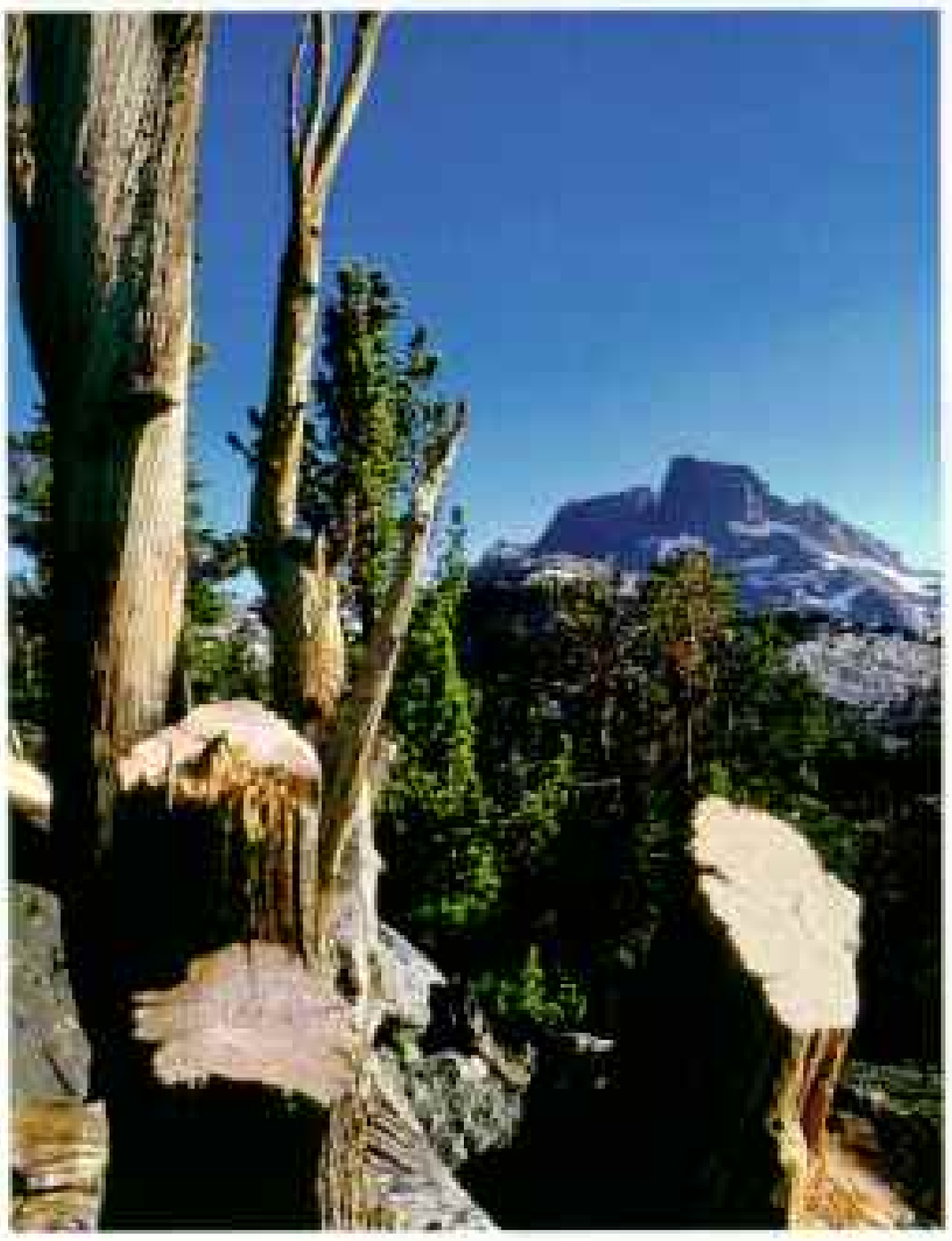
As we turned the pages of the scrapbook together, I mentioned that I didn't see anyone carrying a pack.

"Of course not! I'd never even heard the word 'backpacker.' And we didn't have all those nylon tents, lightweight packs, and freeze-dried foods you now carry on your back. We had a choice of weekend trips, hikes between cabins, or going with a packtrain, which I thought was a once-in-a-lifetime experience that I could never afford again. The mules cost so much! We couldn't rent them, so we bought them outright for $60 each."

She returned in 1951 with her husband and ten-year-old son as part of a comparatively tame Sierra Club outing of 111 souls who camped a mile off the trail for two weeks. Mules carried everything. Camp staff cooked and led hikes. Her son, undeterred by the crowd, felt as if he entered paradise when the narrow trail beneath his feet delivered him into a primeval world of lakes and flowers set beneath sharply etched peaks of rock and snow. As he watched his mother joyfully reunite with her youth and the natural world, the boy began a lifelong love affair with a mountain range that was beginning to win a popularity contest but also to lose its wild character wherever roads provided easy access.

Thirty-seven years later the son thumbed through his mother's scrapbook yet again before hiking the trail himself. I am that boy, and after the snows of my winter journey melted back in June, I set out to retrace the route on foot, trekking in different styles with a variety of hikers, climbers, riders, scientists, rangers, packers, and mules as the brief alpine seasons passed from spring to summer to fall.

I also searched out the inside story behind the trail's creation and present management. Few people realize that the John Muir Trail is not protected by law. It draws its protection instead from the federal lands it winds through—the parks, the wildernesses, the national monument. These are managed by two separate agencies, the National Park Service and the U. S. Forest Service, in two different ways. Thus when a hiker along the trail passes from one area into another, it can be like crossing a border between two countries.



Craving a fire, campers illegally cut a whitebark pine. Fires, where permitted, may burn only dead and down wood.

THE ORIGINAL IDEA of a "crest-parallel trail through the High Sierra" began as the dream of a 14-year-old boy named Theodore S. Solomons, who worked on a cattle ranch within sight of the peaks. He was after a route that could be used by packtrains of horses and mules that could travel long distances with heavy gear.

Eight years later, in 1892, Solomons set out to explore a route from Yosemite Valley southward, with one partner, two mules, a rifle, a Dutch oven, and a big 8-by-10-inch camera loaned by C. E. Watkins, a famous pioneer photographer. Solomons didn't get very far, but he returned three years later to push a hundred miles south from Yosemite, where he encountered a rampart of high peaks above what is now called Evolution Valley. Before turning around a short distance later and

giving up his quest, he named the mountains Darwin, Huxley, Wallace, Fiske, Spencer, and Haeckel, because the grand setting reminded him of "the great evolutionists, so at-one in their devotion to the sublime in Nature."

Parts of Solomons's original trail have been slightly rerouted, but the northerly half continues to follow his wanderings with his mules over ridges and through valleys, thus retaining a distinctly different character from the newer southern half, engineered and blasted by hired crews to pursue more directly the goal of a trail beside the High Sierra crest.

CROWDS ARE CURRENTLY not a problem except near roadheads. In August, at the height of the season, I expected the worst as I hiked south from Devils Postpile National Monument with a group of friends. A swarm of tourists, some pushing baby strollers, others carrying ice chests, plodded down a half-mile spur trail to the monument's chief attraction, a cliff of amazingly regular volcanic columns (page 491). Beyond we had the Muir Trail virtually to ourselves.

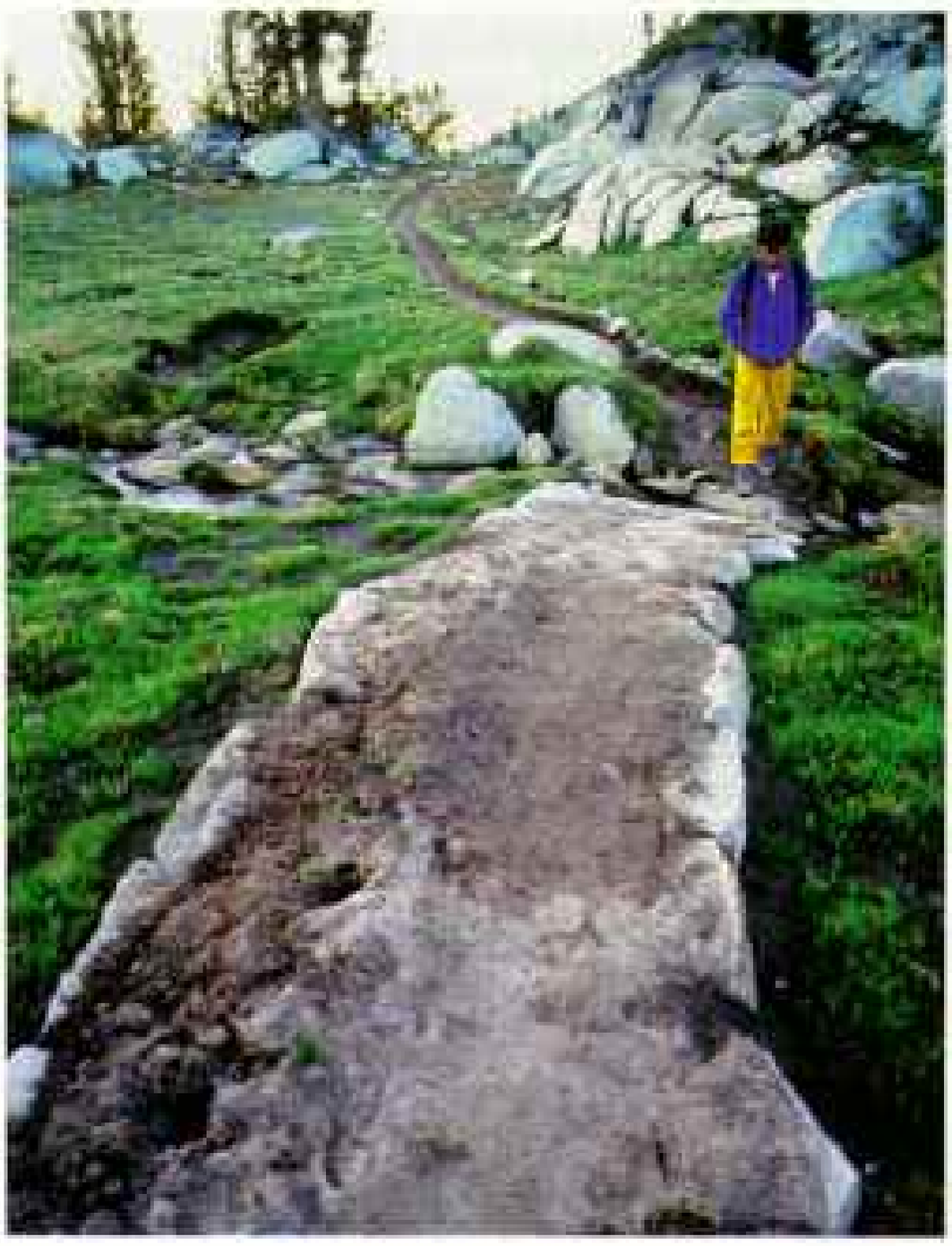
A day later one of the group exclaimed, "This is the best kept secret I know! We passed only 15 people all day. I had this image of a broad, crowded, dusty freeway."

That evening at camp, as we gazed at the wild horizons, he remarked, "It feels kind of eerie that we're all alone. Maybe the trail has been blocked by a forest fire. Or something bad has happened in the outside world."

His comment reflected both the sense of isolation in a place apart from media and phones as well as an understandable belief that the trail was somehow blocked. Instead of catastrophe, however, the cause was purposeful management.

In John Muir's time a wild experience was simply there for the taking. It now exists in our most populous state only because of strict government orchestration. John Muir set the stage a century ago by urging that vast tracts of land be kept in a primitive state forever. National parks were the first patches in the protective quilt that now surrounds the John Muir Trail.

When Congress established a national wilderness system in 1964 to give extra protection to selected federal lands, portions of Sierra and Inyo National Forests were designated as the John Muir Wilderness, an entirely separate



Multi-lane eyesore (above) occurred when spring snowmelt turned the trail to mud. Hikers, horses, and mules chose drier ground, creating parallel paths that also became muddy ruts. As a remedy on another stretch, the California Conservation Corps built a raised bed of rock and gravel—another eyesore to some.

entity from the trail that just happens to pass through it.

After the eight-day group hike through the John Muir Wilderness, I met with Ernie DeGraff, assistant recreation officer for Inyo National Forest.

"Solitude," DeGraff proclaimed, letting the word hang for a long moment, "is a legal requirement of designated wilderness. Congress directs us to provide 'outstanding opportunities for solitude.' The creation of the John Muir Wilderness forced us to make a tough decision on public access. During holiday weekends we had over a thousand people on the 11-mile Mount Whitney Trail, which connects with the Muir Trail two miles below the summit of the mountain. That's hardly what you'd call solitude. We saw just two alternatives: Either remove Whitney from the wilderness or limit access to the mountain. We chose the latter and set a trail quota in 1974. The lure of the summit is so great that we have to use a lottery for summer permits. If you don't apply early, you might be out of luck."

COMPARED WITH THE CROWDS at popular sites along the Muir Trail, relatively few trek the entire 212-mile route. In 1988 only 104 people had registered to hike the length of the trail north from Whitney, and another 134 to walk south from Yosemite. Most hikers use only small parts of it.

One evening as I sat around a campfire with a group of six hikers and two packers, near the midpoint of the John Muir Trail, Sebastian Letemendia, a recent college graduate from Argentina, asked me a question I have faced before: "Won't a NATIONAL GEOGRAPHIC article harm this area by attracting even more people?"

"More people will come," I acknowledged, "but that's only the negative side of publicity. An article can also increase public awareness about the need to preserve wildlands, so that they'll stay just as wild for our children and our children's children."

"You could count me against your story if you were displaying an unknown region before the public eye," said Doug Powell, a bearded geography professor legendary for his encyclopedic knowledge of the High Sierra. "But the Muir Trail is well-known, and it has lots of environmental controls in place. I've hiked the entire trail six times over the past 40 years, but even people who never hike it will benefit from knowing that a place like this still exists in America. If political support for wilderness came only from those who camped here, we'd be in real trouble."

I couldn't have agreed more. "Imagine how different our experience would be tonight if John Muir's buddies had persuaded him not to write about his journeys," I added.

"We would be able to hitchhike home from here," added Dick Duane, an attorney and first-time hiker on the Muir Trail. "And we wouldn't be sitting around this campfire. There'd be a highway instead of a trail and a 7-Eleven right over there."

An evening campfire was something John Muir took for granted. Today it is a dying tradition, a luxury of lower valleys with abundant wood. Someday no fires at all may be allowed along the trail. They are already banned at higher altitudes in the national parks. Muir's ideas about protection of wildlands were visionary in his time, but they don't go far enough to save wilderness in today's crowded world. He wanted to set aside land, but he didn't consider the cumulative effect of his own behavior. To save carrying the extra weight of a bedroll, he sometimes burned centuries-old timberline logs all night to keep warm. When a trail was proposed up Half Dome, he wrote, "No great damage could be done by tramping over it. The surface would be strewn with tin cans and bottles, but the winter gales would blow the rubbish away."

Today's trail restrictions on fires, soap, campsites, litter, stock grazing, sanitation, and group size all force visitors to heed the basic message of the environmental movement: the need to adapt behavior so as not to alter the natural state of the earth. As the cumulative effect of people on the land increases, regulations for minimum individual impact must become ever more stringent.

The original *(Continued on page 486)*

Ascending Mount Whitney to pick up the John Muir Trail, Rob Mackinlay skis past a gnarled foxtail pine. These hardy, wind-blasted conifers, which manage to survive at an altitude of 11,500 feet, are closely related to bristlecone pines—the world's oldest living things—that grow in the White Mountains to the northeast.

Through a shattered grove of lodgepole pines in Le Conte Canyon, Rob Mackinlay, a Nordic ski instructor, glides along the trail through a meadow on a 17-day tour with the author's party in February 1988. Two years earlier a blizzard had partially buried the trees; then an avalanche tore off the tops.

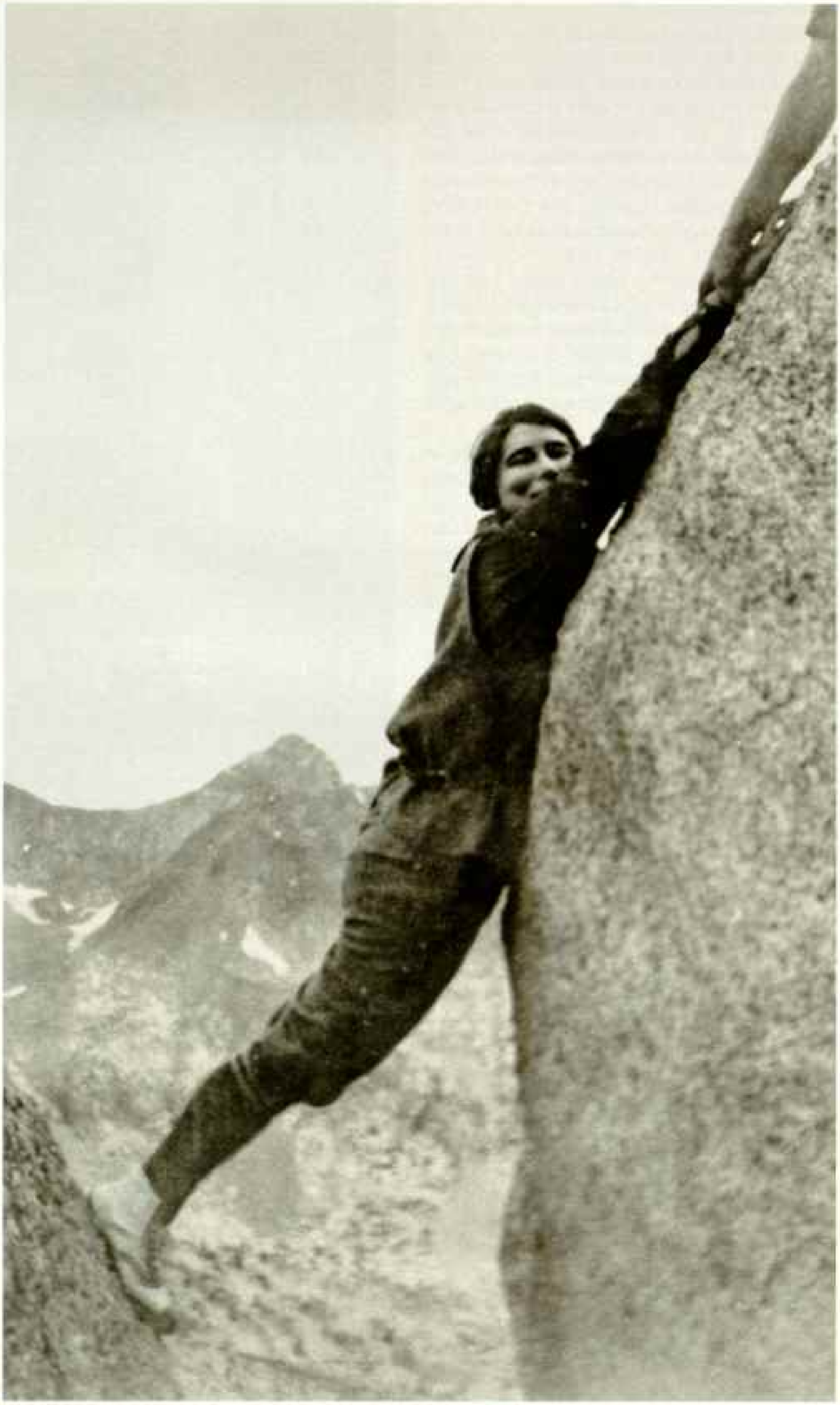
The Sierra rewards a handful of winter visitors with enduring memories, but many other Californians look to the mountains with more pragmatic expectations. Since the 1930s, in the wake of Muir's lost conservation battle, the people of San Francisco and its environs have relied on the annual snowpack for an important part of their water supply. A husband-and-wife team of winter rangers, Brent and Tory Finley, weigh a core sample of snow at Tuolumne Meadows for water content, data used by the California State Department of Water Resources to forecast runoff into the Hetch Hetchy Reservoir. They also perform tests to help predict avalanches. Snowfall in the winter of 1987-88 proved meager, heralding a drought in California the following summer.

The notion of draining and restoring Muir's beloved Hetch Hetchy Valley was raised in 1987 by Secretary of the Interior Donald Hodel. His idea of tearing down the valley's dam—an old dream of many conservationists—resulted in little more than a confusing political brouhaha.

Like mother, like son

SHE MUST HAVE BEEN a real caution, and high-altitude genes run in her family. Fresh out of the University of California at Berkeley 65 years ago, Margaret Avery, a cellist and future mother of author-mountaineer Galen Rowell, decided to tackle the Sierra with her sister Marion—who took these photographs—and several eager friends. They explored the Muir Trail for three summers. Unable to rent mules, they paid $60 for each balky animal, which had to be dragged over Donohue Pass through late snow (above right).

They camped at McClure Meadow (shown above in a hand-tinted scene) beneath The Hermit, a 12,360-foot peak. On July 2, 1924, they became the first to climb it, as a friend pulled Margaret the final few feet up the sheer summit (facing page). "It was her thrill of a lifetime," says Galen of his mother, now 88. During the 1950s Galen, his mother, and his father, Edward Z. Rowell, a professor at the University of California at Berkeley, returned on Sierra Club outings. At a campfire Galen's father spoke about "what mountains can mean for the human spirit" and of the truth of the Latin saying *"Montani semper liberi*—Mountaineers are always free."



(Continued from page 480) Muir Trail passed through private land at Blayney Meadows, but it has now been rerouted to skirt the Muir Trail Ranch, where guests come from across the nation for a remote dude-ranch experience. In 1897 the first owner used the Swamp Land Act to claim meadowland that included natural hot springs. In 1924, the year my mother passed through, the government reclaimed one spring because of an error in the original survey. Today two "rich man's" springs, used only by ranch guests and employees, trickle into tubs surrounded by wildflowers and finely crafted wood (lower right). The "common man's spring" is a chest-deep hole in a mountain meadow that feels like paradise to dusty hikers from all walks of life after long days on the trail.

On a warm August evening I soaked for an hour with hikers age 6 to 73. Swimsuits were optional. I pondered why most people under 40 were clothed, whereas many of their elders were au naturel. As I listened to a matronly Venus from Sacramento chat about her quest to hike the trail in sections over six summers to fulfill a dream she had 20 years before, I found my answer. Many hikers who were young adults in the sixties were now living out old fantasies, both by soaking in the buff in nature's own hot tub and by the vagabond act of abandoning all their settled manners for a new life on the trail, however temporary.

I also had an insight into why the trail is so much less crowded today. During the week quotas are only about half-filled, except on popular sections. The John Muir and Ansel Adams Wildernesses had more than twice as much use in 1968 than in 1988. In Yosemite overall visitation is up 40 percent over the past 15 years, while backcountry use is down from a high of 219,000 visitor nights in 1975 to just 105,000 in 1987.

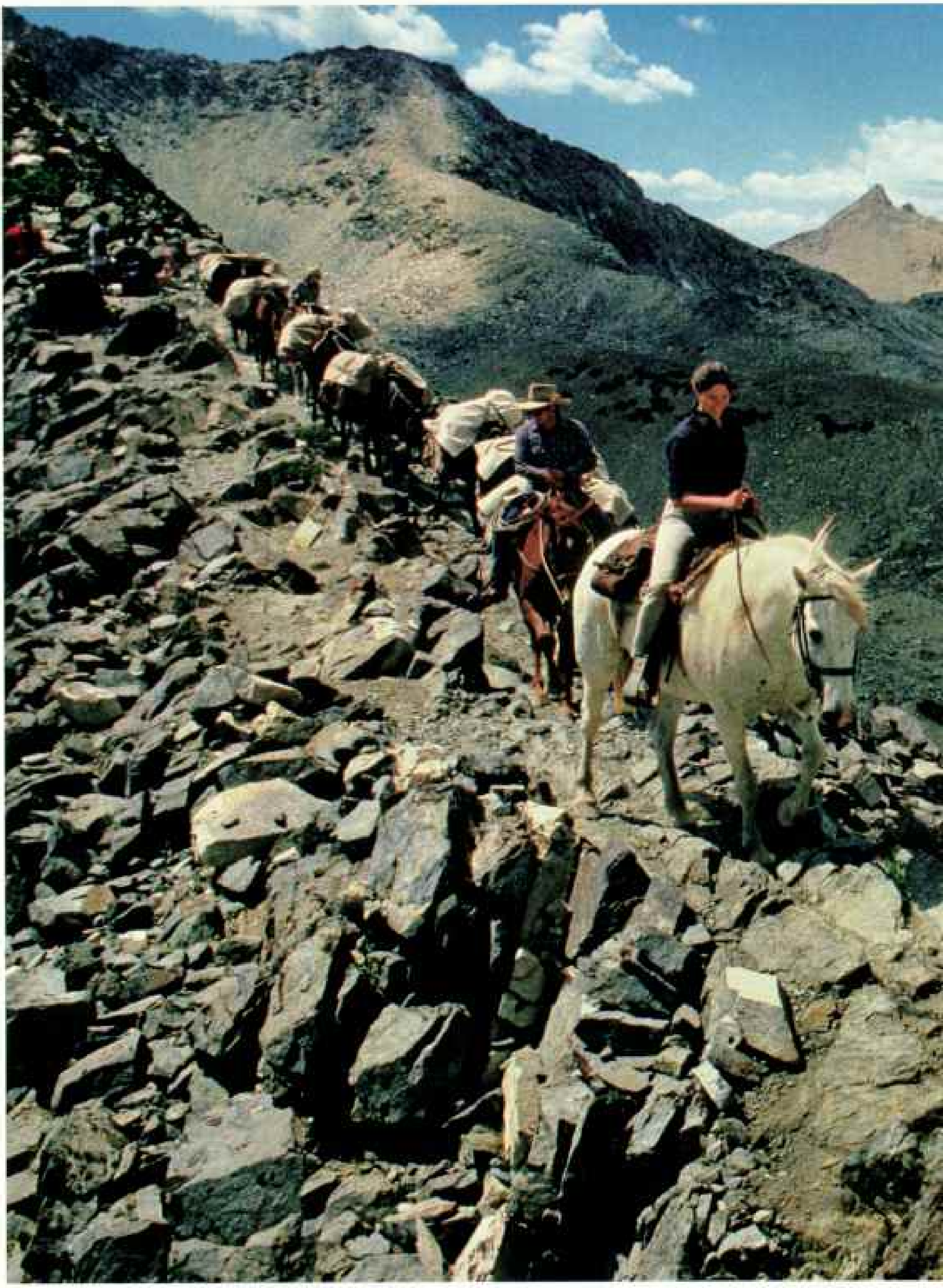
Bob Tanner, a veteran packer who operates mule trains for hire, explains the drop by simple demographics. "The statistical bump of the baby-boomer generation has pushed its way through everything from schools to jobs to real estate. We used to have lots of young people with time on their hands. A disproportionate number headed for the mountains. Now that they have jobs and kids, backcountry visitation is down."

Doug Powell, the professor, sees it more in social terms. "In the sixties backpacking was a real cult affair. My students came to class in

To enjoy the Sierra in style, guests pay as much as $745 for a week at the Muir Trail Ranch. Owned by Adeline Smith, here in her office with granddaughter Hilary, the ranch is part of the only private tract along the trail. Hikers can cache their food at the ranch for a fee.

In 1897 the first owner claimed meadowland around several natural hot springs. Two, stylishly enclosed, are used by ranch guests and staff like Michele Disney. Another, reclaimed in 1924 by the federal government, is a cheerful mudhole where hikers soak for free.


MUIR TRAIL RANCH



On a knife-edge nearly 12,000 feet high, surefooted horses and mules cross Glen Pass, with the author's wife, Barbara, in the lead. Outfitters face formidable Park

Service restrictions. Grazing of hoofed stock is prohibited at some camping areas; at others, pack animals are permitted but horses with riders are not.

lug-soled boots, dressed to climb mountains and save the world from becoming overcivilized. That was the in thing to do. That kind of kid is less common these days."

I MET TWO VETERANS of the 1960s carrying 65-pound packs in Le Conte Canyon. Steve McMillan and John Zalabak were making a 20th-anniversary repeat hike of the Muir Trail. "It seems just the same," Steve said. "If anything, there is less trash and fewer people now."

The next day, however, I had an experience that couldn't have happened in the old days. David Wilson and I took off before dawn to climb a new route up the 3,000-foot east face of Langille Peak. Our plan was then to traverse the canyon rim and meet our packtrain and three other hikers at Sapphire Lake, 11 miles away. We arrived dead tired in the evening without down jackets or sleeping bags. The packer and his string of mules weren't there, and neither were our friends.

We continued on to Evolution Lake. Still no packtrain. After 17 long miles we found them in the bottom of a deep canyon just as darkness was falling, but one hiker was still missing—a doctor on his first cautious outing after major hip surgery. He spent the night out, after hiking 22 miles without finding camp.

"What happened to our plan?" I asked Steve Stewart, our packer, who like all his breed rides a horse to lead his string of mules.

"A park ranger on the trail said we couldn't camp with stock at Sapphire," Steve explained, "so we went on to Evolution. A sign there said we couldn't camp and graze unless we were a walking mule party. In other words, hikers who walk with mules carrying their gear are OK, but not if their mules are led by a packer riding a horse. I don't think the meadow knows the difference between being grazed by an animal that carries a pack or one that carries a packer, but that's the rule there, so we kept on moving to the first legal site. It seems like the Park Service has done everything but stop packers directly."

After a second incident I talked to Alden Nash, backcountry ranger for Sequoia and Kings Canyon National Parks. "Your packer should have read the regulations we sent him with his permit," he responded.

"He says they weren't included, and when I asked him to check by phone that all our proposed campsites were OK for packers and animals, no one at park headquarters could give him the information."

"Well, here's a copy. The regulations haven't changed in two years," Nash said, handing me a typewritten sheet.

"Thanks," I said, as I scanned both sides, "but where does it say anything about Sapphire Lake or a 17-mile stretch of trail being closed to grazing by packtrains with saddle horses?"

Nash searched long and hard for words that weren't there.

"Why does the park discriminate against packers and horseback riders?" I asked.

"Minimum impact on the wilderness is our goal. Stock use affects the land more than hiker use, so we limit grazing in certain areas."

"Packers helped build this trail," I countered. "Don't they have a right to continue the tradition of the Old West on public land?"

"I've heard that argument many times, and it doesn't hold up," Nash replied. "As a hiker once told me, 'Slavery was once traditional, but if slaves had built the Muir Trail, we would not continue that tradition today.' "

Ronald Reagan rode a horse onto the Muir Trail as governor of California in 1972 to announce his administration's opposition to a proposed trans-Sierra highway. Over breakfast one morning a disgruntled packer reminded me, "Do you think Ronnie would have done that if he had to backpack? The rangers who want to kick us out forget that wilderness doesn't exist in a vacuum. The political side of wilderness is just as fragile as the land. Not every American wants wilderness. A lot of people think their tax dollars are keeping these lands pristine so that a rugged few get to have free vacations.

"We packers are the safety valve. We guarantee access for everyone. Last week I took a man recovering from a stroke onto the trail. He fell off his horse a couple of times, but he loved the trip. I've taken blind groups, families with little kids, people in their 80s, and people who simply choose to be around mules rather than try to be one themselves. Access for the disabled is law in the city and in many parts of national parks. To kick us out of here is to risk the whole concept of wilderness as we know it today."

Steve Roper, author of *The Climber's Guide to the High Sierra*, sums up his view eloquently: "The Sierra is eminently suited for walking, and except in very special circumstances,

Like a geologic soccer ball, distorted by the author's wide-angle lens, volcanic columns as high as 60 feet intrigue a hiker at Devils Postpile National Monument. Nearly 100,000 years ago basalt poured from a vent in this valley and cooled to form polygonal columns. Glaciers later sheared off the tops and polished the surface.

it would seem indefensible to ride a horse or let a mule take one's belongings into a semi-pristine world. . . . Perhaps the day will come when a massive campaign will phase out pack-trains once and for all."

Weeks later I met with Ernie DeGraff of Inyo National Forest and Dudley Robertson, a former packer and present recreation officer for Sierra National Forest. When I brought up my problems traveling with stock, Robertson said, "In the Sierra National Forest we do things differently from national parks. I like to think we have better communication with our packers, but we're also guilty of not considering the daily intervals between camps that Muir Trail parties need to maintain when we close meadows to prevent overgrazing. Did you have any problems in my area?"

"No," I answered, "but tell me more about those differences. When I walk the trail, the countryside appears just as wild in a national forest wilderness as when I cross into a national park wilderness, but behind the scenes you seem to be quite different."

"That's right," DeGraff agreed. "Parks are under the Department of the Interior, and we're under the Department of Agriculture. Park rangers have sole jurisdiction, but we don't manage the wildlife—state fish and game wardens do that. Hunting, dogs, and guns are banned in parks but allowed in forests."

"Come to think of it," I interjected, "I did have wildlife come right into camp several times in the parks but never in the forests."

"I'm not surprised," DeGraff continued, "and you probably saw more rangers there too. Park rangers are more enforcement oriented. We put a priority on trail maintenance and site restoration. Every wilderness ranger is issued a 'walking stick'—it's called a shovel. We don't keep every side trail in shape for stock use, but we work them enough to keep them walkable and to prevent erosion."

Robertson added, "The parks use hired trail crews for major work, but the Forest Service has an 'adopt-a-trail' policy. We've got many private groups such as Outward Bound, Sierra Club, and the Heritage Trails Fund maintaining segments of the Muir Trail.

"Where we often differ is on fire policy. Up until 1986 we automatically put out every fire on our land, and parks sometimes let natural fires burn on theirs. Now we look at each fire and deal with it on a case by case basis, taking fire size and intensity, location, weather

conditions, availability of manpower, and other variables into consideration."*

"And then there're helicopters," Robertson continued. "We use them only for emergencies. The parks often use them for routine tasks such as moving crews doing trail work."

"That's a far-reaching difference," I commented. "I know that backcountry rangers along the Muir Trail in Sequoia and Kings Canyon Parks are sometimes flown in and out with their gear, but there's a temptation to use choppers to deal with wildlife too. Do you ever use them to relocate 'problem' bears in or out of the wilderness?"

"Nope," Robertson answered, "but I wouldn't be surprised if some of the bears that destroy food and packs and people's dreams along my part of the trail started their careers in car campgrounds in the national parks."

Bill Tweed of Sequoia and Kings Canyon National Parks confirmed Robertson's suspicions. Over the past two decades, several park bears have become frequent fliers, courtesy of the National Park Service. A few have received one-way tickets to the Muir Trail. On June 27, 1987, a mother bear with three cubs was flown into Goddard Canyon. "We moved the bear against our better judgment," Tweed explained, "because we hated to destroy this beautiful wild animal that had become corrupted by campers and their easily obtained food. We hoped that the cubs might grow up wild, and we took a chance with them." Unfortunately, the bear family soon wandered into Sierra National Forest, and the mother was killed.

"We have largely discontinued bear relocations," Tweed indicated, "because bears seldom stay put. During the past decade we've come to the conclusion that relocation is an ineffective long-term management solution for most problem bears."

Another kind of aerial relocation is having a far more positive result. Only about 300 rare California bighorn sheep survive in the High Sierra. Many of the animals summer near the Muir Trail in Kings Canyon National Park and winter in Inyo National Forest. On a sunny morning in March, I joined a group of biologists and veterinarians from the California Department of Fish and Game, the Forest Service, and the Park Service, who had come together to capture bighorn for relocation to the Yosemite region, where diseases spread by domestic sheep had killed most of the wild species even before John Muir arrived in 1868.

We set up nets on a steep hillside and waited. Soon a helicopter appeared barely above the ground with a charging herd of bighorn in front of it. Eleven animals were caught in the nets and transplanted to a canyon with good winter range just east of Yosemite, where they joined 22 other bighorn, animals transplanted two years earlier and their offspring. As the herd grows and expands its range, Yosemite visitors may once again see bighorn standing tall against the sky.

MY FONDEST MEMORY of the Muir Trail is an experience I thought was no longer possible in today's California. Back in 1919, along the upper Fish Creek region a mile above the present Muir Trail, a well-known Sierra historian named Francis Farquhar saw a "particularly beautiful peak that towers above the head of the cañon like another Matterhorn."

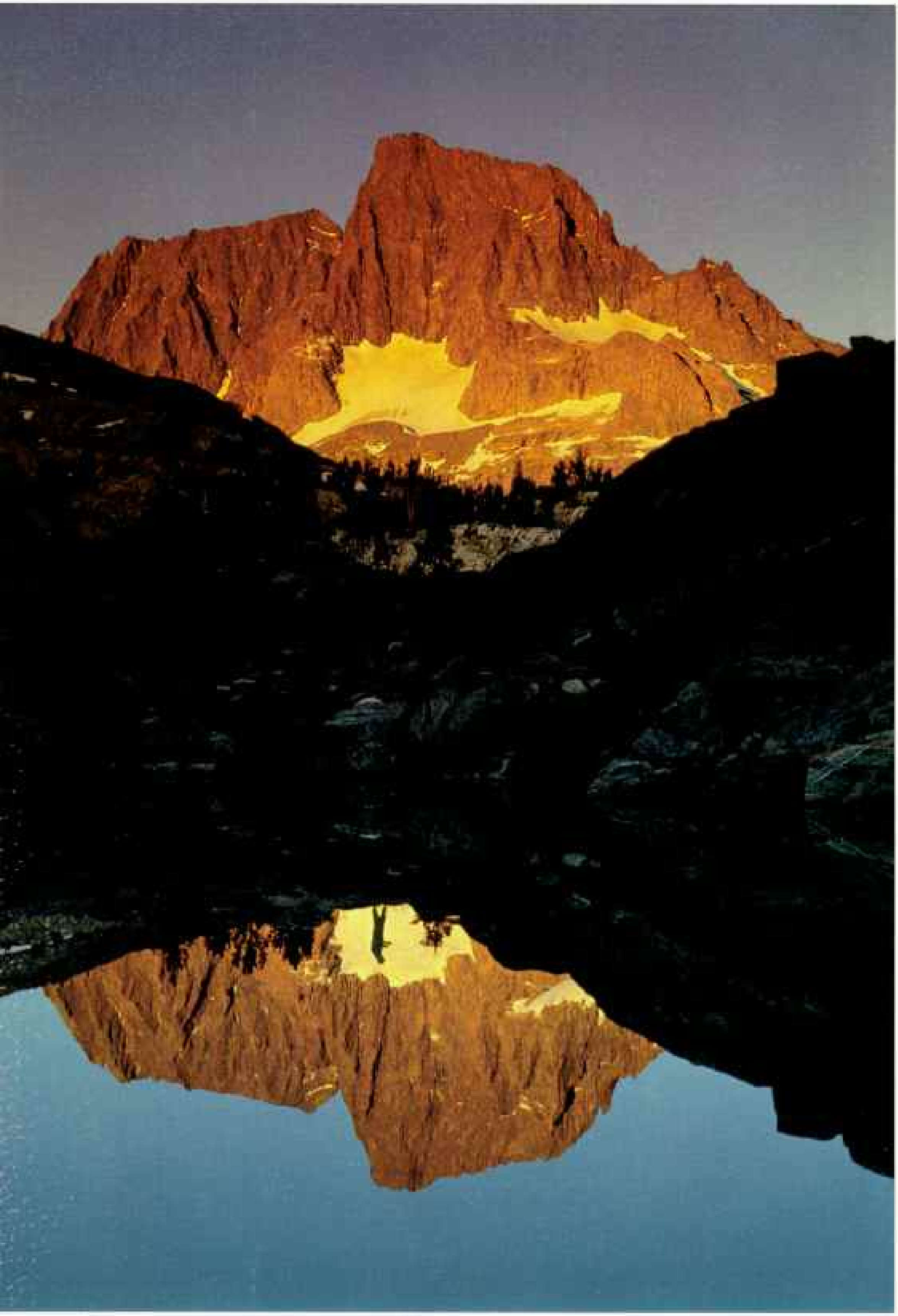
In an article, he proposed the name Piscator Peak, meaning "fisherman's peak," because of its position above Fish Creek. Although several other of Farquhar's place-names are in current use, maps show this peak as unnamed. Unaware of Farquhar's article, I spotted the sheer, 900-foot north face of the peak on my winter ski trip, noting it in my journal as a possible summer climb.

On an August day in 1988 three friends joined me to climb the steepest side of Piscator Peak using ropes and hardware for safety. Although I expected the peak to have had countless ascents from other directions, I found no indication of human presence at the summit. As I gathered a simple pile of stones and placed them on the top, I thought about my mother's party doing the same thing on the summit of The Hermit six decades earlier.

That a distinctive, 11,343-foot mountain in California remained unclimbed until 1988 is a testimonial to the continuing wildness of the John Muir Trail. □

Time for reflection: At dawn a hiker stands mirrored beneath twin titans—Mount Ritter at left, first climbed by Muir, and Banner Peak. The Sierra, Muir proclaimed, should be called "the Range of Light."

*See "Yellowstone: The Fires of 1988," by David Jeffery, in the February 1989 magazine.



By BART McDOWELL SENIOR ASSISTANT EDITOR
Photographs by O. LOUIS MAZZATENTA
SENIOR ASSISTANT EDITOR

Cartagena Nights

WITH WISDOM and hospitality, a former President of Colombia urged his official visitors to see the antique city of Cartagena *de noche y en coche*—a rhyme in Spanish, "by night and by coach."

Romantic notion, and more: This fortress city on the Caribbean is a world heritage site, as designated by UNESCO. Like an aging beauty, Cartagena best recaptures her voluptuous past in the dim light of candles and coach lamps. To the cadence of horse hoofs, on streets so narrow that balconies almost collide, visitors see baroque facades and castellated bastions . . . a shadowy, lived-in museum with street life and laughter and the gossip of history.

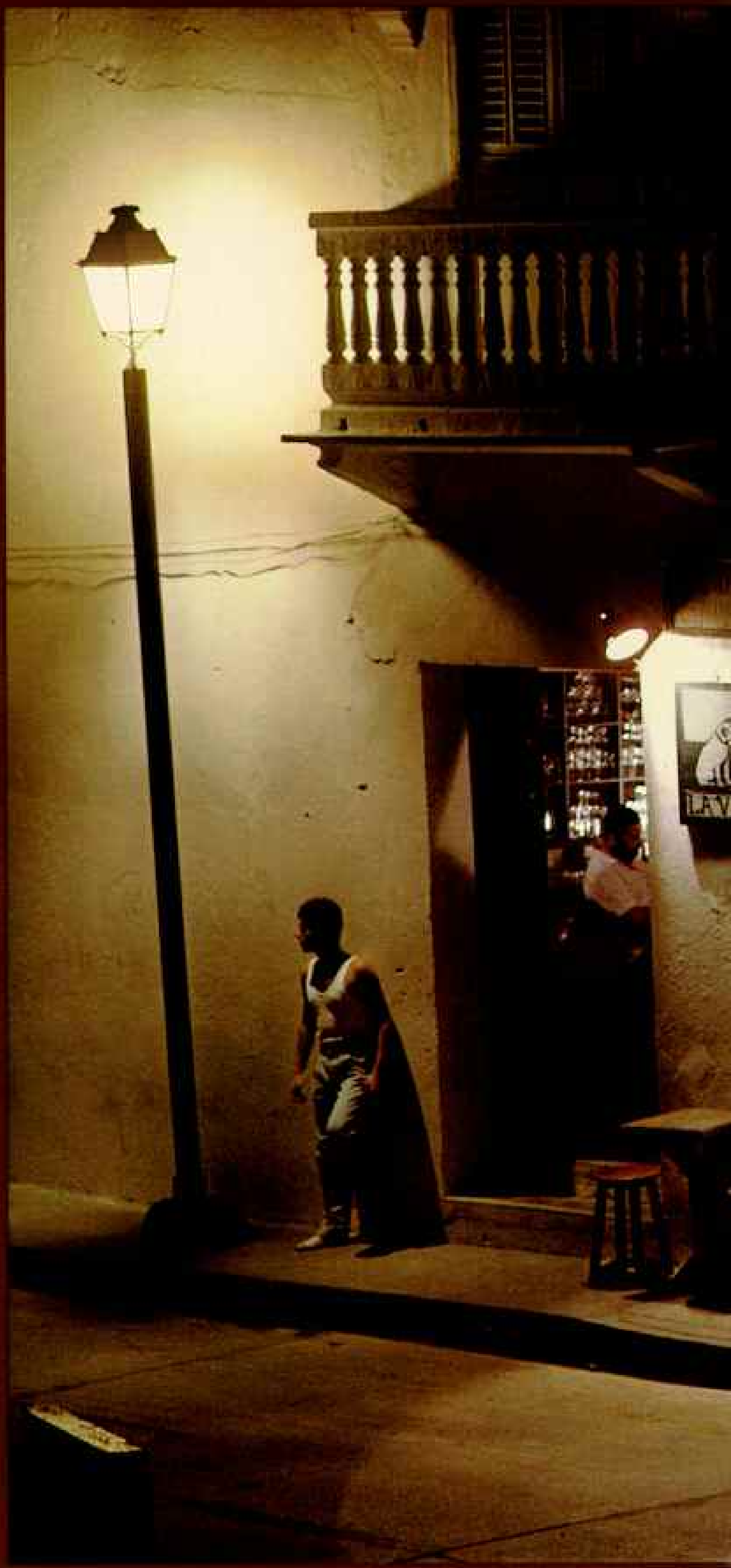
And what history. As a guardian of Spanish sea-lanes for Peruvian silver and gold, Cartagena became the most important port in the New World, a storehouse for provisions and treasure and a fatal temptation for plunderers.

Now, by day, new parts of the city sprawl wide. Sunbathers, basted with lotions, carpet the beach. Vendors sell *raspados*—shaved ice with syrup—seashell jewelry, and garlands of fishy iguana eggs. Colombians from Bogotá—*cachacos* to the local folk—come here "so they can stroll the streets in safety," a young policeman says proudly. "Here people make love, not crime." So growing Cartagena bustles, newly noisy with half a million people.

Some 70,000 still live within the old battlements. And each afternoon they await "that hour of mysterious flourishing," as poet Guillermo Valencia called it. Like an unlucky ship, the sun slips abruptly into the sea. A strong, steady breeze blows in, rattling

Mirrored in a street slick with rain, a hired coach stands topsy-turvy before the Church of San Pedro Claver in the romantic colonial quarter of this historic Colombian city. A key port of the Spanish Main from the 16th to the 18th centuries, Cartagena proudly preserves the grand structures of that bygone era.

In the cool of the evening, customers gather at a streetside café favored by artists and intellectuals. Blistering afternoon temperatures keep many people indoors following **almuerzo**, *the main meal of the day. But once the sun has set, breezes refresh the city, and the streets fill with pedestrians. Friends talk over tall iced drinks. Lovers look for a quiet corner. Dancers step to Afro-Colombian folk tunes called* **cumbias**. *And, during the annual Caribbean music festival in March, feet tap to spicy salsas, merengues, calypsos, and reggaes.*




12-01
LA VIRTOLA

First hint of dawn finds a fritanguera, *or food vendor, stoking the fire of her grill. Across the lagoon looms the fort of San Felipe de Barajas, monument to the might of the empire that directed Cartagena's destiny for nearly three centuries.*

almond leaves, whipping up whitecaps. Winds that once filled the sails of galleons now deliver the city a daily second wind.

Shoeshine boys near the old clock gate fold up their kits. Codgers sit on park benches donated by politicians; stencils promise "deeds not words." The buyers of lottery tickets visit their bookies at El Perro to collect winnings or consolation.

On the Street of the Consulado, I visit a man described as a curer, a sorcerer, or, as he prefers, a "spiritual counsel." His copra-scented office is crowded with jars and one human skull. For some 40 years Jesús Meza has fashioned amulets and come to know his neighbors in a special way: "Other towns

have more culture. But people here have the *instinct* for happiness."

And an instinct for history. A disparate crowd of men—courtly, phlegmatic, young, old—meet as members of the Society of Public Improvements. They are preservationists and historians, here to take refreshments, plan city projects, and quarrel politely. The dean is clearly Don Donaldo Bossa Herazo, a white-clad, white-haired octogenarian, big as a Buddha. He speaks about fortifications and dates: "Remember what Arnold Toynbee said when he saw our walls: 'South America does not speak English because of this!' "

One member mentions "the matter of flowers

on balconies." Purists feel that a fortress city should be "more like a barracks." Others sigh, sneer, roll their eyes.

Everyone agrees on one point—six years ago a Jacob's ladder of telephone and power lines was finally buried beneath the streets, "like dentists' work." Now the old city has become a favorite location for motion-picture companies.

Indeed, here the dimming past seems cinematic. "Francis Drake stayed in this house. They called him *sir*, but he was a common pirate," Don Donaldo tells me. He scorns the privateer who in 1586 took the city and held it for handsome ransom.

Pirate. Local folk use the word to refer to all acquisitive invaders, including Commodore Charles Wager, who brought his squadron of four British ships in 1708 to stalk a Spanish treasure convoy. In a wild sea battle fought by dark of night, Wager's guns hit the great Spanish galleon *San José*. The powder magazine apparently exploded, and the ship sank, as one witness said, "in the short time it takes to pray a credo." The human loss was calamitous: "no more Men saved . . . than 17 out of 7 or 800," according to the official *London Gazette*, or, as others counted, 11 out of 600.

Imposing portal of the Palace of the Inquisition dwarfs historian Donaldo Bossa Herazo (facing page). The building—Cartagena's best example of colonial baroque architecture—housed a tribunal with power over most of Spain's Caribbean possessions. Nearby, a vendor sells snacks by the original city wall outside the Church of San Pedro Claver.

TREASURE was another matter: perhaps five million gold pesos, seven million silver, and the private wealth and jewelry of passengers. The modern value could be three *billion* dollars.

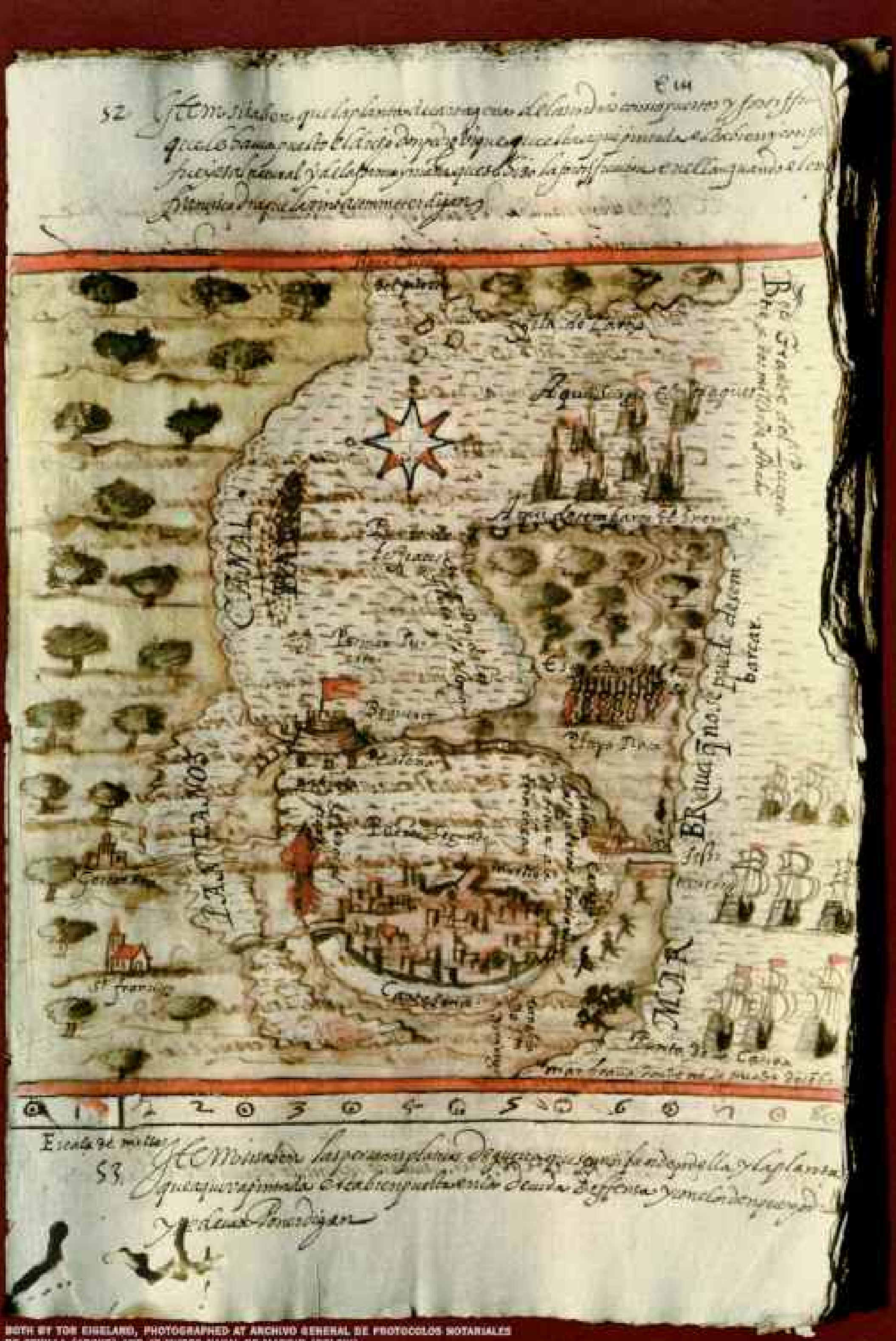
And where is the treasure now? Maybe 30 miles outside the Cartagena harbor at a depth of 750 feet.

Blessed with a superb harbor, Cartagena became a stronghold and center of trade in Spain's New World empire. Founded in 1533, it provisioned the ships that collected the continent's wealth and distributed goods from the mother country to the colonies.

Many tried to take this prize. Francis Drake succeeded most dramatically in 1586, holding the city for ransom. On a Spanish map drawn five years later (right), his troops advanced on the city down the Bocagrande peninsula, where hotels and condominiums now rise (above, at top). With Drake's departure, work began on a system of forts and reinforced walls.

By the time British Adm. Edward Vernon attacked in 1741, silt had blocked Bocagrande, the

Peace permitting, galleons from Spain called at Cartagena on their way to and from Portobelo, where they picked up riches from Peru.



BOTH BY TOR EIGELAND, PHOTOGRAPHED AT ARCHIVO GENERAL DE PROTOCOLOS NOTARIALES DE SEVILLA (ABOVE) AND AT MUSEO NAVAL DE MADRID (BELOW)

bay's wider mouth, forcing him to enter the Bocachica passage (facing page, at right). Vernon—for whom George Washington's home, Mount Vernon, was named—withdrew after 56 days of fighting; a medal minted in England inaccurately pictures the surrender of Spanish commander Blas de Lezo (right).

An arrowhead aimed at the Caribbean, the bastion of Santo Domingo (above) defended the colonial port from pirates tempted by treasures like this recently discovered gold cacique and jaguar from the pre-Columbian Sinú culture. Seven miles of stone walls, 60 feet thick in spots, still encircle a hundred-block area of the old city.

But *exactly* where? Landmarks have changed, but the treasure indeed exists, unfound . . . somewhere in this swelling sea.

The gold can be precisely found only in legend and literature. A 12-year-old diver named Euclides reports having seen "many old sailing ships lying among the coral reefs . . . in such good condition . . . ," their sails intact "as if they had sunk along with their own space and time. . . ." The boy has identified the *San José* by gold letters on the poop and has seen "the body of the commander, dressed for battle and

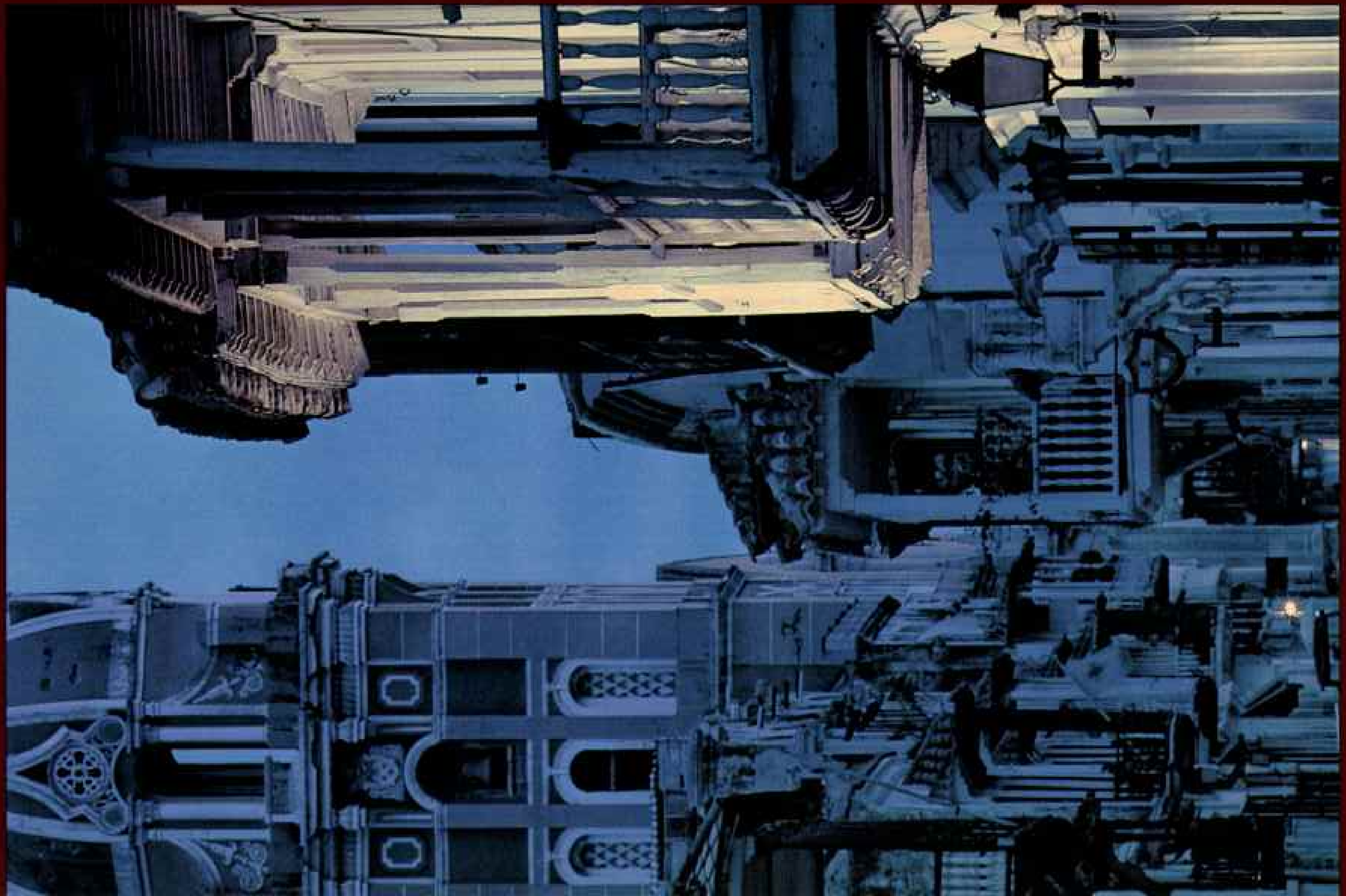
floating sideways. . . .” Thus the flood-tide imagination of Nobel laureate Gabriel García Márquez in his novel *Love in the Time of Cholera*. García Márquez worked as a news reporter here during the late 1940s. What better place for learning the arts of magical realism?

NIGHT CLASSES are now dispersing, and six students take over a palm-garnished corner of the Plaza de Bolívar; one has a guitar, but their song dissolves in laughter. A quieter group, two old women and a dutiful young man, walk toward the

CACIQUE 8.5 INCHES, JAGUAR 4.8 INCHES; BOTH PHOTOGRAPHED AT MUSEO DEL ORO, BANCO DE LA REPÚBLICA, CARTAGENA

Dusk darkens a block near the white-trimmed cathedral in the heart of town. High officials and wealthy merchants in this district by the harbor built houses influenced by the architecture of southern Spain. Residents watch the world go by from their roofed balconies, which deepen cool daytime shadows cast along the narrow streets.

Still under construction when damaged by Drake's cannon, the cathedral was repaired using the original plans of 1575. Alterations in the early 1900s added the bell tower and a stuccoed facade.



Church of San Pedro Claver. The bones and toothless skull of the saint himself lie below the altar, grotesquely benign. When Cartagena had the largest Caribbean slave market, Father Claver styled himself "slave of the slaves," caring for the sick, baptizing blacks by the tens of thousands.

Near the church, impious couples stroll toward the city walls, brightly lit with amber floodlights on the outside but shadowed within for amorous privacy. Lovers call the wall's niches stone beds.

On the waterfront, barges and coastal sailboats are tied up with cargoes of bananas and hardwoods. Sailors prowl ashore, some on Half-moon Street with bar girls from the Hotel Tropicana. Policemen patrol the middle-class *barrio* of San Diego, where families have pulled their rocking chairs onto the sidewalk, the better to visit; their youngsters play games of *tapita* with bottle caps.

The soft notes of a Spanish guitar create a mellow mood at Paco's, a bar popular with tourists and locals alike. Outside the empty Convent of Santa Clara young parents share a light moment (facing page). Projected renovation will make this 17th-century building into a hotel, returning it to the mainstream of a community that throbs with life among cherished reminders of its past.

A roar goes up from the old bullring, tonight used for boxing. In the fancier restaurants late diners are finishing their locally famous coconut desserts. Residents are winding down, turning off television sets, putting youngsters to bed.

Soon the garbage trucks will begin their rounds, and sailors will head for their freighters to catch an early tide. Taxi drivers have begun to wash their cars, and newsboys deliver the morning *El Universal*. Fishermen at La Boquilla are hauling in their catch, and bright-painted *chiva* buses bring maids and kiosk keepers to the Bazurto market.

The dark sky turns pale as milk, then red, and, as it has for four and a half centuries, another day begins for Cartagena. □

By JUDITH W. McINTYRE Photographs by MICHAEL S. QUINTON

The Common Loon

Cries for Help

REGALLY SHAKING water from its breeding plumage, this loon in Wyoming faces an uncertain future. Acid rain, lake pollution, and human encroachment all pose a threat to the common loon.

LAST SUMMER IN MINNESOTA I was staying with a friend near St. Paul. From her deck on a hot July night we could see the lights of the Twin Cities, a busy metropolitan area with more than two million residents. At three o'clock in the morning something alerted me, and I shot up in bed and listened. Nothing. I lay down again, certain I had been dreaming.

The sound began again, and I knew I was awake. A pair of loons were duetting. Over and over they cried their antiphonal calls.

Three loon pairs had territories on nearby lakes. Any one of them could have awakened me during the night. Were they telling the world they owned a lake? Or were they calling for help?

Few areas take better care of their loons than Minnesota, which has even named them the official state bird. Yet my 20 years of study of the beautiful common loon leads me to conclude that they are birds in dire distress.

Loons by the thousands patrolled lakes in the northern tier of states when the first European settlers reached those shores. Today they no longer regularly breed as far south as Pennsylvania, Ohio, Indiana, Illinois, Iowa, or northern California. And of the 14 states where loons persist, it often is as mere handfuls: 20 breeding adults in Massachusetts, 28 in Vermont, 302 (and happily increasing) in New Hampshire, 314 in New York, 2 in Idaho, 8 in Washington. Of the lower 48 states, only Minnesota has loons in abundance—10,000 loons for the "land of 10,000 lakes." Today most loons survive in Canada and Alaska, where perhaps half a million summer.

Gunners were the first to assail the reclusive birds, approaching by boat to shoot them for target practice before they dove or wantonly shooting them along flyways as they migrated. More recently other problems have beset them. Our fondness for lakes as recreational retreats has led us to encroach on their habitat. More insidiously, subtle but lethal pollutants threaten the birds' health and reproduction.

Our invasion of loon habitat has been unintentional but relentless. Over the decades vacation cottages and marinas have encircled loon waters like nooses, evicting the lakeshore nesters. Commercial trap nets take their toll of the fish-chasing birds; each year more than 300 loons perish by drowning in the Great Lakes during spring migration.

Man-made reservoirs have expanded loon habitat, but at a cost. Where flood control and power needs take priority over wildlife, fluctuating water levels inundate nests in some years and leave them stranded high and dry in others. A four-year study of this peril has been funded by William Bantz and F. Michael Tucker of the Mercer Companies, whose new hydroelectric plant is on Stillwater

MOLTING WING FEATHERS give the adult loon a somewhat scruffy appearance in winter but are a healthy sign of the bird's upcoming spring migration northward. This particular loon, however, was still molting heavily in March. Extremely sick, it was found by a stroller at Crescent Beach on Florida's Atlantic coast. Barely able to dive—let alone fly—it soon died, possibly the victim of a mysterious ailment previously observed among loons on the state's Gulf coast. Some scientists speculate that mercury poisoning may be to blame, since high levels of the metal have been found in most of the afflicted birds.

Reservoir, home to New York's largest loon population. To aid the birds, Bantz and Tucker vow to build nesting rafts, monitor water levels, and encourage other measures to keep loons productive.

But the most deadly and insidious threat is in the very water the birds inhabit. The problem is complex, but the evidence points strongly to methylmercury poisoning.

In its inorganic form—whether occurring naturally or released into lakes as an industrial effluent—mercury poses little threat to living organisms. But over decades, sulfate-reducing bacteria convert it to organic, highly toxic methylmercury. The poisonous compound commences a deadly climb up the food chain, from plants to small invertebrates to tiny fish to larger fish—and finally to such top predators as loons.

When mercury contamination in northwestern Ontario waters was identified in 1970, the Canadian Wildlife Service asked biologist Jack Barr to undertake a study of the behavior and reproductive success of the area's loons. His findings were startling.

Loons and fish in lakes within the most contaminated zone carried high mercury loads, and loon reproduction was virtually zero. Many females failed even to lay eggs. Loon behavior also changed.

FIRST TO DISCOVER and publicize the abnormally high mortality rate of loons in Florida was Laurence Alexander, a graduate student at the University of Florida in Gainesville. Determined to find the root of the problem—first noticed in 1983—he has spent countless hours measuring, weighing, and dissecting loons. Tissue samples have been sent for analysis to government laboratories; while awaiting the results, Alexander is studying the birds' ecology.

JUDITH W. MCINTYRE is Professor of Biology at Utica College of Syracuse University in Utica, New York. Her book *The Common Loon: Spirit of Northern Lakes* was published last fall by the University of Minnesota Press. MICHAEL S. QUINTON wrote and photographed "The Great Gray Owl" for the July 1984 NATIONAL GEOGRAPHIC.

Barr reported that loons with heavy concentrations of mercury defended their territories less vigorously, nested less frequently, and deserted their nests more often than other loons.

AT QUABBIN RESERVOIR in the hills of central Massachusetts, loons breed again after abandoning the state for nearly a century. But the site of their comeback contrasts sharply with the pristine waters they once frequented; today acid precipitation joins mercury and other contaminants to plague all wildlife in the nearly 40-square-mile lake. The situation may have been set in motion as early as 1946, when the reservoir was flooded to provide drinking water for Boston.

Several towns were razed, and their remains—including the debris of woolen mills, carriage and paint shops, tanneries, and a silver-plating business—were engulfed. With the action of water and bacteria on the chemicals and metals of those commercial operations, many scientists suspect, dangerous potions began to brew.

From above, meanwhile, acid precipitation pelted the water surface, releasing its burden of windborne sulfates, most of which had begun as sulfur dioxide emissions from power plants in the Midwest.

LURED TO THE SHORE primarily for mating and nesting, loons spend most of their time on water. During a quiet courtship in which a suitable nest site is carefully selected, they clamber awkwardly onto land to copulate (above). After mating, the female rests for a few minutes before rejoining her mate in the water. Within a few days she will lay her clutch—usually a pair of eggs.

Undeterred by a late spring snowfall, an adult loon in Wyoming (facing page) conscientiously incubates its clutch. In the far northern parts of their range, loons often must begin mating and nesting before the snow has melted, in order for the chicks to mature enough to be able to fly away at migration time.

By the early 1980s scientists noted that Quabbin lake trout reproduction had declined, fewer stocked rainbows were surviving from year to year, and smelt in adjacent spawning streams were reproducing at lower rates. These problems are consistent with the increasing acidification of Quabbin as recorded for the past 40 years by the Massachusetts Division of Fisheries and Wildlife.

Swedish studies in 1969 first linked the deadly handiwork of acid precipitation with heavy metal pollutants. Rainborne metals readily dissolve in acidified waters, prompting the rapid release of metallic ions that convert into forms toxic to living organisms. Although all the evidence is not in, there is reason to suspect that a sad and complex cycle is under way.

Loons will continue to come and nest at Quabbin every summer; that is the way of loons. They will continue to preen and bathe in Quabbin waters and eat contaminated fish. I fear that the loons of Quabbin and of northern Ontario, and perhaps loons throughout their range—like the mercury-afflicted Mad Hatter of *Alice's Adventures in Wonderland*—are having their nervous systems literally eroded. The compound interferes with neurotransmitter release, thereby short-circuiting brain functions involving coordination and vision. The result, I believe, is that the loons' ability to catch fish deteriorates, along with their ability to rear two-chick broods.

At my study site in New York State I have seen second-hatched "loonlings" die of starvation; it is pathetic to watch. The smaller chick moves farther and farther from the family group, is not fed, and finally disappears. One dead seven-week-old bird weighed just 12 ounces; it should have weighed five pounds or more.

A corollary to the Quabbin story plays out each winter on the Gulf coast of Florida. Laurence Alexander, while a field worker

with the Nature Conservancy, found a dead loon on the beach of Dog Island in the winter of 1983. Soon he found more, and the total eventually climbed to about 7,500. Tests in federal laboratories showed that most of the loons carried high mercury concentrations in their tissues, but scientists declined to name mercury as the definitive cause of death.

Alexander has continued to monitor the Gulf coast loons, finding thousands of dead adults each year. Almost invariably the emaciated bodies suggested starved birds that could not feed properly.

On the waters off Cedar Key he showed me listless loons making dives that lasted only three to five seconds, brief indeed compared with the 40-second plunges of healthy birds. These weakened loons would be tomorrow's victims.

Handicapped in their quest for swimming prey, Alexander's loons were attempting to subsist on slow-moving crabs. But crabs afford little nourishment for the energy and time expended on their capture. This is especially costly in the winter, when loons need extra resources after the long flight from the breeding grounds, for molting, and to endure frequent storms. Instead their weight is halved or even quartered, molt is delayed, and thousands die.

As human encroachment near nesting sites threatens the birds' reproductive success, loon lovers are joining forces to assist. I went to New Hampshire to observe a band of volunteers sometimes known as the Loon Rangers.

"Loon patrol calling Loon Preservation Committee. Come in, please," radioed Jane Irwin, tanned, determined, and concerned about New Hampshire's loon population. As she has done for the past 12 years, Jane was cruising the waters of Lake Winnipesaukee to check nesting loons.

She had just found a bird swimming close to shore and, raising her binoculars, found its mate nearby on a new nest. It was the exact spot where committee volunteers had cleared excessive brush and replaced it with piles of nesting material. Excited by the success, Jane was now sending a request to biologist Penny Porath for help in roping off the nest site.

Penny soon pulled up in her Boston Whaler, its bow filled with signs saying LOON SANCTUARY/KEEP OUT. She placed three of the signs around the tiny island with its new loon residents.

SPEED-DIVING through the water in pursuit of a suspected rival, this irate loon gouged a half-inch hole in the abdomen of a wooden decoy belonging to the photographer. Highly territorial, loons behave aggressively when threatened and have been known to kill intruders. The adults have few natural predators; an eagle or coyote sometimes attacks a sick bird. Chicks are preyed on by gulls or large fish such as the northern pike. Most vulnerable are the loon eggs: Their predators include ravens, crows, gulls, raccoons, and skunks. Loons themselves feed mostly on small fish; during the breeding season yellow perch is their primary food throughout much of their range.

Penny monitors the behavior of Lake Winnipesaukee's loons, while Jane organizes volunteers for two-hour shifts every weekend to guard loon nests or chicks. These efforts have paid off. New Hampshire's loon population rose from 271 in 1976 to 472 in 1988.

Other volunteers can be found in many parts of the United States and Canada. One of the newest and most dedicated groups is the Loon Lake Loon Association in Washington State. Founded in 1985 by concerned residents, this organization sponsors an annual Loonsday walk, sells loon sweatshirts, makes and launches artificial islands for nesting, and hopes that loons will someday return to nest on Loon Lake. But though at least four pairs summer in Washington, loons have yet to return to their namesake lake.

Nowhere is there more enthusiasm for loons than in Minnesota. Shops offer loon T-shirts, loon carvings, loon thermometers, loon refrigerator magnets, loon wind chimes, loon mobiles, loon coffee mugs, loon posters, loon-calling contests, loon balloons—and soon there will even be a loon shopping center. A mall that will

take up an entire block in downtown Minneapolis will, when complete, be christened Gaviidae Common, honoring the scientific family name for loons.

UNGAINLY AND AWKWARD on turf, loons are marvelously built for the water. With relatively small wings, they seem like feathered seals underwater, where they twist, turn, and pivot faster than most fish, their chief prey. Their powerful legs are completely enclosed within the body; only ankles and feet protrude. Heavy bones, not honeycombed with air sacs as most bird bones are, further equip them to be agile divers and strong underwater swimmers.

Loons rely on superb eyes to locate their food and pursue it underwater. Prowling for fish, a loon slightly submerges its head and slowly turns it from side to side to look deep into the water in a unique behavior termed peering.

Range of the common loon

The world's population of half a million common loons ranges from the North American Arctic to the Gulf of Mexico. After wintering in coastal waters, loons migrate to northern breeding grounds in April; they are thought to follow the fall migration routes —shown in red—in reverse. The birds no longer regularly breed as far south as Pennsylvania, Ohio, Indiana, Illinois, Iowa, or northern California. Lake acidification has resulted in fewer fish, the loon's principal food. More insidiously, it increases the rate at which mercury in ponds is transformed to a toxic form; the poisonous methylmercury enters the food chain and is eventually ingested by the loon. It attacks the bird's nervous system, hindering its ability to feed and reproduce.

RARELY SEEN UPRIGHT, the loon must periodically raise itself to turn its eggs while incubating them. Devoted parents, both male and female loons share incubation duties for some 28 days before the chicks hatch. Occasionally loons will doggedly—and indefinitely—attempt to hatch a foreign object, such as a seashell or an egg-shaped rock.

Swift and powerful fliers, loons have been clocked at more than 75 miles an hour during migration to and from wintering grounds along the Atlantic coast. About two feet long, with a wingspan measuring as much as five feet, the 8-to-14-pound birds show a cruciform shape when they fly with necks outstretched.

THE BREEDING SEASON for loons begins in April. Courtship is quiet as pairs swim side by side on their lakes, nod their heads periodically, slip underwater for brief dives, and finally climb onto shore to mate and build a nest at the lake's edge. Here the birds have quick access to the water. Some pairs have a favorite place where they mate and eventually nest; others mate at several locations and finally choose an altogether different spot to nest.

Pair members share the nearly four-week incubation of two dark olive brown eggs. As soon as the chicks' black down is dry and fluffy, parents lure the loonlings into the water and force them to swim close by, part of the imprinting process. This maiden voyage carries the family as far as a quarter of a mile as the adults seek a quiet, sheltered cove to serve the family as a nursery.

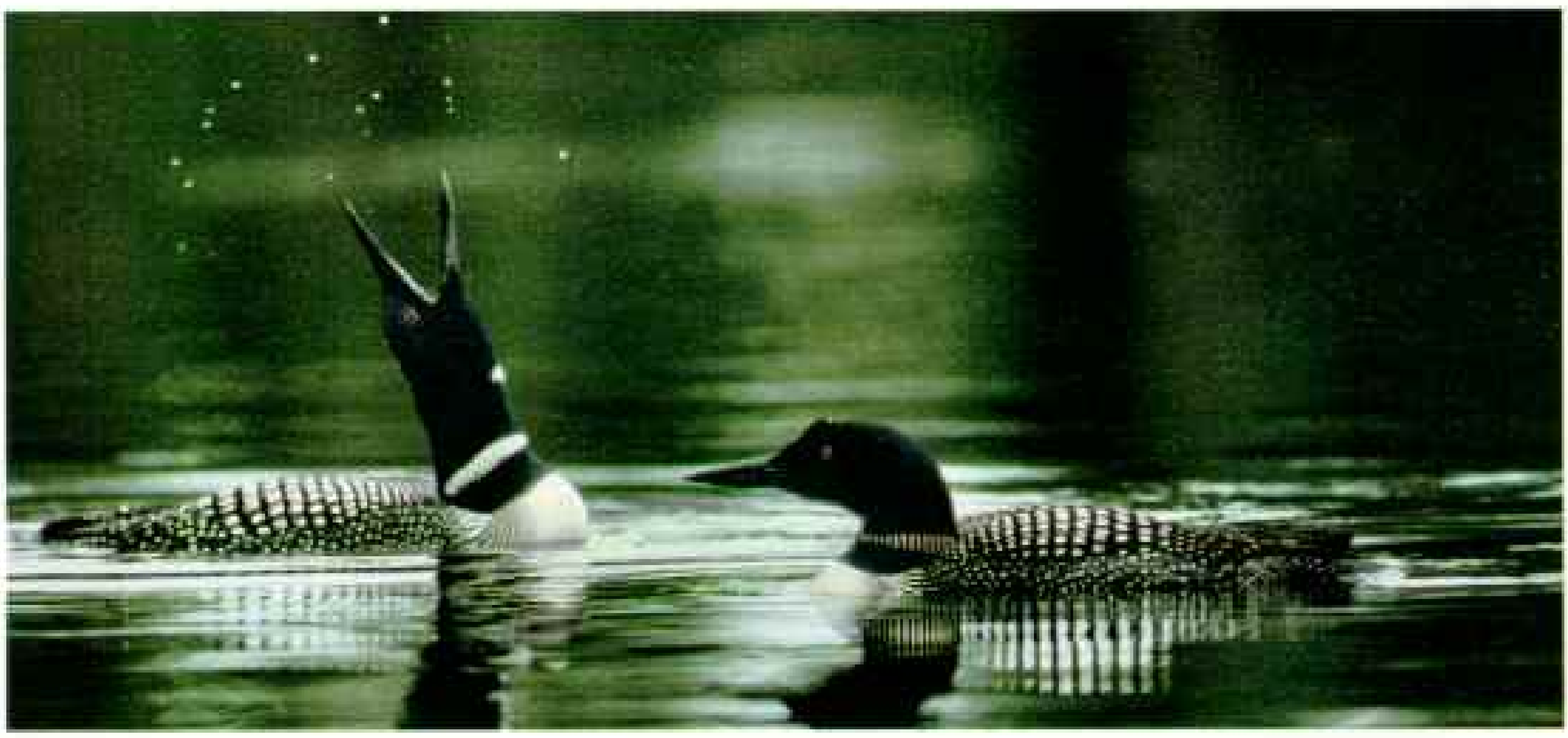
For two weeks after this test chicks are permitted to ride parental backs, insulated from chilly waters and secure from underwater predators. The chicks depend on their parents for food for nearly three months before they perfect their own fishing skills.

To study adult-chick relationships, Central Michigan University graduate student Gary Dulin spent most of his summer days in a muskrat-house blind, floating on one of the lakes on Beaver Island in Lake Michigan. He discovered that even tiny siblings fought for dominance. But the first hatched always won, becoming what I call a boss baby—the first fed and the inevitable survivor if only one chick fledged.

Though loons are water birds, they are not true waterfowl, a separate category that includes only ducks, geese, and swans. Numerous differences in skeletons and musculature distinguish the two groups, among them the fact that loons, unlike waterfowl, cannot walk well on land. Loons represent an entire order, the Gaviiformes, and have no close relatives. In addition to North America, the common loon *(Gavia immer)* occurs in small numbers in Iceland and Greenland; four related species breed in more northern regions of North America and Eurasia.

Loons fascinated the early residents of North America and their descendants. The Inuit, or Eskimos, still use loon skins for ornamental dress. Mang, the name of an Ojibwa clan of the western Great Lakes, translates as "loon" but also indicates "brave" or

SURVEYING THE WORLD through day-old eyes, a newly hatched chick (top) peeps hopefully for food. A second "loonling" has started to poke a hole through its shell, using the egg tooth on its bill. Once each chick has hatched, the white egg membrane and pieces of eggshell are tidily carried off by one of the adults (above) and dropped into deep water—perhaps because they might attract predators to the nest. The chicks will remain dependent on their parents until they are three months old.



STREAKING across the water in a spectacular display of territoriality, an adult loon flaps its wings, pounds its feet, and churns up spray. Loons arrive promptly in the spring to stake their claims on newly thawed lakes and are quick to repel intruders, be they ducks, geese, or fellow loons. Mates from year to year, possibly for life, they will usually return every spring to the same lake, often reclaiming their former nesting site.

A mated pair (bottom left) take a tranquil swim before nesting; the male, on the left, appears to be yawning. A chick rides piggyback on a parent (bottom right), kept warm between the wings and safe from underwater predators. Chicks can float from birth, bobbing about like little corks.

This adult loon issued a two-note wail to summon its mate. Known for their haunting nocturnal cries—which include tremolos and yodels—loons will often join in antiphonal calling, creating an unforgettable chorus.

"proud." Many legends say loons are special messengers of the gods, endowed with magical powers.

Indeed, in the early time when all was water, the Great Spirit of the Ojibwa asked if a creature would dive to the bottom and bring back mud—so there could be land for animals to walk upon. The otter, the beaver, and the muskrat dove, but each failed. The Great Spirit appealed to the loon, who dove deeply and returned with mud on his feet. The effort earned him the title Loon Who Made the World.

One of my chief interests has been loons' remarkable ability to vocalize. Calling primarily at night, when winds are gentle and sound carries far, they communicate with four basic sounds: hoots, wails, tremolos, and yodels.

LEFT HIGH AND DRY on Bergman Reservoir in Wyoming, this juvenile is just a few weeks short of being able to fly. The reservoir is drained in most years to irrigate Idaho potato fields some 15 miles away. Every year loons return here to mate; the majority of their chicks subsequently die. This youngster was captured and released on a nearby lake.

Hoots are short, single notes—contact calls that the birds use to keep track of one another when in groups. Long, piercing wails, hauntingly similar to wolf howls, are used to summon a mate or to tell each other they wish to get together. Tremolos, which signal general alarm or agitation as danger threatens nest or chicks, peal as a pulsating vibrato that rises higher and higher. This is the loon's so-called laugh—the maniacal cry that probably gave birth to the expression "crazy as a loon."

A yodel is the male's territorial call, each individual's slightly different from another's. I can easily identify an individual loon by

his yodel and believe the birds themselves use them as name tags.

Both sequence and pitch of notes in a yodel have been recognized as important in sending information. During studies in northern Saskatchewan I broke a little more of the code of loon language. There I played recordings of the yodels of other loons to 86 loon pairs. In some of the recordings the placement of accents or stresses within calls had been modified with the assistance of Andrea Priori of Cornell University's Laboratory of Ornithology. The loons gave different responses to the altered yodels, suggesting that amplitude as well as sequence and pitch is important in encoding messages.

A RESEARCH PROJECT SUPPORTED IN PART BY YOUR SOCIETY

ONE NOVEMBER DAY in 1970 in Minneapolis, a phone call came advising me of a loon in peril on Pughole Lake, 200 miles to the north. The loon had not departed, although the lake was freezing fast, the caller said. Knowing the bird had no chance of surviving the winter, my husband, Pat, and I embarked on the four-hour drive—and an attempt to capture the loon.

On arrival we saw that the loon had kept a small circle of water ice-free by continuous swimming. Our chances of daytime capture were slim, but that night we shined a light in the bird's eyes, a technique we had used to capture loons for banding. Pat caught the loon almost immediately.

No wonder the young gray bird had not migrated. Feathers had not aligned properly in her right wing, and she could not fly. During the long drive home in the dark car, the loon did not make a sound. I named her Puglet, a variation of her lake's name.

This was the first time I had brought a loon home, and I was excited. The first night I placed her in my closet, which was quiet and dark. The next day I moved her to a water-filled bathtub, where I thought she might be happier. But Puglet leaped from the tub, scooched seal-like to the door, and pecked to be let out.

Pat built a pool in the basement with a small island fashioned from a wrought-iron table with a towel draped over it. Bait dealer Larry Schuchard came to Puglet's aid with thousands of fathead minnows and, for treats, suckers. All winter Puglet kept her fishing skills sharp by foraging in her basement pool for live fish. When she had eaten every one, she would call with the two-note wail that loons use when they want to get together. Pair members use it when

SAFE from the effects of changing water levels on its floating nesting island, this loon incubates its clutch on Lake Winnipesaukee, New Hampshire (above). On nearby Squam Lake another such man-made island is positioned (top) by the author and Rawson Wood, founder of the North American Loon Fund.

FIRST FAMILY PORTRAIT captures two parents seconds after calling their newly hatched chick off the nest and into the water. Having taken the plunge, the looning will be rewarded with its first food, a small fish from the adult on the left.

All too soon, however, the chick will have to fend for itself. For the next 20 or 30 years of its life, its survival will depend on the availability of toxin-free waters and a healthy environment in which to grow, mate, and perhaps even to raise its own young.

calling each other, parents use it to call chicks if they are separated, and Puglet used it to call us. During that winter more than one guest was brought upright by wails emanating from our basement.

A creek ran through our backyard at the bottom of a hill. Until it froze, we gave Puglet a daily opportunity to swim and dive for longer distances than she could in the four-by-eight-foot pool. I dressed her in a bright red dog harness, with her wings coming through the openings made for the dog's front legs. With a long lead attached to a kite reel and hooked to the harness, Puglet became my loon-on-a-leash!

I held tight as I carried her back to the house after each outing, for I quickly found out that she could outpace me. Loons may not be adept at walking, but they certainly can scoot fast up a snowy hill.

In the spring we returned to Pughole Lake and gently placed her at the shore. I knew the youngster would molt her wing feathers during the summer, and we hoped that this time the new ones would come in straight. She slipped into the lake, looked back once, and dove. We never saw her again.

But when the night is calm and a loon lilts its long lament over a nearby lake, our thoughts often return to Puglet and the cry we heeded. □

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FROM THE PRESIDENT

National Geography Bee challenges students across the United States

THE NATIONAL GEOGRAPHIC SOCIETY

DEANDRE BOLDEN, 13, SECOND FROM LEFT, CELEBRATES WINNING THE GEOGRAPHY BEE AT WHITNEY YOUNG MIDDLE SCHOOL IN DETROIT, MICHIGAN. PHOTOGRAPH BY WILLIAM DIRAY

PEERING over his glasses at a nervous student in his seventh-grade social studies class at Sterling Middle School in Sterling, Virginia, Wade Toth poses a question: Which European mountains extend from France to Yugoslavia?

Grimacing with concentration, the student digs deep for an answer. Then his face brightens.

"The French-Yugoslavian Range?" he offers hopefully.

"No, I'm sorry, that is not correct," Mr. Toth informs him—with just the hint of a smile.

If the student had answered "the Alps," of course, he would have improved his chances to advance in the first round of the National Geography Bee, which got off to a great start in January. Almost 25,000 schools across the U. S. registered for the competition, sponsored by National Geographic WORLD for fourth to eighth graders. The contest continues on April 7 at the state level.

The top student from each state will be brought to Washington, D. C., for the national championship on May 18 and 19. The moderator, I'm pleased to say, will be Alex Trebek, host of the television quiz show *Jeopardy!* First prize is a $25,000 scholarship, second prize a $15,000 scholarship, and third prize a $10,000 scholarship.

"We've been overwhelmed by the response," says Mary Lee Elden, who has led the project in its first year. "We hope it will encourage teachers to include geography in their curriculum. Once students are exposed to it, they discover it's fun."

It can also be challenging. Some of the questions asked so far: Which South American civilization built the fortress called Machu Picchu? Name the world's largest inland body of water. Which vegetative zone is located directly above the tree line? Name the most populous city in Africa.

To every student who stepped forward to tackle such questions, I offer my congratulations. To every teacher who asked them, my thanks. And to all of you who correctly answered "the Inca, the Caspian Sea, tundra, and Cairo," a word of encouragement: Perhaps you know more about geography than you thought.

Gilbert M. Grosvenor

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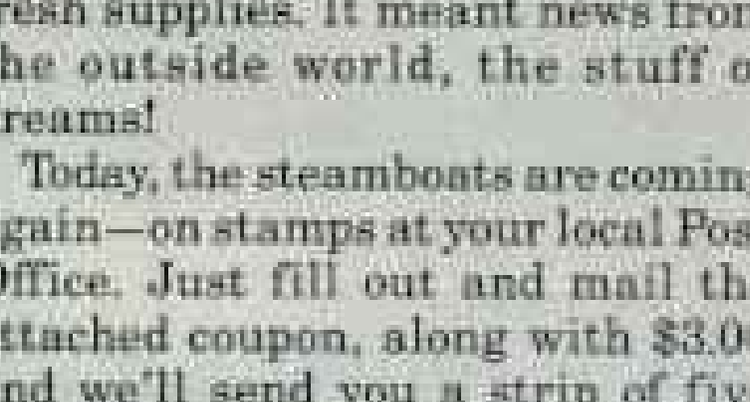

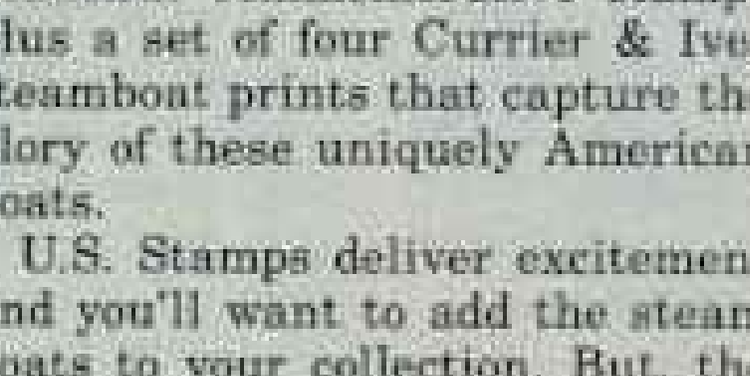

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Members Forum

December Issue

The impressive holographic cover raises NATIONAL GEOGRAPHIC to a new level of prestige. Fascinated by our earth's crystal image, I can almost hear the sound of shattering glass.

MARGARET M. VOLLMER
Butler, Pennsylvania

This cover makes it hard to forget the vulnerable little spaceship on which our lives depend.

ISABEL P. GORDON
Greens Farms, Connecticut

Your vivid and moving account of global environmental dilemmas delivers a critical message: As a global society, we must practice sustainable development as the key to our planet's survival. Next year at this time we will internationally celebrate the 20th anniversary of Earth Day. As we prepare for that occasion, it is heartening to know that we do so amid heightened environmental awareness such as that reflected in NATIONAL GEOGRAPHIC.

JAY D. HAIR, *President*
National Wildlife Federation
Washington, D. C.

The December issue is stunning, not because of its cover or its artistic photography but because of its serious, sober content. Again you have demonstrated leadership in increasing awareness that geography is much more than location. It describes fundamental earth relationships necessary for people to survive on the planet. The issue sets this generation's goals: Stabilize world population, revitalize the earth's environment, and stop the destruction of isolated cultures.

RICHARD A. SANTER
Big Rapids, Michigan

The question on the December cover "Can Man Save This Fragile Earth?" symbolizes the arrogance that got us into the environmental mess. This planet will survive because it has something we do not have—time. When we are long gone, mother earth will continue on her path of growth with a new set of life-forms. Perhaps a better question would have been: "Can man save himself on this fragile planet?" The earth is not going anywhere, we are.

GARRY FRANCELL
Kaneohe, Hawaii

There were approximately ten advertisements from automobile companies in an issue describing the harmful effects of burning fossil fuels. That obvious conflict closely describes the frustration I have every day. I would love to live an "environmentally impact-free" life. My wife and I try to do all the right things, but we are forced into doing some things described as environmentally harmful. I must use a car every day so I can get to my job. I need that job because I have a mortgage and a kid on the way. We heat our home with oil. My point is this: To clean up the world takes a coordinated effort on everyone's part. It also means a lot of people are going to have to drastically change the way they live.

BILL PHARR
Seattle, Washington

I am an environmental engineer. I began my career trying to develop better technologies to control pollution. But eventually it became obvious that this approach was not working. You cannot cure the problems created by and inherent with technology through more and better technology. Our improvements have typically been mere trade-offs, substituting one contaminant for another. We have taken the "dirt" out of our smokestacks only to place it in landfills where pollutants leach into groundwater unseen. We treat our sewage so our waters appear cleaner, but are in fact rivers of nonbiodegradable substances and soluble materials. We can destroy PCBs and other wastes by incineration, but generate even more toxic dioxins in the process. It is all a cosmetic cover-up. We are not making any real progress.

DUANE LEITH
Brazil, Indiana

Population, Plenty, and Poverty

To accept Professor Ehrlich's premise (December 1988) that there is an "overpopulation" problem plays into the hands of those who wish to increase government's intrusion into that most private of all human acts—the conception of children. Only two alternatives are available: Decrease the birth rate and/or increase the death rate. Both alternatives, to be enforced, require that the government intrude into private lives in very unpleasant ways. Once started down this road, the only logical destination is inhumanity. The end of this road is already in view in China, where such brutal policies as compulsory abortions and village "IUD police" have been implemented.

TIM SMITH
Kent, Washington

Humans may be the only species that practices intentional birth control. However, a number of species, such as the coyote, apparently carry

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the biological response to resource shortages by bearing fewer and smaller litters. A more common human response is to breed more intensively. Lemmings apparently breed at a constant high rate, regardless of resource adequacy, until overcrowding triggers a suicidal population crash. Will humans do intentionally what coyotes do unthinkingly? Or will humans self-destruct like the lemmings?

PAUL B. HORTON
Tempe, Arizona

Although there is poverty and misery in any nation with the size and historical background of India, you are judging the Indian family from Eurocentric, not Indian, standards. You seem to suggest that an ecologically sound agrarian lifestyle is a backward one; it is not, particularly from the Indian viewpoint. The Indian value system places the same emphasis on spiritual and emotional wealth as it does on material wealth. While the families portrayed may seem poor to you and me, they are rich in other aspects of life. Children are a family's wealth, not merely as income producers but as blessings who enrich parents' lives.

RASHMI SINGH
Albany, California

Nature Conservancy

I take great solace in knowing that there is a

group of people who have found a way to unite corporate power and environmental conservation. Thank you for making us aware that the Nature Conservancy is out there.

TINA J. HAWN
Lakeside, California

Rondônia

Your article on "Brazil's Imperiled Rain Forest" was fantastic. I find it disturbing, however, that the potential medicinal value of threatened plants and animals was mentioned numerous times as a chief reason for preserving them. Does everything on this planet have to serve man to justify its existence? How about preservation for preservation's sake?

STEVEN P. SEIDEL
Boston, Massachusetts

Working With Whales

In the December issue you say that "regional industrial and agricultural practices are suspected" of causing cancer and high levels of toxic chemicals in the St. Lawrence belugas. The water of the St. Lawrence River also comes from the Great Lakes, which are in one of the most populated industrial complexes of the world and are also the biggest dump of industrial residue.

ROBERT P. FERRI
Ste-Hélène de Chester, Quebec

Low-rises. 2060 A.D.

Hi-Tech. 2060 A.D.

Will today's hi-rises be the low-rises of tomorrow? That remains to be seen. But Samsung audio products will surely be high on everyone's list.

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World Map

Your publication of the world map based on Dr. Robinson's projection (December 1988) is a very exciting event. I have lived with Herr van der Grinten for 42 years, and with all due respect this new projection is a welcome change.

D. Scott Longnecker
Whittier, California

John Garver, Jr., made no mention of R. Buckminster Fuller's Dymaxion Sky-Ocean map. Created in 1930, it depicted, as Fuller wrote, "one world island in one world ocean with no breaks in the continental contours and with no visible distortion of the relative size or shape."

Bill Hallinan
Helena, Montana

While Fuller's Dymaxion map was considered, it did not satisfy our requirement of an uninterrupted view of both land and water; it interrupts oceans, slicing them into unrecognizable patterns in an effort to map the landmasses better.

Alaska National Wildlife Refuge

The photograph of Chevron's exploratory well site on native land near Kaktovik Village (page 863) shows an *initial* stage of restoration work by Chevron. Reseeding with native species began in 1986, but timber and insulation, used for a protective drilling pad, were not removed until the following winter to minimize surface disruption and avoid wildlife disturbance. Further reseeding and clean-up were under way in 1987 when the photograph was taken. Proper establishment of native species will take several growing seasons; only a historical marker post will remain.

Roger H. Severson, geologist
Chevron USA
San Ramon, California

As the largest landholder in Alaska, the United States government finds it easy to deny simple rights such as hunting and fishing access to the public, while disregarding the advice of its own staff when it comes to long-term degradation of habitat. This Alaskan stands with the Gwichin Athapaskan Indians in opposition to development of the Alaska National Wildlife Refuge.

Richard King
Kenai, Alaska

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.*

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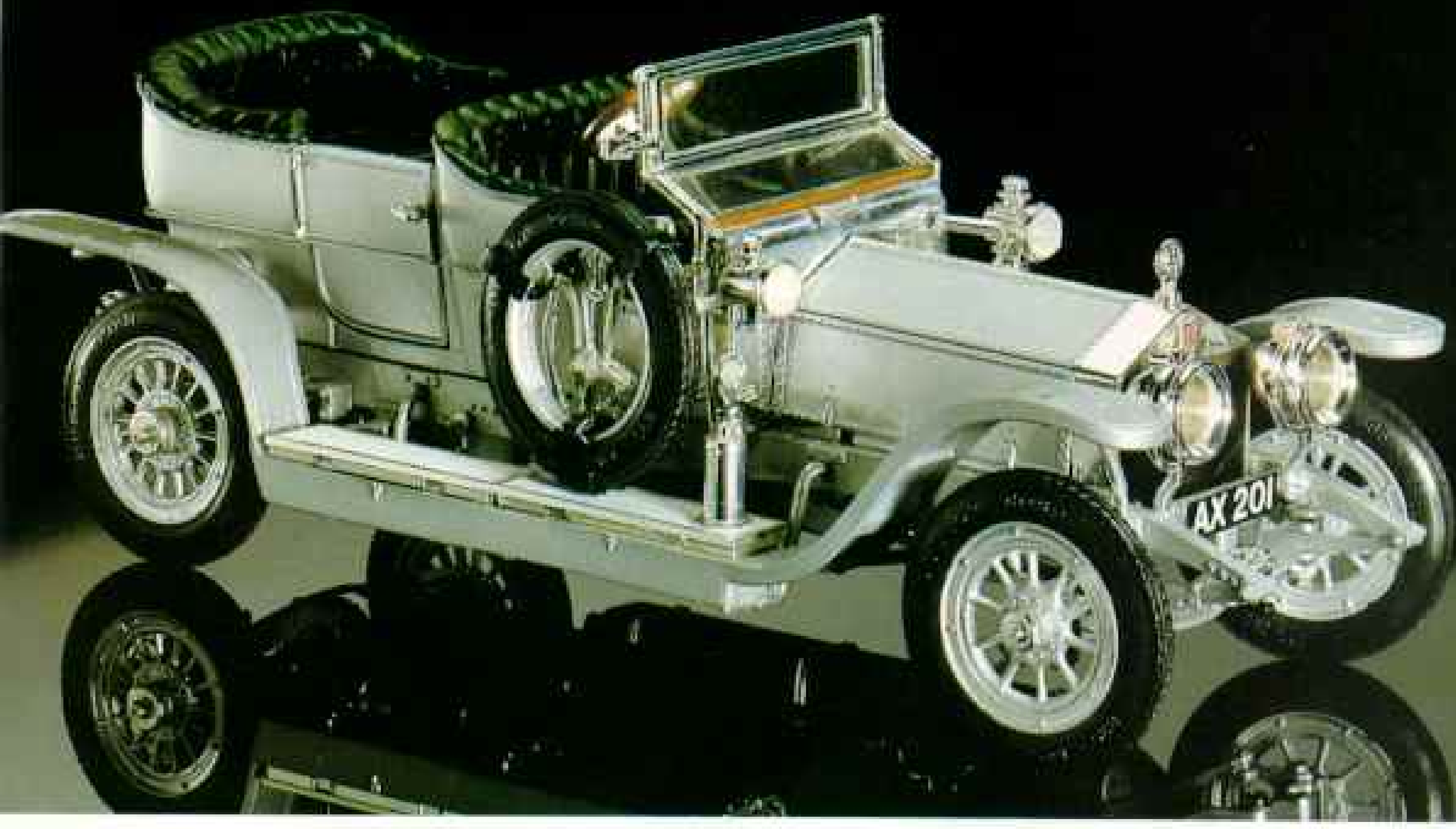

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APRIL 1989

GEOGRAPHICA

NATIONAL GEOGRAPHIC MAGAZINE

A Companion for El Niño

Intensive research is yielding important insights into El Niño, a periodic warming of tropical waters in the Pacific that can trigger devastating drought and flooding. Scientists are finding that the phenomenon exists in reverse; some call it La Niña.

Typically El Niño, like the calamitous 1982-83 event that brought misery to places as far apart as Ecuador, Australia, and southern Africa (NATIONAL GEOGRAPHIC, February 1984), announces itself with strong westerly winds along the Equator, accompanied by a warm current that usually arrives off western South America around Christmas, which led to its name, Spanish for "the Child." Ocean fisheries suddenly collapse, and coastal deserts reel under torrential rains that sweep away villages.

Scientists now believe that between El Niños there often are La Niñas: one- or two-year periods when the surface water of the equatorial Pacific becomes cooler. Experts detected the onset of La Niña in the spring of 1988, leading some to link it to last summer's drought in the United States, flooding in Bangladesh, and the abnormally cold winter in Alaska and western Canada.

The early detection of El Niños and La Niñas is an invaluable tool for long-range weather forecasting.

Space Age Divers, Ice Age Bones

Using revolutionary diving technologies, a 20-member international team of divers has explored and mapped large sections of Wakulla Springs, a huge underwater cave system in Florida.

Before the divers—led by Dr. Bill Stone and supported in part by the National Geographic Society—first splashed down into Wakulla Springs, only 1,100 feet of tunnel had been explored. By the time they finished, another 2.1 miles had been mapped, and divers had reached a point 360 feet below the surface. But the full extent of the system is still unknown.

A major purpose of the effort was to test equipment designed by Stone. An underwater habitat enabled divers to relax in warmth while decompressing as they returned from deepwater exploration. A computer-controlled rebreathing device—tested for periods up to 24 hours—permitted the immediate reuse of exhaled breathing gases. Using the backpack-borne rebreather, Wes Skiles (below) examined a mastodon bone discovered during earlier explorations. This and other bones were found in shallow areas near the cave system's entrance. But Stone's team found other, as yet unidentified, prehistoric bones deep inside Wakulla Springs, too far in to have been "flushed" by natural upheavals over the ages. The animals may have walked in, or humans may have carried them in, when water levels were lower than they are today.

WILLIAM C. STONE

Room for the whole crew.

It seems most mid-size cars these days barely have enough room to accommodate your elbows, let alone a whole crew.

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A Memorable Trip for Science Teachers

For an earth sciences teacher it may have been the ultimate field trip. Thirty high school and junior high school teachers from 24 states and the District of Columbia spent two weeks last summer in the Pacific Northwest in a workshop on volcanism that put them right in the middle of the subject. Literally: One field trip included a helicopter ride into the crater (right) of Mount St. Helens (GEOGRAPHIC, January and December 1981).

The workshop, supported by the National Science Foundation and scheduled to be repeated this summer, is designed to give teachers "a holistic view of volcanism," says David C. Cox of Portland State University, who co-directs the program with Paul Hammond and Steve Carlson.

Participants spend time at Mount St. Helens, Mount Hood, Crater Lake, and the Columbia River Gorge with scientists, government workers, and industry experts. The teachers receive videotapes, computer software, slides, maps, and books for use in the classroom and must also incorporate what they have learned in presentations to the public.

Lawn Study Offers Political Fodder

Which do you prefer: a neat, trim, carefully manicured front lawn or a less orderly front yard filled with a wide variety of trees, bushes, and shrubs?

Are you politically conservative or liberal?

Is there a connection between those two questions? Yes, according to geographer Roger S. Ulrich, now of Texas A&M University. Ulrich and Thomas Cosgrove, a University of Delaware graduate student, studied 66 pairs of neighboring front yards in the Wilmington, Delaware, area. Each pair contained a politically conservative household and a liberal household. Most were next to each other, though some were as much as five houses apart. All yards were maintained by their owners, and the households of each pair were similar in age, income, and education.

The study's findings: The yards of conservatives were neater and more orderly, and their owners spent more time on tidying-up activities such as edging and raking. Liberals, on the other hand, worked harder on nurturing activities such as watering and fertilizing, and had a greater diversity of vegetation.

Is there a political message here?

ALAN BERNER, SEATTLE TIMES

From the GEOGRAPHIC to a House Beautiful

Raymond Chagnon has a new answer to the perennial question of what to do with old copies of NATIONAL GEOGRAPHIC.

Chagnon (below), a carpenter serving an 18-month term in the Franklin County, Massachusetts, House of Correction for driving while intoxicated, was given a copy of the magazine late in 1987. After rolling a page around a pencil, he conceived the notion of building a dollhouse for his daughter using rolled-up pages as "logs." By late 1988 he had built more than a dozen elaborate model houses, as much as five feet in length and three stories in height.

Sheriff Donald McQuade has provided work space and a razor-blade knife to cut paper. Chagnon uses only pages with photographs, none with text, and only from the last quarter century. Pages from earlier years "have a white border around them, and if they are rolled into logs, they come out with uneven stripes."

Why NATIONAL GEOGRAPHIC pages? "I've experimented with other publications, and they just don't hold up to its fine quality," Chagnon says.

Minnesota Landscapes, in Infinite Variety

"Close your eyes and say the word 'Minnesota,'" suggests James Whitley Harris, director of the geography department at the Science Museum of Minnesota, in St. Paul. "Chances are an image of a landscape comes to your mind's eye."

A new permanent exhibit at the museum explores the state's varied scenery, both natural and man-made. Called "Our Minnesota: Changing Landscapes," it demonstrates the way farm and field, city and suburb, forest and lake interact with each other and how they have evolved, challenging the visitor to consider what the face of the land might look like in a hundred years.

SETH RESNICK

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NATIONAL GEOGRAPHIC MAGAZINE

FOURTEEN MONTHS after Chernobyl's reactor number 4 exploded, I stood a quarter mile from it—the closest any journalist had been allowed at that time. All I could see of it was the forbidding gray sarcophagus that now encased the destruction. It was a clear day. Men were welding something on top of the sarcophagus. Within the Chernobyl nuclear complex, traffic moved as usual. Yet the little radiation detector I had brought to Russia was chirping away in my pocket like a cuckoo clock. Nearby, staff photographer Steve Raymer's counter kept pace. Our escort, Alexander Pavlovich Kovalienko, added to the disharmonious chorus with his dosimeter.

Alexander Pavlovich seemed relaxed and a bit amused at our unease. "Don't worry," he said, "you'll only receive about four millirem." It wasn't that I didn't believe him. If there had been any danger, the Soviet government wouldn't have allowed us there; they'd had enough adverse publicity. Yet I'll admit I was uneasy. That insistent clicking reminded us that a life-threatening force was bombarding us continuously—made more ominous because it was invisible.

Yet that may be a good thing, for if all the radiation in the universe suddenly became visible, we'd be virtually blinded by the ever present fog.

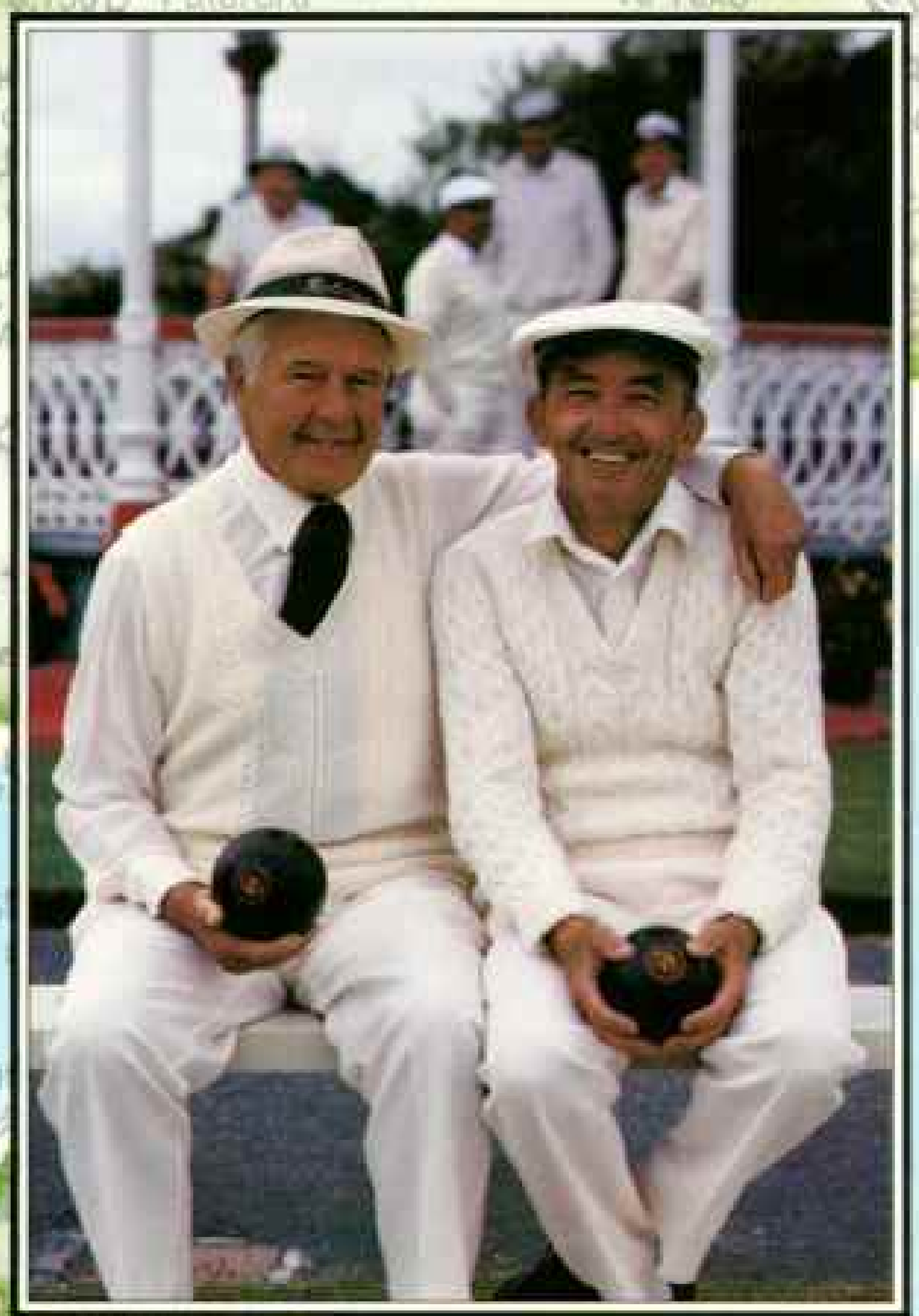
As we learn from Charles Cobb's article in this issue, not all radiation is bad. Properly used, it saves lives, preserves food, produces power, helps date the past. Sorting out the benefits and dangers is one of the great scientific undertakings. Can nuclear plants be guaranteed safe? Is radon endangering us even at home? How much is safe? In the case of radiation "what you don't know can't hurt you" doesn't hold true.

After ten minutes at reactor number 4 we had received—according to all three counters—four millirem of radiation, about half the amount that reached us as we flew through the stratosphere from Washington to Moscow and a fourth as much as we receive from one chest X ray.

I haven't worn the dosimeter since I left Chernobyl, but that doesn't mean I don't want to know what's happening. After reading this article, I may get it out again.

Wilbur E. Garrett

EDITOR



On New Zealand's North Island, in stately Government Gardens, two "Kiwis" await their turn at Lawn Bowls, a Down Under sporting tradition dating back to 12th century England.

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Down Under. It's down home to us.

Margay **Genus:** *Felis* **Species:** *wiedi* **Adult size:** Head and body length, 45-70cm; tail, 35-50cm **Adult weight:** 4-9kg **Habitat:** Forests from Mexico to southern Brazil **Surviving number:** Unknown Photographed by Richard Foster

Wildlife as Canon sees it

Monkeylike climbing skills enable the margay to stalk small mammals and birds from the treetops of its forest habitat. Even when this little-known wild cat is not pursuing prey, it is at home in the trees, effortlessly hanging from branches or leaping from limb to limb. The margay looks similar to an ocelot, but at two feet long is little more than half its cousin's size. Like the ocelot, the margay is overhunted for its luxurious spotted pelt. A more covert enemy is deforestation, which further reduces the felid's already shrinking range.

To save endangered species, it is vital to protect their habitats. Understanding the fragile balance of the earth's ecosystem holds the promise for the future. Photography, both as a scientific research tool and as a means of recording the world around us, can help promote a greater awareness and understanding of the margay and how it lives within its natural environment.

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

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On Assignment

WILLIAM T. DOUTHITT, NGS (ABOVE); KEVIN WORRALL

BEING EXPOSED to risk is nothing new for NATIONAL GEOGRAPHIC photographers. But for free lance KAREN KASMAUSKI, the invisible threat of radiation—encountered during fieldwork for her story in this issue—took some getting used to. Karen underwent tests for contamination at the National Institutes of Health in Bethesda, Maryland (above), after her first brush with the unseen adversary. It came in Goiânia, Brazil, where radioactive material from a medical clinic had turned up in a junkyard after being handled haphazardly.

"I hadn't worn any protective clothing, and there was a lot of dust flying around—that sort of thing," she recalls. "At the time it was pretty scary."

Fortunately, the examination at NIH showed no artificial radioactive substances in her body. In fact, during six months of coverage for this article (her fourth for the GEOGRAPHIC), the only time she showed increased radioactivity was after nine days in Lapland, where she ate reindeer meat that might have been contaminated with radioactive cesium from Chernobyl.

"It was a chance I chose to take," she said. "Months of covering radiation had made me less afraid of it."

"IT WAS a full day's work," says GALEN ROWELL, who with three other mountaineers ascended a previously unclimbed 1,400-foot face of Seven Gables, a 13,075-foot peak in California's Sierra Nevada. Along that range runs the 212-mile trail named for naturalist John Muir. Once a popular pilgrimage for backpackers, the trail, Galen found, "can be crowded near trailheads, but its heart is wilder than much of the Himalaya"—whose peaks he knows well.

Growing up in the San Francisco area, Galen's life took a vertical turn at age ten, when he began joining his wilderness-loving parents on Sierra Club outings. He has scaled the heights of Tibet, Pakistan, and Nepal, as well as Alaska, Canada, the American West, and the Andes, making more than a hundred first ascents. Veteran of eight GEOGRAPHIC assignments, he has also produced seven books and took the photographs for a new edition this fall of Muir's classic *The Yosemite*.

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