DOUBLE SUPPLEMENT: ANTARCTICA • PINNIPEDS AROUND THE WORLD

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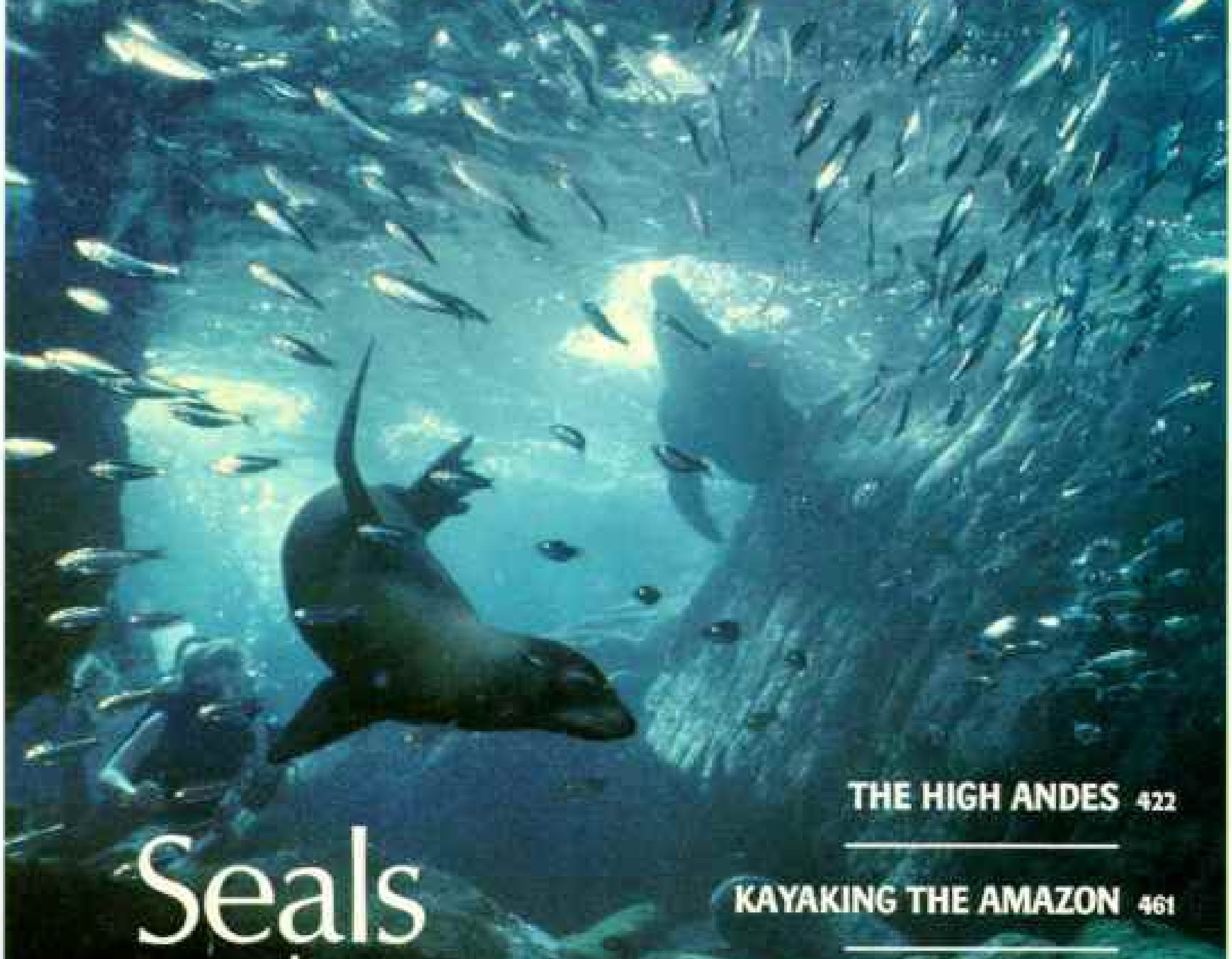
NATIONAL GEOGRAPHIC



Seals and Their Kin 475

SEE "TREASURES FROM THE PAST" WEDNESDAY, APRIL 15, ON PBS TV

FRANKLY, Noel Grove's article and Ted Spiegel's pictures this month on global air pollution frighten me. I suppose it's a bit like a child frightened in the dark, where each shadow holds a potential danger. But the dangers they have found are very real, though we can't see most of them even in the daylight.

Now Noel is not an alarmist by nature. He is no Chicken Little claiming the sky is falling. Quite the contrary, it seems the sky has become dangerous because substances in it do not fall fast enough. We have collectively burdened the atmosphere with compounds that rise into the air long enough to get out of our immediate neighborhood. Some of those neighborhoods are nations. We would never tolerate neighbors tossing their trash into our front yards or let some clever trash company dispose of its collections by flying over a neighboring city and shoving them out the door. But a company can vaporize trash, send it up a chimney, use the wind to deliver it, and we are more tolerant.

There might be no serious problem except that most life—plants as well as animals—must breathe this air. Given a few million years, human beings might adapt to thrive in almost any mix, but you and I don't have that long to wait. We seem to be turning our only air supply into a low-grade, long-term Bhopal.

We are strangely inconsistent in our concern for air quality. By international agreement, poison gases have been outlawed as weapons of war, but in peacetime we release chemicals into the air that in larger concentrations would be banned from use in combat.

Few issues have been given more press space or caused more hysteria than the idea that someone is putting something in the air that falls as "yellow rain" and sickens or kills people. Yet not even the wildest claims of yellow-rain casualties can hold a candle to the deaths and suffering caused by inhaling the smoke of burning tobacco. Breathing polluted air may be just as dangerous, but it seems to be a hard thing to prove. Perhaps one of you reading the article will be inspired to invent a hearing-aid-size gas mask to filter the air we breathe.

More realistically, the article will help all who read it see the dangers—invisible as they may be—that lurk in the only air we have. And once we really see them, they won't be so threatening, because together—as individuals and as nations—we can do something about them.

Wilbur E. Garrett

EDITOR

NATIONAL GEOGRAPHIC

APRIL 1987

COVER: *A school of anchovies scatters before hungry California sea lions feeding in the Sea of Cortés. Photograph by Marty Snyderman.*

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The High Andes

South America's Islands in the Sky

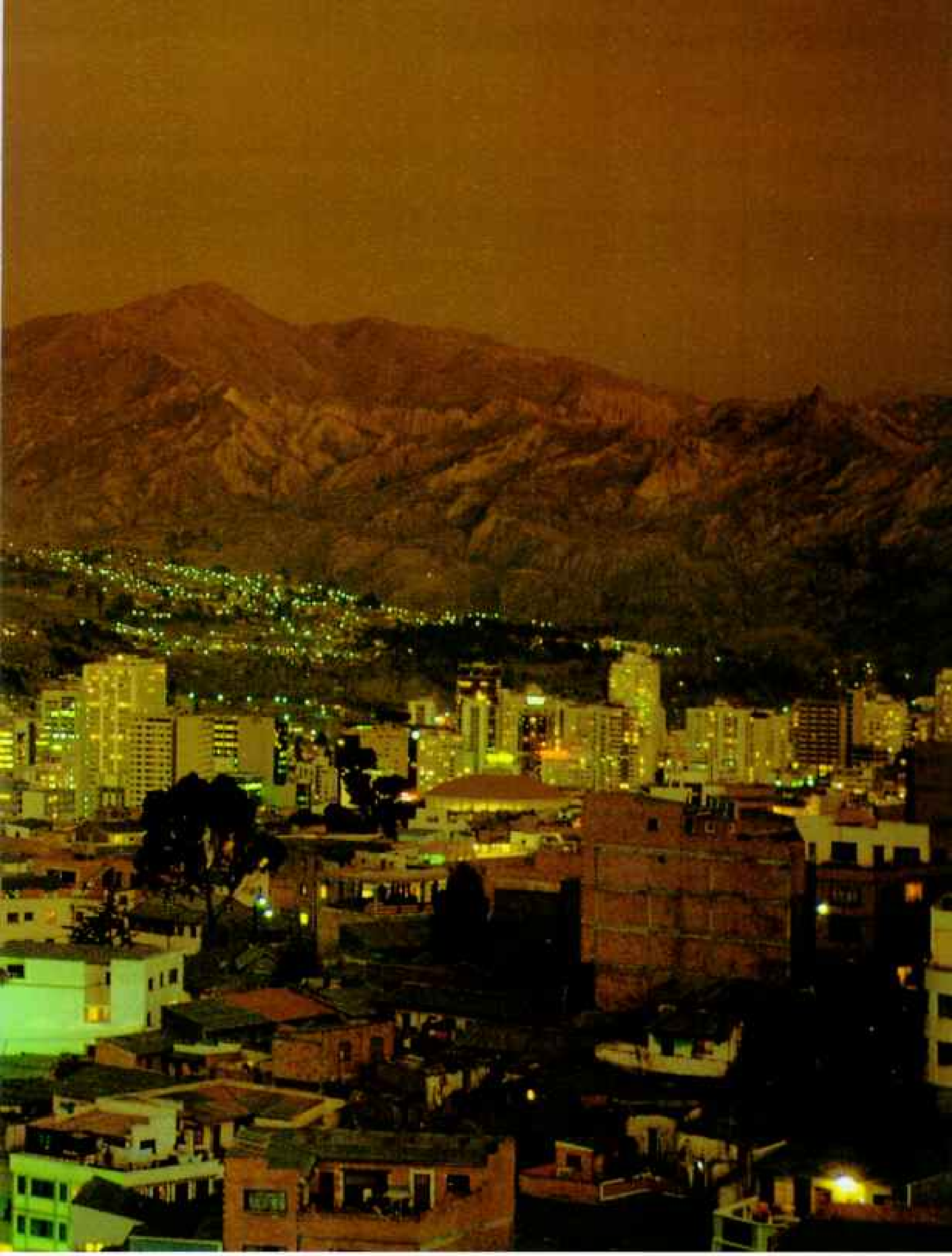
ARTICLE AND PHOTOGRAPHS
BY LOREN McINTYRE

A primeval landscape of volcanoes and salt lakes unfolds to the horizon on the high frontier between Chile and Bolivia.

Surmounting Cotopaxi's frozen cone of fire, six climbers conquer the summit of one of earth's highest active volcanoes. On clear days many of Ecuador's 50 other volcanoes are visible from the 19,347-foot peak, along with the high mountain

valleys that harbor nearly half of the nation's ten million people. In 1877 one of the most violent of Cotopaxi's 60 recorded eruptions melted its thick mantle of ice and snow, unleashing torrents of mud and water on the countryside below.

A deepening dusk ignites the city of La Paz, Bolivia, and its 21,201-foot guardian, Illimani—site of a 1985 airliner crash fatal to all 29 aboard. Inhabitants of the world's loftiest metropolis, a million Paceños thrive in the rarefied atmosphere



at 12,000 feet, which often afflicts visiting lowlanders with altitude sickness. Nestled in a deep canyon, the city is given a degree of shelter from the chill winds that whip the surrounding 600-mile-long plateau, the Altiplano.

Praying all the way, pilgrims en route to a mountain shrine east of Cuzco lead their packhorses along a trail scarcely an animal wide. Hewn from a canyon wall several hundred feet above a riverbed, the vertiginous trail follows a remote Amazon

tributary in Peru's eastern cordillera. Gullies scarring the slopes become rivulets when easterly winds discharge their moisture, which is returned to the Amazon basin by countless such canyon-bound rivers.

IF PARADISE indeed is in the sky, Juliana Quispe lives almost as close to it as anyone on earth, so high is her home near the glaciers of Peru's Ausangate, a 20,945-foot Andean snow peak visible from the onetime capital of the Inca Empire, Cuzco. Juliana's house of fieldstone thatched with bunchgrass faces a little lake named Comercocha. When her daughters fetch water from the lake, they walk barefoot upon treeless sod higher than the loftiest summits of the American West.

At that elevation, about 15,000 feet, the air is so thin that, for lowlanders like me, simply breathing enough of it to stay alive is trying. I got somewhat adjusted to it during a recent trek along the spine of the Andes, the South American mountains that stretch 4,700 miles down the western edge of the continent from the Caribbean to Cape Horn. My goal was to see how people survive—and, in some cases, thrive—here at extreme elevations.

Juliana was born to the altitude. Clad in 12 black wool petticoats, each in turn exposing one inch of embroidered hem, she scrambled about her rocky acres as if she were at sea level. I watched the small Indian and her chapped-cheeked daughters scrape llama dung into piles and carry enormous loads of

Potatoes cook endlessly over a llama-dung fire at an elevation of 15,000 feet in Juliana Quispe's stone house in southern Peru. The author found few people living higher than here, where water boils at the low temperature of 185°F. Several miles from their closest neighbors, the Quispes subsist primarily on potatoes – a crop native to the Andes – and their large llama herd. Through subfreezing nights, when the hearth is in embers, they sleep in warm clothing homespun from native alpaca wool.

it home for fuel. They need a lot; in such thin air water boils at 185°F, and it takes hours to cook potatoes. I could not keep up with them although I carried only my camera bag. I felt as if I were climbing endless stairs and often paused to catch my breath. The women seemed to breathe without effort.

My small expedition journeyed there in June, in the deep-felt sunshine of midwinter, to avoid the hailstorms and the sometimes lethal lightning of summer in the central Andes. So pristine is the air and so still the winter waters of Lake Comercocha that at nightfall a schoolgirl could wish upon a reflected star. Despite the numbing cold that descends "when the sun swims under the earth," as the Incas put it, I liked to wrap my hands around my evening mug of coffee and walk to the edge of the lake to marvel a moment at mirrored stars and distant planets without lifting my head.

JULIANA'S daughter Santusa shyly revealed that a paradise of sorts exists in a vast hollow within the god-mountain Ausangate itself. "The chamber is full of palaces and herds of sheep and llamas. If you listen after dark, you may hear the chiming of golden bells hung round their necks."

The thunder of an avalanche in the Ausangate night conjured a vision of a great boulder rolling away to reveal the opening into the mountain that Santusa believed in. Then laughter pealed across the lake. My guide said sleepily that it was the whinny of a vicuña, that fleet and elusive wild cousin of the llama. His brother thought it was the call of a bird, perhaps a *huallata*, a white goose with black markings that often feeds and flies in pairs; the Indians say that when one dies, the other mourns and soon follows. Juliana knew the guffaw came not from a goose but from the spirit of a dead infant.

Juliana's place fell short of paradise: She spent much time in tears. Through my guide she explained in Quechua, the lingua franca of the Incas, that rustlers had stolen the family's three cows and a bull. Cows at this altitude? Oh yes, and two were pregnant. She valued them more than all 200 of her llamas. Her husband had gone after the cows and failed to return. "He is faithless," she wailed. "He is drunk in God knows what tavern! His soul wanders in the night!"

I left Juliana's place for one of several thermal springs that ring Ausangate, each

about four hours' walk from the next. Paradise for me was soaking in a steaming pool hard by a freshet from a glacier.

From the heights floated the pentatonic notes of a *quena*, an Andean flute. Probably shepherds tending llamas and alpacas. They must have seen my camera, for in the morning three young Indians came with a cowboy costume and demanded that I take their pictures. Each in turn put on plastic chaps, a western hat, and my dark glasses, admired himself in a compact mirror, and struck a pose for the *foto instantanea*.

Their women came to peek and giggle at the pictures. Each carried an infant slung on her back in a *lliclla*, a square Andean shawl. The babies were swaddled in layers of wool that immobilized their bodies and covered their heads completely. How do highland

Heart of the High Andes

THOUGHT TO BE the world's highest mountains until the Himalayas were surveyed in the early 19th century, the Andes form a titanic bulwark extending 4,700 miles from the Caribbean to Cape Horn. For this article the author, who has lived and traveled in South America for nearly 40 years and has climbed several Andean peaks, fulfilled a longstanding desire: to explore the "two-mile-high world" of Andean nations with landscapes above 3,000 meters, or about 10,000 feet.

The clash of tectonic plates, which crumpled the edge of the continent to begin forming the Andes some 180 million years ago, continues to stoke subterranean fires, whose fury is vented through hundreds of volcanoes and frequent earthquakes. Blocking Amazon moisture carried by prevailing winds from the east, the mountains help create some of the world's driest deserts in the rain shadow along the Peruvian and Chilean coasts.

Though man may have arrived at the peripheries earlier, most of the Andean highlands were uninhabited until some 10,000 years ago, toward the end of the last ice age. In the wake of retreating ice, a freshwater sea covered much of Bolivia's Altiplano. In this vast flatland drainage basin, 3,200-square-mile Lake Titicaca is a remnant.

children like these escape suffocation so far above sea level? I wondered whether chronic shortage of oxygen can stunt an infant's growth—or does that shortage simply accustom the child to coping with the heights when he grows up?

ACCLIMATIZATION is the key to survival at extreme altitude. It has taken me days or weeks to adjust every time I have tackled Andean mountains higher than 18,000 feet. At that elevation air pressure falls to half what it is at sea level, and a normal breath brings only half the normal amount of oxygen into the lungs.

"Above that level even fit climbers risk HACE [high-altitude cerebral edema] and possible death when they go up too fast to adapt," said Dr. Charles S. Houston, author of *Going Higher*, my physiological guidebook on the trek. I tried to watch for signs of HACE—hallucinations, stumbling walk, drowsiness—while realizing that one of the main afflictions, faulty judgment, probably defeats attempts at self-diagnosis.

A more sinister peril haunts ascents of the Sierra Nevada de Santa Marta, whose snowy summits, marking the northernmost end of the Andes, overlook the Caribbean Sea. They are ringed by marijuana and coca plantations. The adjacent Guajira desert is strewn with wreckage of aircraft downed in drug wars. Years ago the only narcotics I saw were the coca-leaf kits of highland Arhuaco Indians. In 1968 chief Apolinar Torres charged me ten dollars' tribute to climb his sacred mountain: Cristóbal Colón.

At 18,947 feet Colón is Colombia's highest ground. Its rock is solid underfoot compared with the volcanic ash of Colombian snow peaks to the south. The ash grows world-class coffee but is treacherous. In 1985 a minor eruption melted snow that liquefied ash-laden slopes of Nevado del Ruiz. A flood sluiced Colombians out of bed 30 miles away and drowned 20,000 of them in mud.*

*See the NATIONAL GEOGRAPHIC's May 1986 issue.

THE MASSIVE VOLCANOES of Ecuador, farther south, have been mileposts in my life. Cotopaxi, nearly a mile higher than Mount Rainier in my home state of Washington, was the first great Andean peak I climbed, some 20 years ago. Its glaciers groan with ceaseless slippage. From the icebound rim of Cotopaxi's steaming crater at 19,347 feet, I could see 12 other snow peaks, most of them volcanoes, lifting out of meadows and rain forests.

Cayambe, smack on the Equator, towers 18,996 feet. A glacier on its southern flank flows from the Northern Hemisphere into the Southern. Thus I have walked from summer into winter there—the only place on earth where that can be done on natural ice in a single step.

Driving south from volcano to volcano along the Pan American Highway, I saw a column of Indians carrying enormous loads of cornstalks, skinny legs sticking out of the bottoms of huge bundles. As I stopped to take a picture, a truck carrying a loud brass band came tootling by, and since it was June 24, the Festival of the Sun, all the skinny-legged haystacks began to dance.

That was in the province of Chimborazo, named for Ecuador's tallest mountain. At 20,702 feet it was thought—until Asia's Himalayas were measured in the 1800s—to be the highest in the world. In a way it is: The equatorial bulging of the earth raises Chimborazo almost two miles higher than Mount Everest if the peaks are measured from the center of the globe.

Sangay, Ecuador's southernmost snow cone, has long been listed at 17,159 feet, although it must be growing. Swathed in clouds from the Amazon forests below, it has erupted almost unseen throughout recorded time. From a plane I have watched glaciers of lava sizzle down its Fujiesque slopes, displays of ember, ebony, and ice. Out of the crater floor burst glowing blobs of lava that whistle in high trajectories, freeze into misshapen stones, and arc back down to bombard the snow.

DAVID W. OSTERHUS

Fire and ice deck the seething summit of Sangay in central Ecuador (right). The Andes' most active volcano, Sangay has spewed lava, ash, and steam for centuries. Usually shrouded by clouds, the cone is seen during a 1969 eruption (above) in a time exposure taken from 40 miles away. The 17,159-foot-high mountain marks the southern limit of the Andes' northern belt of recently active volcanoes. After almost 1,000 miles free of volcanic activity, the fire breathers reappear intermittently from southern Peru to the tip of the continent.

South of Sangay for hundreds of miles there are no active volcanoes or permanent snows. In northern Peru the main pass over the continental divide is only 7,000 feet above sea level, compared with the paved Trans-Andean Highway out of Lima farther south, which reaches 16,000 feet. In northern Peru one travels in only a few hours from barren Pacific sands to sopping forest.

Clouds driven westward by trade winds cross the Amazon basin, strike the Andean barrier, rise, chill, and begin unleashing rain. It falls in torrents that cascade down mountainsides and broaden onto flatlands. Before reaching the sea, much of it

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This article marks the 13th NATIONAL GEOGRAPHIC byline for free-lance writer and photographer **Loren McIntyre**, who last authored "Humboldt's Way" for the September 1985 issue. Based in South America off and on for most of the past 40 years, McIntyre also wrote and photographed the Society's book *The Incredible Incas* and has contributed to more than two dozen of its other publications.

evaporates to form clouds that repeat the cycle by dumping enormous tonnages of water again and again against the eastern wall. Spray saturates gulches; mist wreathes the cliffs. The blockaded clouds part now and then to let sunshine hasten photosynthetic sorcery, drawing steep tiers of trees from cracks in rocks and conjuring out of the fog great snarls of giant ferns and epiphytes.

In that cloud forest few settlers venture today above 8,000 feet. They fear the heights are haunted. I learned that from my explorer friend Gene Savoy when I joined him in 1985 on a quest for lost cities above the Amazon headwaters of northern Peru. Gene had reported dozens of such finds nearby in the 1960s—including a now famous one he had named Gran Pajatén. So many ruins lie hidden in the clouds that almost every year brings another discovery, or rediscovery.

IN CHACHAPOYAS our expedition based itself down the street from the Temple of Good Death, not far from a studio offering INSTANT FOTOS IN 5 MINUTES. It is still as quaint and amicable a town as most of Peru was in 1947 when I moved there. Chachapoyans live up to the saying that mountain ways are "*más amable, más sano, no tanto en vano*—friendlier, wiser, not so frustrating." Few Chachapoyans look Indian or even mestizo—of mixed blood. Even the aborigines had been reported to be fair skinned.

Our horses scaled unshod the eastern palisades of the Marañón River gorge. Hired hands kept pace, their sandaled feet almost as indestructible as hooves. They carried their scant gear over one shoulder in cotton saddlebags, *alforjas*. They often paused to *coquear*, to renew their wad of coca and with it their fortitude. A Chachapoyan stuffs one

Survivors of a cataclysm, palms mark the plaza of Yungay (left), a town of 18,000 that was buried on May 31, 1970, when the Western Hemisphere's most deadly earthquake dislodged nearly two billion cubic feet of rock and ice from Nevado Huascarán, Peru's highest mountain. Crosses top an entombed church, at right, and a huge boulder that landed nearby.

Originally situated in the mountain's avalanche chute, Yungay sought to protect itself after a 19th-century landslide by relocating behind a high ridge. But in the 1970 disaster a wave of debris crested over the ridge and engulfed the town, as seen in this aerial view (right).

FOTO SERVICIO AEROFOTOGRAFICO NACIONAL, LIMA

cheek with coca leaves and sucks powdered lime from a stick that he constantly pokes into a little gourd containing ashes of roasted snail shells. The lime releases anodynes from the leaves.

In the cold rain of evening we pitched our tents in lumpy black bogs or on bunchgrass. Wild things hummed and gurgled in the dark of Antisuyu—the Inca name for this region, this *suyu* of their realm. From *Anti* came the Spanish word "Andes."

Even noisier in the night than croaking frogs and rooting boars were our men, especially when they had shared a bottle of cane alcohol. They kept up their fires and boisterous chatter to harden their nerve. They worried about *chirapa*. Chirapa? "A sickness," one explained. "Hives, and fungus under fingernails. It attacks you in high country . . . whenever it rains in the sunshine."

Horses and men followed us reluctantly into the cloud forest. We fanned out to search for ruins. I would creep hand over hand along exposed crags, gnawed by acrophobia. Next I would feel engulfed by spongy vegetation and whack my way out by machete as if small dinosaurs were at my heels. Gene could sense where to strip moss from a ledge—just at arm's length yet completely hidden—to reveal a cut stone balustrade embraced by roots.

He had to double men's pay to get them up to summits shunned by local folk. The men would hand around a bottle smelling of camphor and kerosene, rub some on their necks, and swallow a drop to steel their courage. They called it *antimonio*. "Not the metal antimony associated with combating parasitic diseases," Gene explained to me. "What they mean is *anti-demonio*—or anti-demon—medicine, prophylaxis for the high-country hex."

The men asked me for "some of the antimonio you use to make yourself invisible to *duendes*—spirits of the dead." My insect repellent. They thought it immunized me against evil because I had applied some before crawling into a cave strewn with human and animal bones.

Within a month we found four urban sites, mile after mile of circular buildings and strongholds. "The ruins belong to the culture of the ancient Chachapoyas," Gene concluded. "They occupied this region for centuries before the Incas invaded. In their day thousands of buildings covered these ridges above the east bank of the Marañón." He named the ruins Gran Vilaya.

The agony of hot candle wax on her hands brings ecstasy to a Penitente (left) in Huanca, a small town near Cuzco, Peru. Self-flagellation is among other forms of penitence practiced at Huanca's church, which was built to commemorate a peasant's vision of Christ being flogged. Vestiges of medieval Roman Catholicism discouraged by the modern church, such customs are still followed in some Indian parishes throughout the Andes. In Huanca's marketplace (right) an herb vendor sells folk cures for impotence, hexes, and fever, along with sea stars for heart disease.

The crests rise to two miles above the Marañón River, making its gorge one of the deepest on earth. Upstream, snow masses west of the river tower as high as 22,205 feet. Called the Cordillera Blanca, that White Range is a mountain climber's mecca. Runoff from its Pacific side drains into the valley of the Santa River called the Callejón de Huaylas. The callejón is cursed with natural disasters, caused not by volcanoes (there are none) but by nature's everlasting effort to pull down the mountains.

Of the 100,000 or so Andean people killed by earthquakes in my lifetime, some 60,000 perished in this region on Sunday, May 31, 1970. That afternoon the most catastrophic Western Hemisphere quake in recorded history triggered thousands of landslides that devastated the Callejón de Huaylas.

A slab of rock and ice weighing millions of tons shook loose from the 21,830-foot-high north peak of Peru's Nevado Huascarán. Falling free from the summit, the mass skidded down a glacier at nearly 200 miles an hour, then hurtled through meadowlands, scooping up earth as it went. Boulders and chunks of ice as big as houses sailed miles through the air.

Yungay, a picture-postcard town presumably secure from slides, lay 13,500 feet below. After an avalanche obliterated it in the 1870s, the town was rebuilt behind a barrier ridge 750 feet high—but not high enough that Sunday afternoon. Yungay's survivors were still gasping in the adobe dust of demolished homes and calling on Our Lord of Earthquakes for help when part of the pulverized peak shot over the ridge. The great blob of muck transformed the town of 18,000 into an instant mausoleum.

"All gone, except some children—not mine—watching a circus, and some old folks lighting candles at the cemetery on the hill," a survivor told me. "A wind blew people off the hill when the avalanche struck." He had been out of town that doomsday. Now he was plowing weeds above his buried house and family.

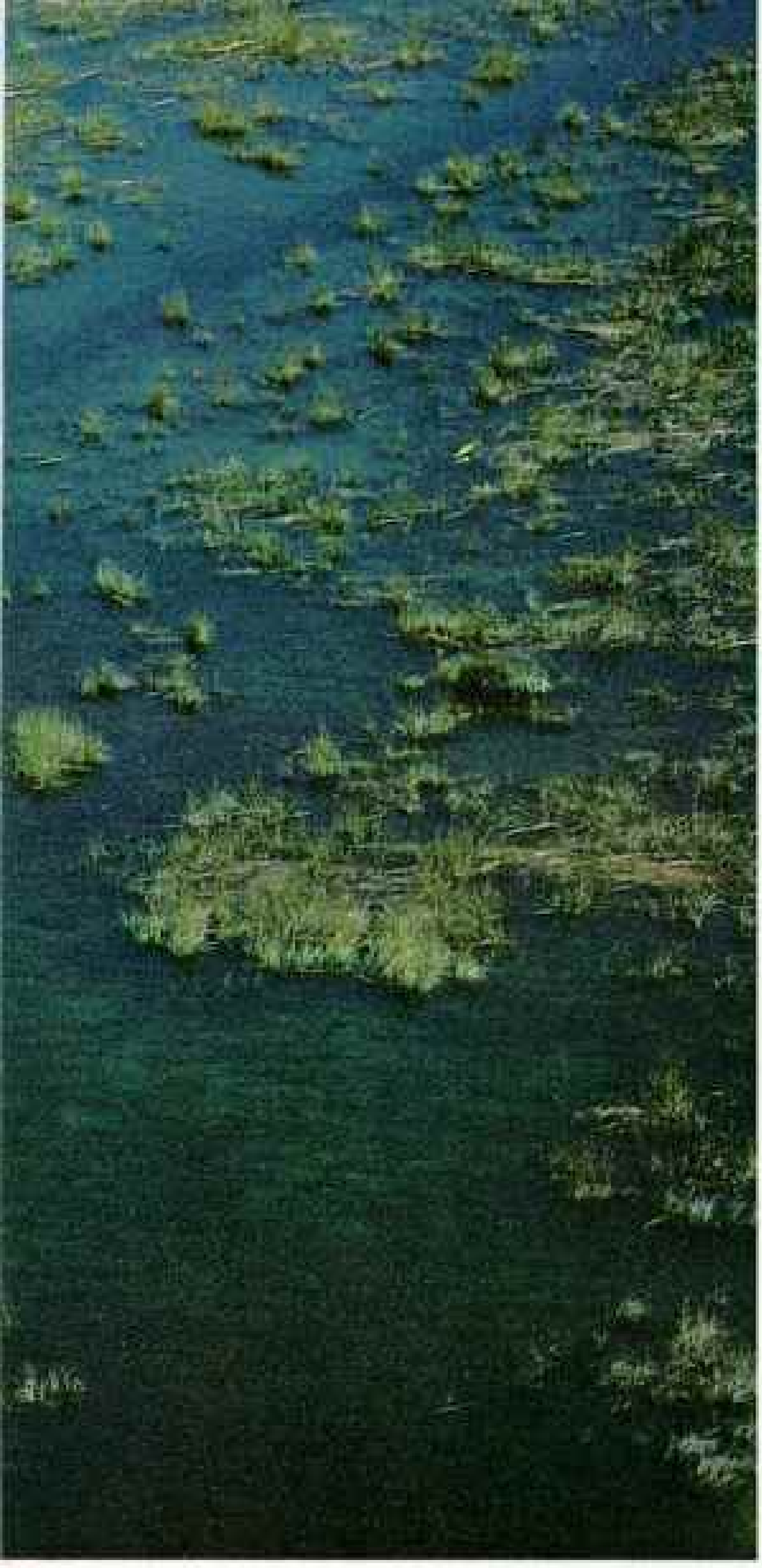
NOT UNTIL southern Peru, nearly a thousand miles south of ever erupting Sangay, do snowcapped volcanoes reappear. I could see four from the continental divide above a lake named for me. It really should be named Amazonasmayu Puquiococha—Source Lake of the Amazon River—in the descriptive Quechua language spoken by about ten million highlanders. But a marker to honor my discovery of the Amazon's most distant source on October 15, 1971, was recently set up there by members of the Los Angeles Adventurers Club. "The plaque weighed 55 pounds; we

had to hire an Indian to pack it up to 16,700 feet to mark 'Laguna McIntyre,'" reported Emil Barjak, their expedition leader.

In NATIONAL GEOGRAPHIC—the Society sponsored my climb—I wrote in October 1972 that the lake might cease to pinpoint the source by 1985, since its runoff feeds the upper Apurímac River, eventually to be dammed. "Tunnels will tap the headwaters and send a flow 43 miles under Andean crests . . . to irrigate nearly 150,000 acres of Peru's rainless coast."

Yet by the start of 1987 no Amazon water had reached the Pacific side, even though 650 million dollars had been spent on the first stage of the project, half of it loaned by the governments of Sweden, Canada, South Africa, Spain, and Great Britain. This Majes Project reshaped the flow of the Colca River on the western watershed of the continental divide. Tunnels and canals encased in concrete lace its awesome gorge, twice as deep as any in the United States. But Colca water will provide only one-third of the system's capacity.

"The second stage, a dam and tunnels to tap the upper Apurímac, may cost 200 million dollars more," explained Kjell Lundquist, the Swedish manager. "Only then can the hundred kilometers of hydraulic system



On the world's highest navigable lake, Aymara-speaking fishermen center their lives around the totora reeds of Lake Titicaca, a 12,500-foot-high body of deep, icy water on the Peru-Bolivia border. Pulled from shallows on the Peruvian side, the reeds are piled up on the lake bed, forming a spongy substrate for island communities (left). Islanders such as this woman drying barley on an Inca-style clay stove (above) use the reeds to build boats and houses.

now in place be fully utilized. And only then can this project show how famine can be put off in Peru for at least a century by farming the coastal deserts." Within 220 years the population of Peru, at its present growth rate, would equal that of the entire world today.

WHEN HIGHLANDERS—population six million or so when the Spaniards came—ran short of farmland, they flattened mountainsides by cutting terraces into them, like giant stairways, as high as 13,000 feet. On narrow plots held in place by rock retaining walls, they raised maize or potatoes, the Andean people's most valuable gift to the world. Inca armies carried dehydrated potatoes called *chuño* on their campaigns.

Between 1438 and 1532 the Incas built the greatest empire ever to flourish at extreme altitude. From southern Colombia to central Chile it stretched 2,500 miles. Inca nobles told Spaniards that their dynasty sprang 12 generations earlier from the Island of the Sun in Titicaca, the lofty lake on southern Peru's frontier with Bolivia. They said their progenitors wandered from Titicaca to Cuzco, their gold-adorned capital, whence they sallied forth to impose

The classic cone of El Misti in the arid western cordillera of southern Peru wears a snowcap following a rare day of precipitation. Scribed by the infrequent rains, ashfall on the slopes testifies to sporadic activity. Typical of many Andean

volcanoes, El Misti spews only ash and gas, not lava. Layers of fallout from countless ancient eruptions blanket the central Andes, lying as thick as 3,500 feet. Much of the city of Arequipa at El Misti's foot is built of soft, white volcanic rock.

their well-organized will on more than a hundred nations.

Tellers of Andean creation myths have short memories. Distant Indian forebears of the Incas came from Asia into a New World empty of man and full of game 10,000 to 15,000 years ago, perhaps earlier, and several Andean empires rose and fell before the Incas strode upon the scene.

In following their campaign trails to write a National Geographic book about the Incas, I had empathized with their times most easily in the imperial heartland, a very Indian region strewn with stone ruins that reaches out on both sides of the railroad and highway linking Cuzco with Lake Titicaca. Airliners now fly directly over it.

For a condor's view of my old stamping grounds I recently rode up front in a Boeing 727 leaving Cuzco for La Paz, Bolivia. Columns of cumulus stood in our way.

"In the Andes even the clouds have rocks," the Bolivian pilot said. One rock was Ausangate. The 727 veered around its ice pinnacles as if laying out a slalom course for Andean deities, too fast for me to make out Juliana Quispe's place. Beyond lay the Quelccaya Ice Cap, where Ohio State University scientists were drilling cores to determine climate a millennium before Inca

Back-to-back basics characterize the three years of schooling that children receive in Altarani, a village in northwestern Bolivia. Sharing a one-room schoolhouse, two teachers use this novel approach to instruct their students in both Spanish and Aymara, one of the two Indian languages—the other is Quechua—spoken in Bolivia and Peru. Barely literate, most of Bolivia's Indian children leave the classroom by age 12 to work with their families.

times. Two specks were crossing the ice.

The captain, a former fighter pilot, pushed the wheel forward and buzzed the specks. The dive alarmed an electronic watchman in the cockpit that ordered "Bzzz, PULL UP! Bzzz, PULL UP!"

"Did you get their picture? Too fast? Let's try again with flaps down to cut speed."

He zigged and zagged all over Lake Titicaca's 3,200 square miles, banking sharply to show passengers the Island of the Sun. Its sprawling ridges rise from Titicaca like the spine and limbs of a sleeping leviathan.

We landed late at El Alto, the 13,350-foot-high airport of La Paz. Passengers debarked, some clutching barf bags and muttering about mortality. A U. S. mountain climber cursed the pilot. His feelings hurt, the captain turned to me. "I gave him a good look at the Andes. Isn't that what he came for?"

LA PAZ occupies a canyon a thousand feet below the airport. It was an adventure, many years ago, to move my family by automobile from Lima, at sea level, up to La Paz. As a youth I thought it was a feat to climb peaks a thousand times taller than I in the Olympic Mountains, near Seattle. In La Paz my foreign-aid office was twice that high.

We lived closer to the Equator than Tahiti is, yet three fireplaces and five electric heaters failed to warm the house—especially on the night when hailstones broke our windows. Fires were hard to start; conflagrations were almost unknown. We opened cans and bottles carefully lest the contents blow up in our faces. We were grateful for pressure cookers, and we ate quickly, before meals chilled.

Flowers didn't smell much, but neither did disagreeable things. My wife, Sue, and I remember weight loss, cracked skin, and our sons' injuries and illnesses taking longer to heal in La Paz. And we recall soroche, the altitude sickness—headache, nausea, and gasping for breath at night—that still besets lowland visitors. They adapt in a few days, mainly through an increase in their breathing rate and in red blood cells whose colorant, hemoglobin, carries oxygen from the lungs. But few ever run easily up a full flight of stairs.

Despite warnings, visitors would sunbathe. Twenty minutes was too much unless their skin was already as dark as an Indian

Hazards of the "high life" are specialties of Dr. Gustavo Zubieta and his son Gustavo, Jr., of the High Altitude Pathology Clinic in La Paz. X rays contrast a normal heart, left, with one that is dangerously enlarged, a condition suffered by some who, like tin miners in Potosí (right), work at oxygen-poor altitudes.

farmer's. And at embassy receptions visitors from the States would stroll outside, drinks in hand, despite the cold. We old-timers knew that they went out to break wind. Unless they were aviators, few newcomers realized that their symptoms were not peculiar but shared by all. The cause might be likened to uncorking a bottle of champagne: Normal intestinal gases expand with increased elevation.

I RECENTLY LEARNED that worse things can happen to highlanders with poor diets. "If the colon is blocked, intestines swell with gas, leading to death from a ruptured gut if not surgically punctured," explained Dr. Gustavo Zubieta (above). With his son and daughter, both doctors, he owns the High Altitude Pathology Clinic in La Paz. The city, now twice as big as when I lived there, offers a million subjects for his computerized studies of response to hypoxia—oxygen shortage—when living near the upper limit of the biosphere.

"I would guess that about 99 percent of all living things on earth are found within two miles of sea level, where oxygen is more plentiful," Dr. Zubieta told me. "Nearly all the remaining one percent live as we do, within the next half a mile."

Some of Dr. Zubieta's patients dwell at the upper limit of that zone. Brick houses lining the sides of the great abyss that holds La Paz are overflowing onto the Altiplano above town. About 300,000 people now live in El Alto, a suburb alongside the world's highest international airport.

"Many up there have chronic altitude sickness, especially if they are miners or have cardiopulmonary diseases and develop a dangerous excess of red cells," said Dr. Zubieta. "And the higher above two miles that children live, the more their growth and maturity tend to be retarded."

The Zubietas doubt that being born in the Andes or of Indian parentage provides much genetic adaptation to hypoxia and its ills. "Lowlanders can adapt almost as well. Their average chest capacity is the same as highlanders, despite the 'barrel-chested Indian' cliché. Consider this: All highlanders, including *(Continued on page 450)*


NITRATO
50
RUHR

A real-life El Dorado when it was the largest city in the New World, Potosí appears in a 17th-century portrait (above) much as it does today (far right) at the foot of Bolivia's Cerro Potosí—the richest source of silver that history has known. Above a religious procession on the lower slopes, llama trains carry ore from the ancient volcano, whose bounty produced billions of dollars, in today's currency, for the Spanish Empire. In the mountains at left, dams capture summer rainwater, vital to the mining operations that were manned by thousands of Indian conscripts. By the 19th century Potosí's population had shrunk from 150,000 to 8,000 as the silver lode played out. But a humbler mineral from deep in the mountain's depths caused the city's fortunes to rise once again. "One of my ancestors pioneered the switch from silver to tin a century ago," says Juan Jorge Aitken (right), manager of a nearby dairy farm.

MUSEO COLONIAL DE CHARCAS, SUCRE, BOLIVIA

Indians, forfeit their acclimatization if they sojourn long at sea level."

Highland Indians may be born with at least one trait no lowlander can acquire: more capillaries in the fingers and toes, hence warmer extremities. Having watched them break ice with bare feet to launch reed boats on Titicaca, I agree with the 17th-century chronicler Bernabé Cobo: "In freezing weather, if you touch their hands, you find them remarkably warm. . . . They sleep by the road . . . wherever night overtakes them, uncovered to the sky; though inches of snow may fall, they sleep as if in soft beds. This extreme warmth can also be seen in that they have stomachs more rugged than the ostrich. . . ."

So far I have found nobody dwelling permanently in the Andes much above three miles—15,840 feet. A few herders and miners live and work at times beyond that limit, but in those barren heights energy ebbs away and the daily grind gets too disheartening to long endure.

TO LEARN HOW MEN TOIL at that limit, I set out on the road to the legendary mines of Potosí, truly a "high way." It never dips below 12,000 feet in all its 343 miles. Four centuries ago it teemed with travelers bound for the largest and richest city in the New World. Many were Indians headed for servitude in the mines. Caravans of llamas from Peru bore kegs of wine and leather bags of the mercury needed to soak silver from crushed ore. Vendors came loaded with such luxuries as carpets from Turkey, silks from China, and paintings from Rome. Outbound mule trains carried tons of coins mined and minted in Potosí, treasure to help maintain the worldwide Spanish Empire.

The city, which numbered more than 150,000 people before the Pilgrims landed at Plymouth Rock, lies at the base of an ancient volcano so laced with metal that it became the most vaunted of all the ten to twenty thousand peaks in the Andes. It was the richest; its old name, Cerro Rico, means Mountain of Riches. The city's coat of arms reads: Rich Potosí—World Treasure—King of Mountains—Envy of Kings.

Like gnomes, many Potosinos lived for as long as a week at a time underground in the "devil's domain." The cerro was honeycombed with 5,000 tunnels where Indians dug by the light of oil lamps. The catacombs beneath Potosí's churches were connected by underground escape routes where swordsmen scurried during uprisings.

"Of ten or twelve children each Indian mother bore, only one or two survived," said Wilson Mendieta Pacheco, historian and former editor of Potosí's newspaper *El Siglo*. "No Spanish children at all survived the hostile environment until 1584. A woman who had lost six children prayed to St. Nicholas to save her seventh. He lived. She named him Nicolás. For years thereafter every Spanish boy and girl born in Potosí was named Nicolás."

Since Potosí has never suffered a major earthquake or fire, colonial balconies still overhang winding streets. At daybreak woolen-shawled women in witchlike hats sweep the city clean. One sweeper complained about the injustice of having to work until age 50, when the city would pay retirement for her and her family.

"And how many children, señora?"

"Six. Three grown, and three little ones."

"And your husband, señora?"

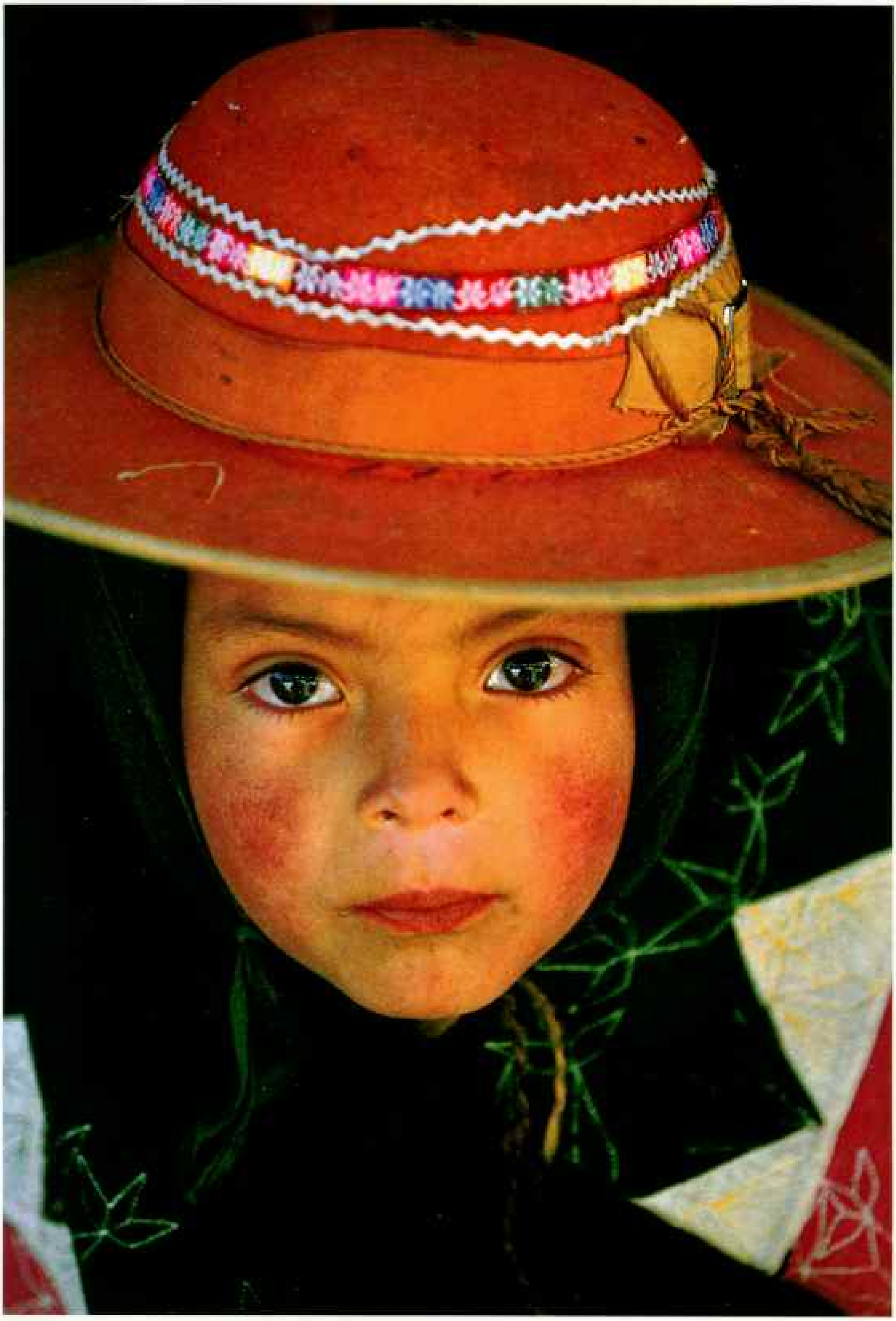
"He went away 12 years ago. You rich Americans don't know what it is to work for a living."

"Not so, señora. Last night I worked till ten. I bet you were asleep by then."

"Oh no! I was watching my color TV!"

Silver lodes capping Cerro Potosí's 15,827-foot summit eventually played out. By 1825 the population had fallen to 8,000. However, the heart of Cerro Rico is veined with tin, and skewered now with vertical shafts. Tunnels branch out from them, but only one reaches daylight: the entrance on level zero.

Her cheeks chapped in the high altitude, a young Bolivian models a traditional Inca passport—a hat that identifies the wearer's place of origin as the village of Calcha. Descendants of several Andean civilizations, some 12 million Indians in Bolivia and Peru constitute half their nations' populations.



I followed it a mile into the cerro, my hard hat banging icicles and a 440-volt trolley wire. Then down by cable 800 feet to level eight's convoluted tunnels, so thunderous and muggy from blasting that miners call them the "devil's gut." My guide wouldn't go deeper; he said the devil hangs out on nine. He warned me to ignore faceless miners; they might be demons in disguise.

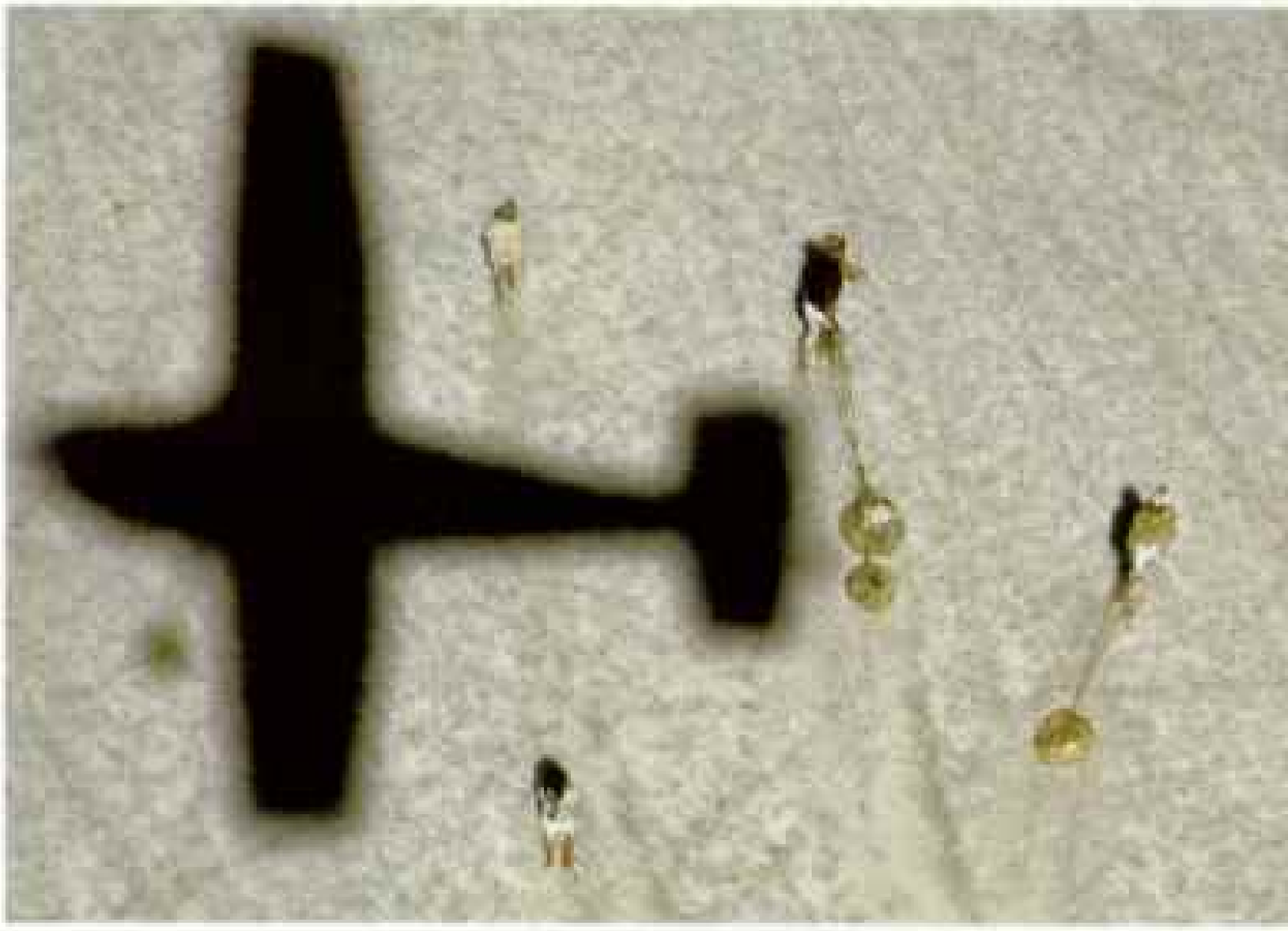
We entered a drift where operators, stripped to their skivvies, were jackhammering holes to insert explosives. A little way into picture taking, my arms got heavy. The deeper I breathed, the dizzier I became. Chagrin was the last sensation I recall.

I came to in a sick bay with bloodstained walls on level zero. A lame dwarf (a paramedic goblin?) brought coca-leaf tea and a soiled aspirin tablet. He pronounced that I had succumbed to carbon monoxide gas. Perhaps. It impairs red blood cells—already in short supply at Potosí's altitude.

When I recovered, I drove down from once again populous Potosí—it now has at least 60,000 inhabitants—and by nightfall reached the Salar de Uyuni, a salt flat where no one has ever lived. This desert is a 3,000-square-mile precipitate of prehistoric Lake Minchin. A causeway over treacherous slime along the shore led to routes concealed in shimmering brine that only a few truckers know.

After shivering all night in Uyuni, a forlorn road-and-rail junction, I headed west toward Chile, following tire tracks across the clayish Salar de Chiguana. The salar borders the south end of Bolivia's Altiplano, a vast basin of lakes that drain into neither Pacific nor Atlantic but only earth and sky. In Bolivia one blames poor judgment and memory on the altitude. So naturally it was hypoxia that made me mislay my keys, forget to read my compass, lose my way, fail to make camp before dark, and founder in gumbo while hail and salt peppered the jeep. By morning the mud had frozen hard enough to drive upon.

Caught in the act by the author's lens, egg robbers (below) drag laden hides across the salt flats of Laguna Colorada in a 1972 photograph. One of the world's most inaccessible nature preserves, the Bolivian lake, tinted red by algae, is a major nesting ground for rare James's flamingos (facing page). To discourage poaching, Bolivia appointed one of the men in the old photograph game warden. Remarkably, when the author returned for the present article, the warden remembered the aerial "attack," as he called it.



A SEETHING VOLCANO, Ollagüe, marks the Chilean border. Beyond it towers Aucanquilcha (following pages), at 20,262 feet almost as high as I have ever climbed. In 1985 I did the final vertical mile in an hour. On wheels.

Aucanquilcha's summit craters, shattered by eruptions that exposed rich deposits of sulfur, support the highest mine I have ever seen or heard of. In 1913 the brothers Carrasco of Antofagasta, Chile, began to bring down sulfur with pack llamas, two or three thousand of them looping up and down like a living conveyor belt.

"The llamas ate up all the forage for miles around," said Raúl Carrasco, the present owner of Amincha, the Chilean mine. "Mules? It took eight to haul an empty wagon to 16,000 feet. Fords and Chevys? Their radiators boiled. In 1935 we built 14 miles of aerial cable to lower the ore in buckets. Now we use 20-ton trucks, Mack, White,

At the upper limits of human endurance, miners shatter boulders of sulfur ore (above) at the highest mine in the Andes, if not the world. Chile's Aucanquilcha, at 20,262 feet only 858 feet short of four miles high (left), is one of dozens of sulfur-rich volcanoes in the western cordillera, which divides Bolivia from northern Chile. When the snow is deep, the miners, all Bolivians, ascend the mountain's upper slopes on foot, climbing 2,000 feet an hour. At the end of the day, they toboggan down the mountainside at breakneck speeds on home-made sleds that they carried with them on the morning climb. "They put most mountain climbers to shame," says the author, who was driven to the top in one of the 20-ton turbocharged trucks used to haul the ore down and to transport the workers when weather permits.

Highest point in the Western Hemisphere, 22,835-foot Aconcagua towers above surrounding peaks in the Argentine Andes. Were it not for the bitter cold winds that lash its summit, the mountain would be relatively easy to climb, says the author. In 1973 he helped recover the body of one of dozens of climbers who have succumbed to its challenge.

International, Caterpillar. Supercharged. Almost ideal, but, unlike llamas, one falls off the mountain now and then."

From the foot of the mountain the sulfur ore goes by rail to be made into sulfuric acid at nearby Chuquicamata, Chile, site of an open-pit copper mine, the biggest man-made hole on earth.

I rode up with truckloads of miners, all sun-goggled and given to raucous horseplay. They looked like they had picked clothing out of a Goodwill bin. I was clad to the nines, remembering that in 1973 I had helped Argentine climbers recover the body of a well-outfitted NASA engineer who had frozen to death in bright sunshine at this altitude. Aucanquilcha's sulfury summit is only 58 feet lower than Mount McKinley's, the highest in North America.

My raffish friends began swinging pickaxes, making little yellow rocks out of big ones. "None are Chileans. Only Bolivians can work worth a damn up here," a foreman boasted. Watching a small man lug his own weight in blasting powder up a cliff, I agreed. Having come from sea level with only one day's adaptation, I could not even stroll up the road worth a damn.

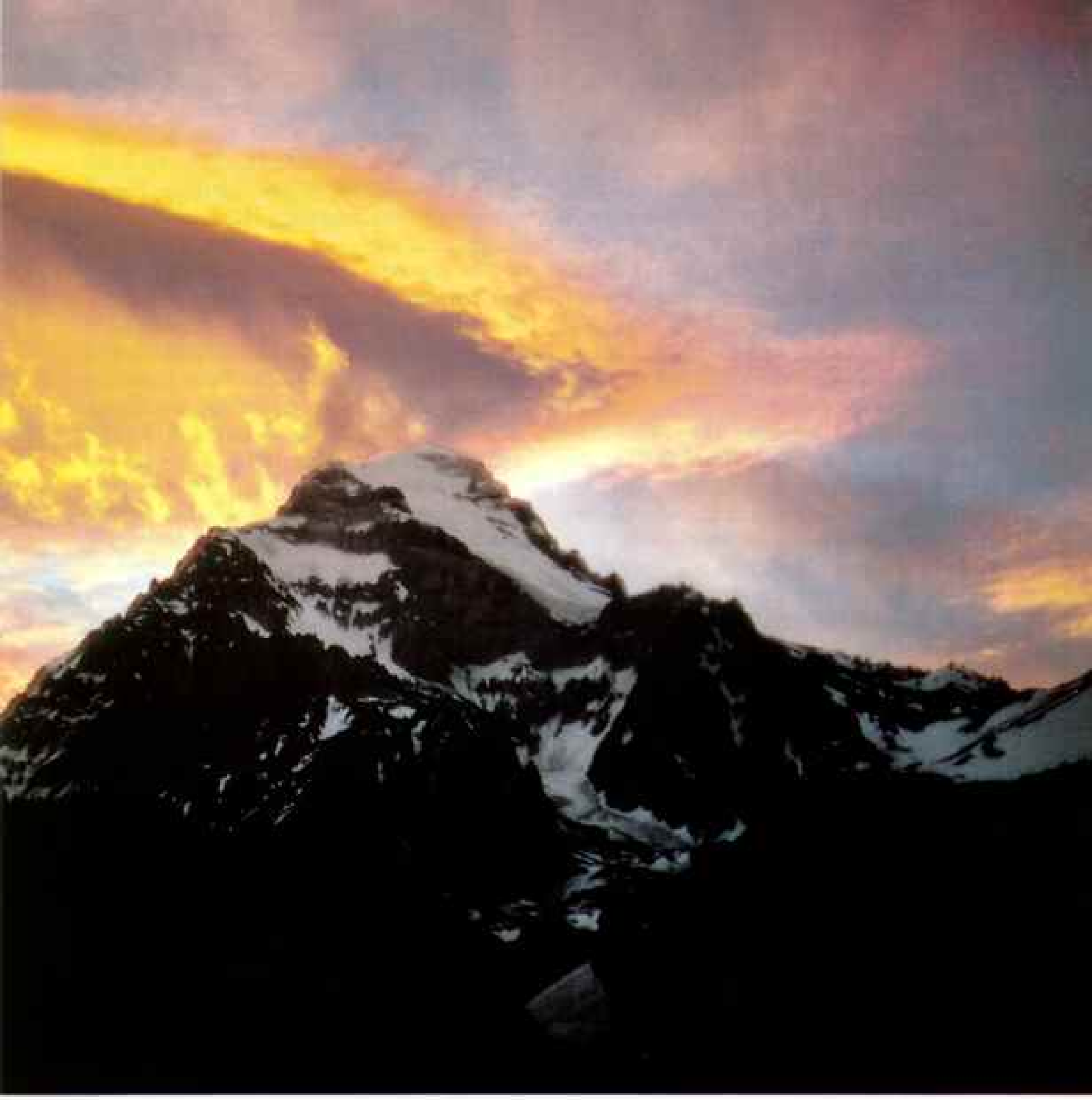
I photographed a miner clamping detonators to fuses with his teeth, a procedure liable to blow off his head. He asked a question I had heard before in the bowels of Potosí: "How far into the mineral can your lens see? Does it tell how much ore remains?"

From Aucanquilcha's crest I could look back 50 miles to Uyuni's brine. In other directions my view was blocked by so many tall volcanoes it seemed as if a childish giant had poured umber sand into dozens of neat piles. Some were frosted with recent snows; none in sight held glaciers. Extreme aridity allows mining on many summits.

For me, to travel that igneous realm was to explore an alien planet, frozen yet menaced by a sun too near, airless yet scoured by jet-speed winds, at first sight lifeless but for this lone transgressor encircled by solitary volcanoes—god-mountains without worshipers. On their summits, long ago, the Incas sacrificed children to the sun.

AT 22,057 FEET, the crown of Llullaillaco is the loftiest archaeological site known, with fallen buildings, an altar, and scraps of handicrafts, meals, firewood, and ashes. Its stone corral is still deep in 15th-century llama droppings.

Elsewhere in this frontier region, geysers



gush and volcanoes fume. Some simply gape, their craters blown away, their calderas smeared with sulfuric yellows and oxide reds. Eruptions in recent geologic time filled spaces between the cones with sloping plains, wind-smoothed and gentle enough for a jeep to climb three miles high. Lakes abound, for brooks cannot escape the inland basins. Some are blue, others are red or green with algae, and all are bitter with minerals once spewed from craters in incandescent clouds. Cumulus clouds ferry tons of fresh water through dark blue skies, but the skinless sky ships spill little in midyear.

Few roads and no bridges exist. Fresh snow concealed mining-truck ruts I had hoped to follow. The only signs of man's passage were hunks of dried *yareta* fallen from trucks. Yareta is a highland plant resembling a huge hard cushion that takes hundreds of years to grow, an instant to dynamite loose from rocky soil, months to dry, and a few minutes to burn away in miners' stoves. *Yareteros* now search as high as 15,000 feet to gather what's left of it.

I followed yareta droppings through the mountains like Hansel and Gretel following bread crumbs through the woods. By matching mountains with those on maps, I found my way with compass and altimeter.

When clouds hid the mountains and I strayed from the yareta trail, I got lost, as Hansel and Gretel did when birds ate their path-marking crumbs.

When I arrived at Laguna Colorada, a red salt lake six miles long with white islands, I anchored my tent to lava bombs near a freshwater hot spring at the shore, built an oven, and fired it with yareta. As the sun set, the temperature of the thin July air sank to minus 15°F, and the katabatic wind of evening roared down the shadowed slopes of volcanoes to the west.

At daybreak, chitchat cries of flamingos wakened me. Chilean, Andean, and the rare James's flamingos stalked the ice-caked shallows to feed on algae. I rowed an inflatable boat out to an island to examine sediments alternating with layers of centuries-old ice discovered recently by ecologist Stuart Hurlbert of San Diego State University. Landing, I sank up to my hips in quicksand. Another day a whirlwind struck out of a blue sky, blinding me with white dust. When it lifted, I saw my equipment awash in red brine and my boat drifting toward the mainland, a mile away. While I was wading after the boat, the wind returned it.

As I was breaking camp on the fifth day, I noticed a man with a bicycle watching from a hill. I waved. He approached warily and announced that he was Eustaquio Berna, "warden of the Laguna Colorada faunal reserve." Hurlbert, who knew Eustaquio, had told me that he was an experienced warden; he used to collect eggs from flamingo nests to sell for food in his hamlet, 30 miles away.

I mentioned photographing Laguna Colorada egg robbers from a plane 12 years before. Eustaquio remembered the aerial "attack," but insisted that he no longer stole. He asked me to remind authorities that his warden's pay was long overdue.

Just as I emptied my tent, an explosive gust whisked it aloft like a kite and dropped it far out into Laguna Colorada.

IF COLD IS THE ANDEAN HELL, wind is its devil. "Very windy and completely exhausted. . . . For 2¢ I'd go back . . . nowhere is sheltered," were the last scrawls in the diary of the frozen climber I helped bring down from Aconcagua. With windchill factored, Aconcagua's summit temperature may drop to minus 100°F. Storm victims populate its cemetery. High-velocity winds—125 knots or more—whip Aconcagua's summit. At 22,835 feet it is the highest mountain in the Western Hemisphere and the Southern Hemisphere, too, for that matter.

The distance from Aconcagua's crest to the bottom of the Peru-Chile Trench offshore is 49,292 vertical feet if measured to the deepest abyss. The trench was formed by the heavy Pacific Ocean floor thrusting beneath the lighter rock of the mainland. The initial collision about 180 million years ago crumpled the edge of the continent and created the ancestral Andes. Continued underthrusting causes earthquakes, ignites volcanoes, and allows the injection of superheated, mineral-bearing fluids into belts of fractured rock parallel to the coast.

Along the belts from central Peru through western Bolivia to central Chile, copper, tin, lead, zinc, and silver tend to concentrate near the surface. Copper and tin are the big money-makers. But ever since the conquistadores glimpsed Inca artifacts, gold has been the metal to get one's hands on.

The latest find to gladden a gold digger's heart is El Indio mine in Chile. "Imagine the bonanza! An area the size of five soccer fields, about 250 meters deep, with veins of gold that yield up to 3,500 grams per ton!" exclaimed Hector Araya, Chilean manager of the mine, which is owned mainly by U. S. interests. I couldn't imagine it at all. Araya expanded his smile and his arms. "That single block of ore is worth a billion dollars."

And worth a look. From Santiago I took Route 5 north to La Serena and turned inland up the Elqui River to the mine site between two volcanoes: Doña Ana and 20,745-foot Tórtolas, which straddles the barren border with Argentina.

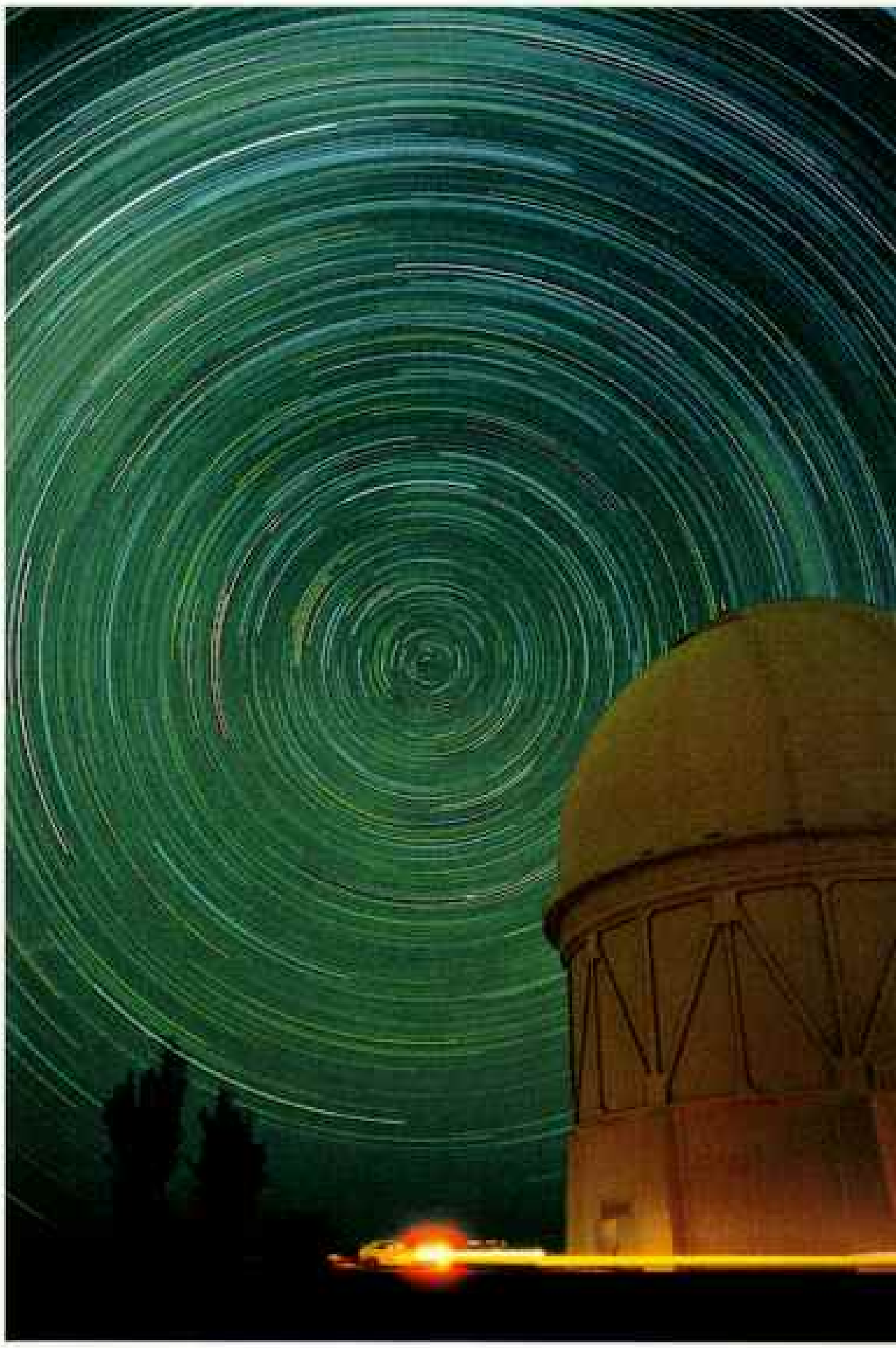
Mineral deposits exposed by wind and water erosion are scattered along 150 miles of continental divide, in a belt averaging two miles wide. Now mountainsides for miles around El Indio are clawed with roads and jabbed with tunnels by prospectors hunting for more ore. Housing resembling a ski resort eases discomforts of altitude and isolation. The warehouse was a million-dollar trash dump: A recent avalanche had crushed it.

I took the road back down the Elqui River halfway to the sea and looked across the highway from a shrine above Vicuña, birthplace of Nobel Prize-winning poet Gabriela Mistral. A mile and a half above the vineyards an alabaster dome sits on Cerro Tololo. By moonlight it is as pale as a temple. And it is a temple of sorts for those of us who stand in awe of high technology and the stars.

I asked quasar astronomer Patrick Osmer—then in charge of Cerro Tololo's four-meter telescope and six lesser domes—whether the telescope soon to be launched in space, free of atmospheric interference, would put the observatory out of business.

"Quite the contrary. Hundreds of scientists are already waiting in line to use the Space Telescope. Its discoveries will load all three observatories in this region with endless needs for follow-up." The other two are the Carnegie Institution's Las Campanas, with four domes, and the European Southern Observatory, with 14. ESO is mapping billions of objects in the southern celestial hemisphere. Some astronomers have visualized an array of giant telescopes erected and maintained by technicians living in pressurized cabins on border volcanoes two or three times as high as Cerro Tololo. It could be operated by remote control from London, Munich, Pasadena—or elsewhere. The array might perch in solitude beside some ruined shrine where Andean ancients worshiped the sun.

Yet for me even such a technological wonder as that would fall short of seeing our galaxy as I saw it one night, sojourning at Juliana Quispe's place under Ausangate: the Milky Way as an emperor's garden of fireflies in the dark of a mountain lake. □



Showcase for the southern skies, Cerro Tololo observatory in north-central Chile has a waiting list of hundreds of astronomers eager to use its telescopes. Capturing colors barely perceptible to the naked eye, a time exposure traces the stars of the Southern Hemisphere as they appear to circle the south celestial pole. Operated by a consortium of U. S. universities, the observatory enjoys views of celestial bodies unseen by most of mankind, revealed from its perch high in the pristine Andean night.

Through Wild Andes Rapids

Kayaking the Amazon

By PIOTR CHMIELINSKI

Photographs by ZBIGNIEW BZDAK

NO ONE had done it before. No one had traveled the full 4,000-mile length of the Amazon River under his own power. Pride kept us going. But during the first three months of our half-year trip through the white waters of the high Peruvian Andes, our pride was sorely tested by fear of the unknown.

Much of the area was unexplored and unmapped. Seven expeditions had already challenged the upper Apurímac, the Amazon's most remote branch. Two people had died. Boulder-strewn chutes and monster whirlpools tossed us like flotsam. Gigantic rocks rained from the 1,300-foot-high canyon walls. Often we couldn't stop to scout ahead. When we were sucked for nine days into the dark and savage gorge called the Acobamba Abyss—where Jerome Truran tested his skill (*left*)—we lived only on oatmeal, nerve, and a sense of survival. At night we could hear the sound of the churning river beside our tents, and I would dream of kayaking into a canyon and seeing a sudden 200-foot drop ahead. I would wake up in horror.

As a schoolboy in Poland, I had dreamed of seeing the Amazon. That became a reality in 1979, when I left with an official Polish expedition to conquer the rivers of South America. In December 1981, while we were in Peru, martial law was declared in Poland. In protest we led thousands of marchers in Lima to show support for the Solidarity movement. I couldn't go home after that.

In the summer of 1985 I joined an international crew of 12 for this expedition. Sponsoring us were two American businessmen, Jack Jourgensen and Bryce Anderson, and CANOANDES, a nonprofit organization based in my adopted hometown of Casper, Wyoming. Only four of us finished—photographer Zbigniew Bzdak, American writer Joe Kane, Kate Durrant, an English physician, and I.

We had to make a deal with the Amazon, to accept its power. The river, after all, makes the rules.

THE MIGHTY RIVER begins with a few icy drops of water from the Mount Mismi snowfield, 18,000 feet up on the spine of the Andes. For us it was a symbolic place, not far from the lake that Loren McIntyre named as the Amazon's source (***map***) on his 1971 National Geographic expedition. I carried the kayak up to place it at our beginning (***above***).

A closeness came over us here, and a feeling that we would make it. Six months was a long piece out of our lives, but I was not claustrophobic about time. The world would not disappear.

We had started on August 26, 1985, by truck from Arequipa, then trekked with full gear for three numbing days to the top of Mount Mismi. At night snow covered our tents, and we could feel our hearts beating wildly in the thin air. On that bare, uninhabited plateau, we felt as remote as astronauts in space.

Portages were frequent on the upper river, and the first 600 miles took half the time of our trip. At the end of a day-long, 400-yard detour, Jerome Truran and I slid a kayak down to the water (***right***). My helmet was essential for paddling safety. Despite such precautions, I broke my nose twice while rolling my kayak.

In 1968 a team had deemed the upper Apurímac unnavigable, but now the trip was possible because of new materials and improved techniques. Our 45-pound plastic kayaks are virtually unbreakable. Fold them in half, and they snap back. We would need a resilience equal to that of our boats.

Much of the upper river was blocked by rock slides, the water flowing beneath them. Sometimes we looked down canyons and saw only rocks. Lord! That's what finished off previous expeditions. They simply got out, left their equipment, and went home. We had to keep moving, to take that next step, or all would be lost. Delay now, and it would kill our spirit. Even those 400 yards were progress.

The Amazon

THE PACIFIC lies only 100 miles from Mount Mismi, source of the Apurímac. This Amazon headwater drops 13,600 feet in 310 miles, a gradient six times as steep as that of the Colorado River through the Grand Canyon. Gathering strength as it courses through the ancient land of the Incas, the stream is called the Tambo by the time it reaches Atalaya and the rain forest. Finally, as the Amazon, it surges into the Atlantic with a flow 60 times as great as the Nile's.

IN MARSHY HIGHLAND flats at 14,000 feet, well above timberline, rivulets from snowfields create the Río Hornillos (*left*), the beginning of the Apurímac. Joe Kane, Sergio Leon, a naturalist from Costa Rica, and Kate Durrant look back at Mount Mismi, just a bump in mid-horizon.

Here we found water six inches deep, enough to float our kayaks, and split into a kayaking team, a hiking team who would parallel the kayak route, and a two-man film crew in a Land-Rover, who would resupply us at strategic points.

About 75 miles from the source we paddled between walls of volcanic rock in one of the Apurímac's small gorges (*below*). The water was silty and turquoise with runoff from gold and silver mining. Alpacas and herds of sheep grazed on the plateau above. The first 90 miles served as a training run before the rough water began. We never saw rain, but nights were freezing, and we built fires of bunchgrass to keep warm.

In this remote landscape we still saw people, including this onlooker on the left bank. Some even recognized me as "El Polaco"—The Pole—from city newspapers that had written of me as the man who had navigated the great whitewater rivers of Peru.

Farther downriver, toward the Acobamba Abyss, we saw no one. In these elevations people rarely use the river. They don't know how to swim. The river to them is only an obstacle. They don't even like to sleep close to it, for the Indians believe that the water is an evil spirit.


BLAZER
AMAZON!

I MUST HAVE LOOKED like a man from Mars to a fisherman I surprised (***left***). He was too shocked to move. Fear was the usual reaction to us, especially among gold panners without permits. They would grab their equipment and run, even though—or perhaps because—police authority here was nonexistent.

"How far to Pillpinto?" I asked him in Spanish. He didn't understand distance, only time. "One day of walking," he answered. For us it would be an hour of easy paddling. He wanted to give us a trout for dinner, but it was midday, and we knew it would spoil.

We tried fishing ourselves, but with little luck. Later, when we were detained by a nervous band of Communist guerrillas, we gladly offered our only fishnet as toll for continuing safely.

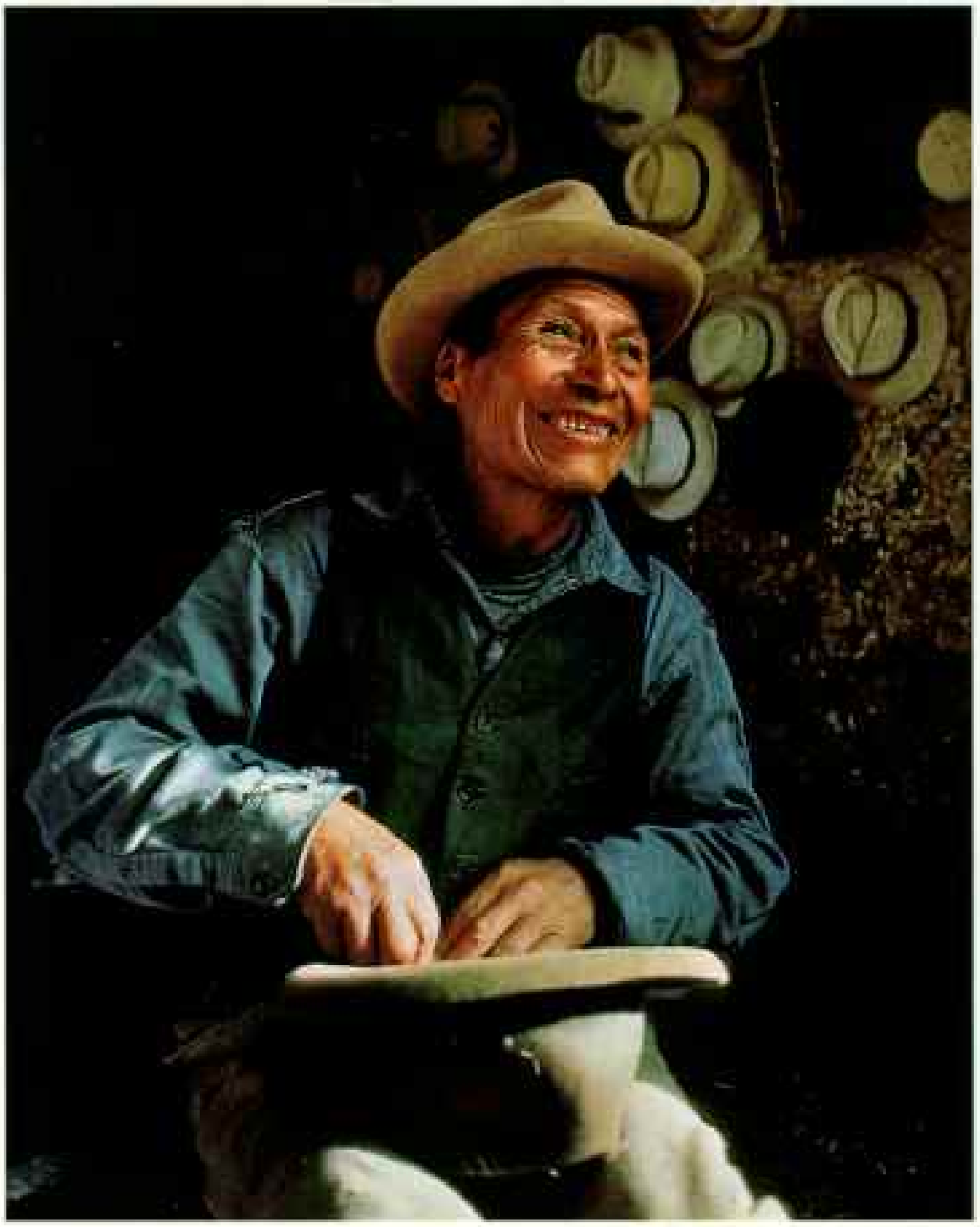
In small villages such as Huayque (***above***) the Indians spoke little Spanish. Even when we could speak with them, it was impossible to explain what we were doing. Always their first question was: "Do you look for gold? What? Passing through on the river and doing nothing? For what?" We had no answer that was reasonable to them.

They didn't know that these were the headwaters of the Amazon. They had never even been to the next village downstream. But travelers were treated like kin, and we were always offered *chicha*—the home-brewed beer—or coca leaves to chew.

WE FOUND living history near the village of Yauri, our first resupply point, at a folk festival in the ruins of an old Inca marketplace at Canamarca (***facing page***). Half of this dancer's costume is of Inca origin. Her felt hat is a legacy of the Spaniards, and her stringless *charango*, a small guitar, mere decoration. We were the only outsiders, but villagers were so absorbed in the festival that we were virtually ignored. They asked us, "Please, do not bother us with your cameras."

Downriver in the village of Accha (***above***) devilish bear figures posed for us during a raucous Roman Catholic festival. Lower in elevation and closer to Cuzco than Yauri, Accha has a mixture of Indians and mestizos and a more hybrid culture.

Nearly everyone in these parts wears a hat, which is good business for Antonio Farfan (***right***) in Acomayo.



IN A WORLD without wood, the Incas built bridges of grass so strong that the 16th-century Spanish conquistador Pizzaro could take even his cannon and horses across. Preserving such technology, the remarkable hanging bridge (***right***) between Yauri and San Juan is made of 22,000 feet of hand-spun grass rope, braided into cables, with a footing of twigs. Now the bridge is little used; its rope is replaced during a celebration every two years.

We had planned to meet team members here for resupply, but when the Land-Rover arrived the night before we did, our cameramen were driven out of their tents by villagers who demanded money and threw stones when they didn't pay.

The next day we walked into trouble. Local authorities demanded our papers, escorted us six miles inland, and placed us on a stone platform surrounded by a semicircle of 48 local chiefs. They were hostile: "What are you doing here? You cannot take pictures without our permission!" And they accused our cameramen of trying to attack the villagers.

It was tense, but through a Spanish interpreter I finally convinced the tribunal that they would be better off with more tourists who brought money, and that they could take pride in the river as the source of the Amazon. At the end they asked only for medical help. They had children with broken bones and women with headaches.

Dr. Kate Durrant (***above,*** at right) and I tried to aid a man whose elbow had been dislocated in childhood, but we knew it was not possible. The women with headaches were helped by aspirin, if only temporarily. Others with heels cracked open from working barefoot had long-term infections. They had been sewing the cracks together with needle and yarn. Kate gave them antiseptics.

People brought potatoes and corn to repay us, even a chicken. When we left them, we were good friends.

I ALMOST LOST MY HEAD coming through a chute near Pillpinto (***above***). I had broken my paddle on a submerged rock and couldn't right myself. It was a bad place to be, trapped under the circulating pressure of the whirlpool, with the water bouncing my head and arms over rocks. I grasped desperately for some leverage. This lasted perhaps ten seconds but felt like minutes. Jerome Truran pulled me upright. He was always at the right place with his kayak. It became routine to be saving each other's lives.

The rubber raft (***below***) was delivered by truck to Cuzco. At the beginning of the Acobamba Abyss we launched the boat to transport the hikers and extra gear through the canyon.

Fear stayed with us throughout this unnerving canyonland, where Jerome contemplated another unknown bend (***right***). The worst time was afternoon, when rocks fell from canyon walls heated by the sun. We would almost tiptoe on the portages, thinking: Where do I jump if a rock comes? It was like being under fire.

At Atalaya, below the abyss, this most treacherous part of our trip finally ended. We still had 3,600 miles to go, but now it would only take time and strength to finish. The expedition split here in November 1985. For some it had been adventure enough. Joe and I pushed on in the kayaks, while Kate and Zbigniew continued in motorized boats.

Here we were on the part of the river where people *use* boats: It had become a highway. For the next three months, we paddled our kayaks through brutal heat and storms. We reached the highway's end on February 19, 1986, when we tasted salt water in the open Atlantic. □

MITSUAKI IWAGO

Pushed to the brink of extinction by centuries of exploitation for furs and oil, pinnipeds–or "fin-feet"–have rebounded, thanks to their natural resilience. But new threats created by man's negligence pare away at some populations of

Seals and Their Kin

By ROGER L. GENTRY

With rasping growl, a southern elephant seal warns an intruder on the Kerguélen Islands in the Indian Ocean. These are the largest pinnipeds—amphibious mammals with paddle-like limbs that include seals, sea lions, and walruses.

Male walruses materialize from fog's soft focus at Cape Newenham, Alaska, in summer. Bottom feeders, walruses eat clams, crabs,

STEVE KAUFMAN

and worms that they ferret out with highly sensitive whiskers. Breeding occurs in winter, underwater amid ice floes.

Frosted by overnight snow, a Weddell seal rouses from sleep on a blanched Antarctic landscape. A plume of steam escapes Mount

MICHAEL CASTELLON

Erebus, an active volcano. Protected by their remote habitat, these seals have not been extensively hunted and do not fear man.

A harbor seal sprints by with an octopus off southern California's Channel Islands. Seals are rarely seen, much less photographed,

KENNETH HOWARD, EARTHVIEWS

while feeding. "It's probably the luckiest shot I've ever made," says the photographer. "I just turned, and there he was."

WITH EARSPLITTING BARKS aimed at our approaching boat, 200 sea lions rose from the beach on California's Año Nuevo Island.

A wave suddenly threatened to capsize us into the path of the animals, which were now racing toward us surprisingly fast for their 400-pound size.

In alarm I glanced around at my colleagues from the Stanford Research Institute. Unlike me, they were all experienced seal biologists. From their bored expressions I gathered I was the only one who realized we were about to be attacked and drowned.

I said something useful like "WUGH!" as the others unexpectedly vaulted into the surf. But instead of abandoning the boat, they only steadied it. To my surprise the closely packed throng of chocolate-colored animals divided neatly around the boat, surged past my friends' legs, and gathered in a raucous mob 20 feet offshore.

Panting from another routine landing, our leader and my new employer, Dr. Thomas Poulter, turned to me and said dryly: "If you're through resting now, would you mind just stepping out of the boat?"

I apologized later for being so useless during the landing. But as a new student of seal behavior I couldn't confess how badly I had misinterpreted the intentions of the first wild seals I had ever met.

That summer day in 1963 literally launched my career in seal biology. It introduced me to the first of 18 types of seals—about half the world's 34 species—that I have studied over the years. The quest has led me to New Zealand, the arid beaches of South Africa and Australia, and ultimately to Alaska and the vast Antarctic ice fields.

Wildlife biologist **Roger L. Gentry** has studied Hooker's sea lions in New Zealand under research grants from the Society.

FRANÇOIS GOHIER

On the rocks, *a harbor seal mother and pup sleep on a Monterey Peninsula shore. Harbor seals have a wide range, inhabiting both coasts of the North Atlantic and Pacific Oceans. Pups can swim almost immediately and sometimes must, if born during a high tide that submerges their shoreline birthplace.*

A quarter of a century may seem a long time to devote to such an esoteric pursuit. But seals are so diverse, so unusual in their life-styles, and breed in such amazing corners of the world that it is easy to be drawn back year after year.

It is not merely the mystique of seals that draws researchers on: The more we learn about seals, the more concerned we become for their welfare. Modern seals face many problems, not the least of which is recovery from near extermination by sealers over the past two centuries. And though most seal populations are healthy today, there is still cause for concern as they increasingly compete with man for food and suffer from man's abuse of the oceans. In facing these problems, the best ally seals can have is an educated human society.

One of the wonders of seals is the fact that they are amphibious. Generally speaking, they mate and give birth on land as most mammals do, but they feed at sea as whales do. Seals have webbed flippers modified to resemble paddles that can stroke independently. In fact, Pinnipedia—the name of the order that includes all seals—means "fin- or wing-footed."

Pinniped names are wonderfully confusing. To simplify them, I will use the catchall term "seal" for all pinnipeds. The order Pinnipedia contains three families: walruses, so-called true seals, and eared seals. (See the supplement chart **Pinnipeds Around the World**.) The last group includes sea lions and fur seals; named for their small but visible ears, they evolved from the same land ancestors that gave rise to dogs and bears.

True seals and eared seals differ in movement as well as appearance. True seals hunch caterpillar fashion on land and use their fishtail-like rear flippers for swimming. By contrast, eared seals use all four limbs for walking on land and ice and their front flippers for swimming. Walruses, which do not have visible ears, walk like eared seals but swim like true seals.

Until recently it was believed that true seals (so named because they were the first to be described by European scientists) developed about 15 million years ago on the shores of the northern Atlantic, and that modern eared seals appeared first in the northern Pacific during the heyday of the walrus, some 12 million years ago. As this is written, however, paleontologists are actively reevaluating old assumptions and studying new fossil evidence. Although final conclusions are not yet in, it may turn out that true seals originated in the northern Pacific along with eared seals, and some lines of evidence even suggest that walruses are more closely related to true seals than to eared seals.

There is no question that at least one early species of true seal found a home in the Pacific. It survives as the endangered Hawaiian monk seal, considered a "living fossil" because of its age. Other true seals spread north and south, eventually populating Arctic and Antarctic waters. Some even invaded freshwater lakes such as Baikal in the Soviet Union.

IT WAS THE RICHNESS and diversity of food in the oceans that allowed seals to spread and multiply. Today's pinnipeds eat a variety of fish and invertebrates. There are also some specialists, like the crabeater seal, whose name is misleading because it actually eats small shrimplike crustaceans known as krill.

Some seals eat seabirds. A group of friends and I were once crossing Arthur Harbor on the Antarctic Peninsula in a whaleboat when suddenly an Adélie penguin burst from the water like a Polaris missile and landed in the back of our boat. It ran squawking to the highest point of our bow, then turned toward us, panting, with blood streaming down its white breast. Silently a leopard seal surfaced where the penguin had left the water and intently followed us. We were amazed that the bird, which later died, could ever have escaped that huge mouth.

Leopard seals, walruses, and some sea lions eat other seals. At St. George Island, Alaska, Steller sea lions kill and eat as many as 6 percent of all the northern fur seal pups born each year.

On tiny Enderby Island in New Zealand's Auckland Islands group, marine mammal biologist Martin Cawthorn had a far different introduction to pinnipeds from mine. He had come to study the female Hooker's sea lion. "There were no females on shore when I first arrived," he told me, "so I lay down on the grass to observe the males. Soon a lone

adult female emerged from the surf, looked around, and headed straight for me. She sniffed along my leg, then snuggled into the curve of my body and fell asleep. So did I, after counting her pulse and breathing rate."

Whether seals fear humans or tolerate them is probably traceable to their history with land predators. Those such as the Arctic ringed seal that have been preyed upon by land animals treat man as an enemy. Others view man as an object of curiosity.

But not all seal behavior is determined by whether they have faced land predators. A woman once asked me if it was true, as she had read, that harp seal females nurse their pups for only six weeks. When I told her it was more like ten days, she was skeptical. "I'm sure they are better mothers than *that!*" she exclaimed.

The lady was a victim of her human heritage—maternal love has little influence on how seals nurse. Ancestry is a key. For example, eared seal mothers alternate between feeding themselves at sea and nursing their young on shore. But true seal females store up great layers of fat before giving birth, then transfer the fat to their pups as incredibly rich milk. Unlike eared seals, true seal mothers seldom leave their pups to feed until they are weaned.

SEALS ARE QUITE LARGE, as mammals go. Adults range in weight from the 85-pound female ringed seal to the 8,500-pound southern elephant seal male. Large body size helps seals stay warm in cold oceans.

In some species males grow to four times the weight of females. Greater size may give these males an advantage in breeding by helping them to remain on shore longer. Larger males store more fat, which provides the fuel and water for long fasts. Northern fur seal males in Alaska weigh an average of 450 pounds and can abstain from food and water for 70 days.

Most seals are long-lived, attaining 20 years or more. This longevity, combined with short breeding seasons, makes it hard for scientists to learn much about individuals in only one season. It often takes years to understand even the basics of seal biology. And those years in the field are seldom comfortable. Summers are rarely warm,

TOM BLEDSOE, DRK PHOTO (FACING PAGE); KENNAN WARD (ABOVE)

JOHN W. MATTHEWS, DRK PHOTO

Wall-to-wall walruses *carpet Alaska's Round Island, where males congregate in summer (**facing page**). They spend several days on beaches like one at the island's north end (**top**), then leave en masse to feed. Valuable ivory tusks await the carvers' tools on a Bering Strait beach (**above**). For native peoples the harvest is unlimited; they took some 3,000 last year. While walruses face no immediate threat, limitless kills could have future repercussions.*

and breeding areas are often too dangerous for a researcher's family to go along. Every May as I leave home my daughters, Erin, 11, and Alison, 8, ask wistfully, "Dad, can't you find a different job?"

To understand seal behavior, it helps to forget how we ourselves behave. Seals act toward each other like humans that never meet a friend; that is, they are formal. Even in dense groups seals do not form social bonds except with their own young. Each animal acts on its own behalf, and for its own benefit. Thus, seals simply don't have the behavioral means to mount a group attack of the kind I feared from those male California sea lions on Año Nuevo Island.

But that is not to say that individuals will not bite. They will, and from a tender age. Of the six species that have bitten me, a 400-pound northern elephant seal pup was the most impressive. It seized my left forearm and, with a completely benign look on its face, bit down with nearly bone-crushing pressure. Fortunately, I escaped with only a large cut.

Within the same species, seals bite each other too, but only under special circumstances and usually at breeding season. Most disputes among male pinnipeds are resolved by ceremonial threats, not by fighting. Ceremonial or not, the threat of harm is real. Several times during my studies of Steller sea lions at Año Nuevo, one-ton males thrust their huge heads through the window of my blind to threaten me as a suspected rival. I usually decided I had collected enough data for the day and left by the back door.

SEALS will not produce pups just anywhere; the areas are very specific. This is especially true for species that migrate long distances to mate. Female northern fur seals, for example, give birth within about ten yards of the same spot year after year, many on the site of their own birth. Female seals usually bear only one pup at a time, probably because the young must be fairly large to survive the cold oceans. Besides, feeding one large pup is all most mothers can manage.

Females normally mate only a few days after giving birth. Technically they are pregnant 12 months of the year, but development of the fertilized egg temporarily halts after about a week. For three or four months it floats around the uterus before implanting

FLIP NICKLIN (LEFT); MICHAEL CASTELLINI

Playing fetch, *a California sea lion clamps a retrieval line onto a dummy missile as part of the U. S. Navy's Quick Find program* ***(left)****. The animals can recover objects more safely and economically than can divers or mechanical submersibles. Biologists approach a Weddell seal* ***(above)*** *at McMurdo Station, Antarctica, to immobilize it with a hood and remove an instrument that has recorded its dives.*

in the uterine wall, where development resumes. An eight- or nine-month active gestation period follows, assuring birth at the right season.

Unlike dogs and cats, seal young are not helpless at birth. They sometimes have their eyes open, and their rubbery flippers flailing wildly, before they are completely out of the birth canal. Most seals can swim on the day of their birth.

Pups start life well equipped with inherited behavior, probably because they don't stay long with their mothers and never form long-lasting groups or packs where they could learn proper behavior. They therefore have no need for—and little opportunity to learn—complex ways of relating to others.

Seals are not the top predators in the oceans; they, too, have enemies, especially sharks and killer whales. My colleague Dr. Burney Le Boeuf, of the University of California at Santa Cruz, graphically describes dissecting a white shark that washed up near Año Nuevo Island.

"We opened its stomach," Burney says, "and found part of a young elephant seal inside in really big chunks. It was so fresh the seal still had all its hair. The head had been completely severed from the body, and, because its eyes were closed, it had a serene look on its face, like a statue of Buddha."

WHEN WE HUMANS try to free-dive in cold water without a face mask, we sense the problems that must have confronted the terrestrial ancestors of pinnipeds. Underwater we are nearsighted, hard of hearing, and cold, and most of us can dive to 30 feet only with pain and difficulty.

But seals have solved all these problems. In dim light, thanks to their large eyes, they see better underwater than humans do in air. Their sharp vision is essential for finding food at great depths.

Nor is the undersea world of seals a silent one. Some seals make clicking sounds like those of a thumbnail drawn across the teeth

of a comb. Other seals make long sweeping trills, and walruses sometimes gong like church bells. We know that seals can discriminate among sounds four times higher in pitch than humans can, and they can locate sounds well. Whether wild seals use echolocation, however, is still an open question.

Because seals dive far deeper than we do, we would expect that their physiology would have many unique properties. But after working on diving physiology of seals for years, my friend Dr. Gerald Kooyman, of Scripps Institution of Oceanography in La Jolla, concludes otherwise. "Seals have no traits for diving that are totally unique among mammals," Gerry says. "They've only exaggerated a few traits that other mammals, man included, already have."

One of these traits is the need for oxygen by muscles in order to function. Half of a seal's required oxygen on a dive is stored in myoglobin, a pigment similar to hemoglobin, that makes seals' muscles almost black.

Seal meat's dark color and gamy flavor don't prevent its being eaten by many peoples of the world. Even the British, with their traditional love of beef, have learned to appreciate seal meat. At one of their Antarctic research bases I was given a wonderfully funny cookbook with a chapter on the gourmet cooking of seal meat. It particularly praised "Tournados of Seal Portugaise," and claimed seal brains to be a true delicacy of the Antarctic.

When seals dive, they stop breathing. For very deep dives they conserve their oxygen stores by stopping or slowing blood circulation to all but critical organs. They can also slow their heart rate, sometimes to a mere 10 percent of the rate at the surface.

Man shares some of these same traits. Reduced heart rate and slowed circulation along with lowered body temperature and holding the breath are all involved when people survive accidental submersion in very cold water for as long as half an hour.

But how do diving seals avoid the bends, the condition caused when nitrogen that has been dissolved in the blood under pressure suddenly forms bubbles as the pressure decreases? According to Dr. Sam Ridgway, physiologist with the U. S. Naval Ocean Systems Center in San Diego, seals avoid the bends by not absorbing nitrogen in the first place. "The lungs of marine mammals," Dr. Ridgway explains, "are designed to collapse under the pressures exerted on deep dives. Air from the collapsed lungs is forced back into the animal's windpipe, where the nitrogen simply can't be absorbed by the blood."

BOB SLOAN (LEFT); MICHAEL GOSSOW

Deadly net *proved fatal to a California sea lion (**left**). Fishing gear kills many pinnipeds, but statistics are unreliable. Animals drown, never to be found; some work loose, only to be snared again. Five snared seal pups (**above**) washed ashore on the Pribilof Islands. A biologist found, photographed, and released them.*

FOR ALL THE HARDSHIPS involved in the study of seals, we researchers have occasional moments of pure exhilaration over some new idea or discovery. One of those moments came for me in 1975, when Gerry Kooyman and I recovered a dive instrument we had sent to sea on a female northern fur seal. It was a simple mechanical instrument that scratched a line on a moving strip of paper to record changing depth. Until that time most of what was known of fur seals at sea was learned from animals that had been shot. Gerry's new instrument had been attached to the seal for a week, and we weren't sure it would work.

The great day came when Gerry retrieved the instrument *(Continued on page 494)*

Snitching a free lunch, *South African fur seals surround a trawl net bulging with hake. Fishermen blame seals for reduced catches. Such claims are unproven, but fishermen remain convinced. Attempts to deter seals by playing recordings*

ROD THOMAS

of killer whale sounds have met with little success, and the practice of scaring them away with explosives has been outlawed. Shooting seals is illegal, but frustrated fishermen often shoot anyway.

ALL BY JEFF FOOTT

Targeted: *A sea lion pup is the unwary victim of a killer whale off a sharply sloping beach in Patagonia (**left**). A similar episode ended in the death of a southern elephant seal (**top** and **above**) by a killer whale that flung itself onto the beach to capture its prey. The whale waited for successive waves to help turn itself around and then wriggled back into the water. Sharks also claim seals. Sea lions, leopard seals, and walruses feed on seal pups. Terrestrial predators include polar bears, which take ringed, harp, and hooded seals in the Arctic, and jackals, which kill South African fur seal pups in Namibia.*

from the apparently unconcerned female. Four of us crowded around him. With hands shaking, Gerry opened the instrument case.

"Look at that!" he croaked, in a voice strained with excitement. There, in a faint trace on the paper strip, was a line representing hundreds of dives, many to 300 feet or more. It was hard to grasp the significance of the event. This hundred-pound female fur seal was routinely diving at least ten times deeper than most humans can. But more important, the diving instrument worked. We had a new tool for measuring what seals do at sea.

Thanks to Gerry's instrument, and to new ones since, we have learned more about the diving ability of seals in the wild during the past decade than in all the years before. Using such instruments, Gerry and I, along with a dozen colleagues, have recently compared diving in fur seals worldwide. We've found that they are fast divers: Animals weighing 100 pounds can go to 600 feet and back in five minutes or less. Gerry's conclusion: "Seals are a lot better athletes than most people realize."

Further research has taught us a great deal more. Generally, the larger the seal the deeper it can dive. A 240-pound Hooker's sea lion female at Enderby Island dived repeatedly to 1,400 feet. A Weddell seal dived to 1,900 feet, and a northern elephant seal was recorded at an incredible 2,900 feet by Burney Le Boeuf. There are probably species of whales and porpoises that do not dive to such a depth.

It appears that seals expend the least possible effort when feeding. They can usually find food at less than their maximum depth. Fur seals normally feed on fish or krill at less than 300 feet, Hooker's sea lions feed on squid at about 600 feet, and northern elephant seals feed, possibly on ratfish, at around 1,500 feet.

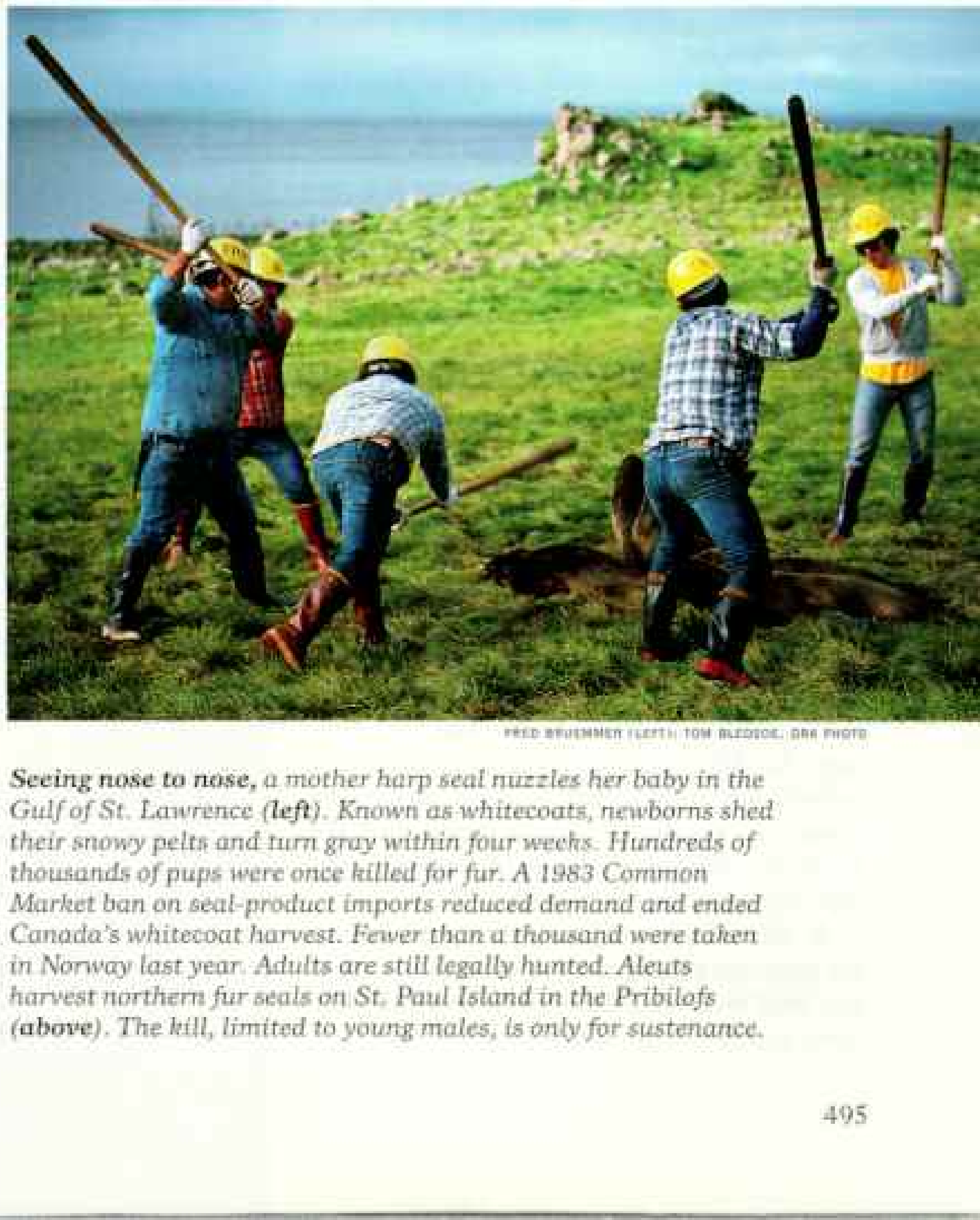
Stupid predators do not last long. Pinnipeds have evolved a high level of intelligence, in part because their prey are hard to find. Psychologist Dr. Ronald Schusterman, of the University of California at Santa Cruz, has studied sea lions' learning abilities for many years. "They can perform complex learning tasks that only the highest mammals, such as apes and dolphins, can perform," he says.

Dr. Schusterman recently demonstrated that sea lions have the conceptual skills necessary to learn an artificial language. After an animal has learned words and signals for objects and actions, it can carry out very complex commands, such as: Take the large white cube over to the small black ball. Sea lions can follow such commands without practice, even when as many as ten such objects are involved. In short, pinnipeds, like porpoises, are able to comprehend a simplified human language.

SKIN LOSES HEAT many times faster to water than to air. To retard this heat loss while they are in water, seals, like whales, have developed blubber, a special dense form of fat that insulates the body core. To lose heat, seals flush warm blood into their normally cool flippers, like a radiator.

Ironically the fur and blubber that allow seals to survive in the cold seas very nearly led to the extermination of some of them. Seal oil for lamps and pelts for leather or furs set off large-scale commercial hunting in the 18th and 19th centuries—the darkest years in seal history.

Humans have killed seals for food since Stone Age times, judging from ancient seal clubs and bones found along Denmark's Kattegat strait. But the advent of fast sailing vessels and later steamships capable of penetrating ice packs opened up the most remote seal haunts. In their shortsighted



FRED BRUEMMER (LEFT); TOM BLEDSOE, DRK PHOTO

Seeing nose to nose, *a mother harp seal nuzzles her baby in the Gulf of St. Lawrence* ***(left)****. Known as whitecoats, newborns shed their snowy pelts and turn gray within four weeks. Hundreds of thousands of pups were once killed for fur. A 1983 Common Market ban on seal-product imports reduced demand and ended Canada's whitecoat harvest. Fewer than a thousand were taken in Norway last year. Adults are still legally hunted. Aleuts harvest northern fur seals on St. Paul Island in the Pribilofs* ***(above)****. The kill, limited to young males, is only for sustenance.*

Lounging room only: *Northern elephant seals and smaller California sea lions share limited space* ***(below right)*** *in the Farallon Islands off California. On the mainland tourists visit Año Nuevo State Reserve's growing elephant seal population to observe behavior such as two males fighting* ***(far right)****. By 1890 fewer than a hundred elephant seals remained. With hunting suspended, the seals proliferated and now number about 100,000. Violent battles between males* ***(right)*** *occur at territorial boundaries or near females. Usually losers signal submission and leave.*

greed, early sealers killed all they could find, with little thought of species survival or even continuing profit.

Walruses and true seals, such as the harp and hooded, sustained the first major slaughter, largely for ivory, oil, and skins. Both northern and southern elephant seals were killed for oil.

When an efficient way was found in the 1800s to rid fur seal hides of their outer guard hair, leaving only the soft, durable underfur, millions of those animals were slaughtered for garments. The trade was enormously lucrative: Revenues from northern fur seal skins equaled the entire Alaska purchase price—$7,200,000—in less than six years. Elsewhere some of the world's largest fur seal colonies, such as that of the South Shetland Islands, were virtually exterminated in only four years.

Not even sea lions escaped the slaughter. Steller sea lions in California were killed in part because their 16-inch-long whiskers proved ideal for cleaning opium pipes.

The era of unregulated seal killing ended when populations became "economically extinct"—that is, no longer profitable enough to hunt—in the mid to late 19th century. Luckily this happened before the last individuals were killed, and no species we know of actually became extinct. But the Juan Fernández, Galápagos, and Guadalupe fur seals very nearly did.

At least a hundred years have passed since the heaviest killing of most seals. Today species that were reduced are recovering, and most species are now healthy.

PEARS LANTING (BELOW); KEENAN WARD

On a worldwide scale only two species, the Mediterranean and Hawaiian monk seals, are in danger of becoming extinct in the foreseeable future. The Hawaiian species' prognosis is the better of the two. There has not been a confirmed sighting of a close relative, the Caribbean monk seal, since 1952, and it may already have succumbed.

But large-scale sealing is no longer a threat to most pinnipeds. Even the harp seal kill in Canada, Greenland, and Norway has been much reduced; about 60,000 are taken each year, down from the 350,000 in 1963. Increasing costs and growing repugnance toward wearing furs have finally put the era of massive killing behind us.

For the Pacific walrus there is still concern about modern harvesting. In 1986 10,000 to 12,000 animals were killed by Alaska natives and Soviet harvesters. The size of the kill has been increasing and may now be more than the slowly reproducing walrus can sustain.

PETER JOHNSON

Five times as heavy *as the female he mates with, a male South African fur seal shows the size differential between sexes. A bull may mate with 30 females during the summer breeding season.*

UNFORTUNATELY the end of unregulated seal killing did not end conflicts between seals and man. Today's problems are far more pervasive and complex. No one knows, for example, why the northern fur seal and Steller sea lion have recently declined, and many scientists are concerned.

A major problem facing seals is the overlap of their ranges with those of commercial fisheries. A comprehensive study in California showed that this overlap cost the combined fisheries $600,000 and took the lives of about 2,200 seals in a single year, mostly California sea lions and harbor seals. But this is a rare study. The cost is so great and the issues so complex that most jurisdictions have not tried to repeat it.

One difficulty is that we don't always know what or how much seals eat or, equally important, what they pass up. In the absence of this information seals are sometimes used as scapegoats to explain declining fishery catches. Years ago some Oregon salmon fishermen complained to a state game warden that a large Steller sea lion at a river mouth was eating spawning salmon. When the animal was shot, its stomach was found to be full—not of salmon but of lamprey eels, known salmon predators.

Fish is one issue, fishing gear another. According to Dr. Riki Ott, a biologist and gillnetter in Alaska's salmon industry, damage to nets caused by sea lions, especially, results in a twofold cost. "First," she told me, "it takes time and money to repair the nets, and, second, repair time means less fishing time where seasons are already short."

Fishermen have mixed feelings toward other seals, and can even appreciate them as fellow fishermen. "Harbor seals," Dr. Ott told me, "usually pick fish cleanly out of nets. But fishermen, after all, are businessmen, and they'll treat any serious conflict as a business matter."

According to a 1972 U. S. law, if a seal species becomes depleted, then any fishery that takes them accidentally could be fined. Thus, seal conservation is in the best interests of fishermen if they wish to preserve their own livelihood.

Sea lions and harbor seals are the most likely pinnipeds to drown in fishing nets. Perhaps the most alarming case of drowning is the loss of rare Hooker's sea lions in squid trawls off New Zealand. Of the world's 5,000 Hooker's sea lions, 75 females were accidentally drowned in a single year.

Another modern specter is the problem of entanglement in marine debris, both floating and submerged. Fishing nets, monofilament lines, plastic strapping rings, even plastic six-pack bottle and can holders in the ocean end up around the necks of seals and undoubtedly kill some in a horrible way. The question is how many?

Knowing the real entanglement rate of any species is nearly impossible. An unknown number may become entangled and die at sea without being counted by researchers. On the other hand, as many as 50 percent of tagged northern fur seals that had nets around their necks lost the nets within a year. One returned with a green net one year and a gray net the next.

Chemical pollution of the oceans is another problem for pinnipeds. Being near the top of the food chain, they tend to concentrate pollutants in their tissues. Pesticide residues have even been found in the blubber of seals in remote Antarctica. The biological effects of such contamination are not entirely known.

THE REAL ESSENCE of modern problems facing pinnipeds is that we can't measure well any single factor that affects their survival. At the same time we have yet to measure the negative and positive impacts that seals have on fisheries. Where do we begin the process of rational problem solving?

Our solutions are limited by the fact that we can take no direct actions to stimulate population growth in pinnipeds. Females almost always produce only one pup a year. The best we can do is leave them alone, reduce man's impact on the oceans where possible, and try to keep seal populations from declining. A healthy seal population may be able to maintain constant numbers in the face of entanglement, pollution, and competition with fisheries. But it may be impossible for a reduced seal population to recover in the face of such hazards.

Hunkered down *in damp sand to cool off, a monk seal naps in the Northwestern Hawaiian Islands. Some 1,400 live here, but human disturbance and sharks take a toll, and extinction is possible.*

FRANS LANTING

Reducing ocean pollution and the loss of fishing gear are obvious ways to help pinnipeds and other wildlife. A 1972 treaty on ocean dumping is in effect, but it concerns chemical pollution more than floating fishing debris.

Several current international treaties also aid the conservation of seals. Unfortunately one of the oldest of these, concerning the northern fur seal—which must be ratified periodically—was not renewed last time by the United States. Animal protection groups and the Aleut people of the Pribilof Islands argue over the taking of seals and the sale of their pelts and "seal sticks," or penis bones, which are thought by some Asian cultures to be aphrodisiacs. Until the two groups agree, re-ratification of the fur seal treaty is stalled, and the seals are declining at an alarming rate.

The conflict between seals and fisheries can be resolved by getting more information about the numbers and ecological role of pinnipeds and by educating fishermen about these findings. Without new information and public participation, no consensus will be reached on seal management.

Much of the information we need about pinniped diet and foraging behavior will come from instruments. Even simple mechanical recorders can show how deep, how often, and at what times of day seals dive for

food. These simple measures, applied over time, should provide an index of the amount of food available to seals.

With these recorders Martin Cawthorn, Wendy Roberts, and I, jointly sponsored by the National Geographic Society and the U. S. and New Zealand governments, have been measuring the foraging behavior of Hooker's sea lions at New Zealand's Enderby Island. If we can determine how far offshore and how deep these sea lions feed, perhaps the squid fishery there can be geographically limited to reduce the accidental killing of these rare animals.

Still newer instruments promise even more useful information. With microprocessors that are in effect small submersible computers, we can record not just diving behavior but also virtually any action or process that can be converted to an electronic signal. Already these units are recording seal heart rate and swim speed. The instruments can collect blood samples during dives for physiological measurements. It will soon be possible to determine water temperature and salinity where seals feed and migrate. The small size of these instruments will allow us to collect data on any seal, young or old.

In the not too distant future the locations of seals at sea will be routinely correlated with satellite images of ocean surface temperatures and other features.

Ironically research funds for pinniped studies have been decreasing at a time when new technology promises the most fruitful results ever obtainable. To get funds, many researchers have had to justify their pinniped work in terms of fisheries, rather than on its own merit.

WE CAN EXPECT conflicts to occur between seals and fishermen as long as both exist. These problems can be mitigated somewhat by education, legislation, and more treaties for research and conservation. International treaties already in effect could serve as models for others.

Most seal species are resilient enough to accommodate slow changes in their environment. As long as man's influence on the oceans doesn't escalate rapidly, seals will continue to thrive. Seals existed in balance with their prey for millions of years before man arrived on the seas; they can do so again if they are allowed to.

*A logjam of elephant seals crowds Año Nuevo Island (**facing page**). Elsewhere on the island a pup peers over an ice plant (**below**). Although natural survivors, seals remain vulnerable where their interests conflict with man's.*

FRANS LANTING (FACING PAGE); KENNAN WARD

Pinnipeds have begun to act as a portal for viewing the oceans. Instruments have begun to show how seals forage and move in the seas. These same instruments, speaking through satellites, can also tell us more about the oceans and about those properties in them that control the lives of both seals and whales.

No matter how much one knows about seals, they leave us with a profound sense of wonder. Anyone who has huddled in 75-mile-an-hour winds watching baby seals actually playing in 15-foot surf knows that feeling. And those lucky enough to see seals thriving in frozen polar expanses or flying with birdlike grace underwater certainly feel it. Our unspoken response is always "How do they do that?" Even though, technically, we come closer to answering that question each year, our sense of wonder still remains. □

AIR

AN ATMOSPHERE OF UNCERTAINTY

By NOEL GROVE
NATIONAL GEOGRAPHIC SENIOR WRITER

Photographs by TED SPIEGEL
BLACK STAR

Paintings by WILLIAM H. BOND
NATIONAL GEOGRAPHIC ARTIST

Thick with sulfur dioxide, smoke belches from the 550-foot stacks of the Phelps Dodge copper smelter in Douglas, Arizona. Too old to be profitably tamed by anti-pollution devices, the 85-year-old plant was closed in January. It was a victory for environmentalists (left) who had long protested the smelter's operation. Solutions to other air-pollution problems are not so clear.

A DEATH brought a nightmare to life for me, the kind that is difficult to flee. Most of us have dreamed of running from some awful dread, on feet that seem encased in leaden shoes.

I was watching a pathologist perform an autopsy on a man who had drowned at Newburgh, New York. The lungs, when exposed, were blotchy with stiff dark spots.

"Ah," I observed, "a smoker."

"Not necessarily," said soft-spoken Dr. Torrence Payne, as he continued unhurried incisions. "Those are deposits of carbon. Virtually everyone has lungs like that after their mid-40s if they've lived in or near an urban area."

Another dying, far distant, drove the nightmare home. Germans call it *Waldsterben*, or forest dying, in which conifers weep needles and beeches grow bald with premature aging. In January I stood on a snow-covered slope east of Cologne and looked at Norway spruces with skeletal outlines.

"Normally they shed old needles after seven years, but look at this one," said green-coated forester Dieter Deumling, pointing to an anemic specimen as we crunched across deep snow to a low, barren branch.

According to West German scientists, the trees are being stressed by air pollution. Perhaps by sulfurous clouds from power-generating smokestacks. By the breath of automobile exhausts and metallic compounds drifting from a smelter. By all of these and more, coming sometimes from hundreds of miles away and, like the carbon in human lungs, having a cumulative effect. Forests are afflicted not only in central and eastern Europe but also in Norway, Sweden, the United States, and Canada. Scientists debate the role of pollution in killing trees—how it works in conjunction with onslaughts of insects, disease, or climate changes. Most agree, however, that airborne pollutants play a significant role.

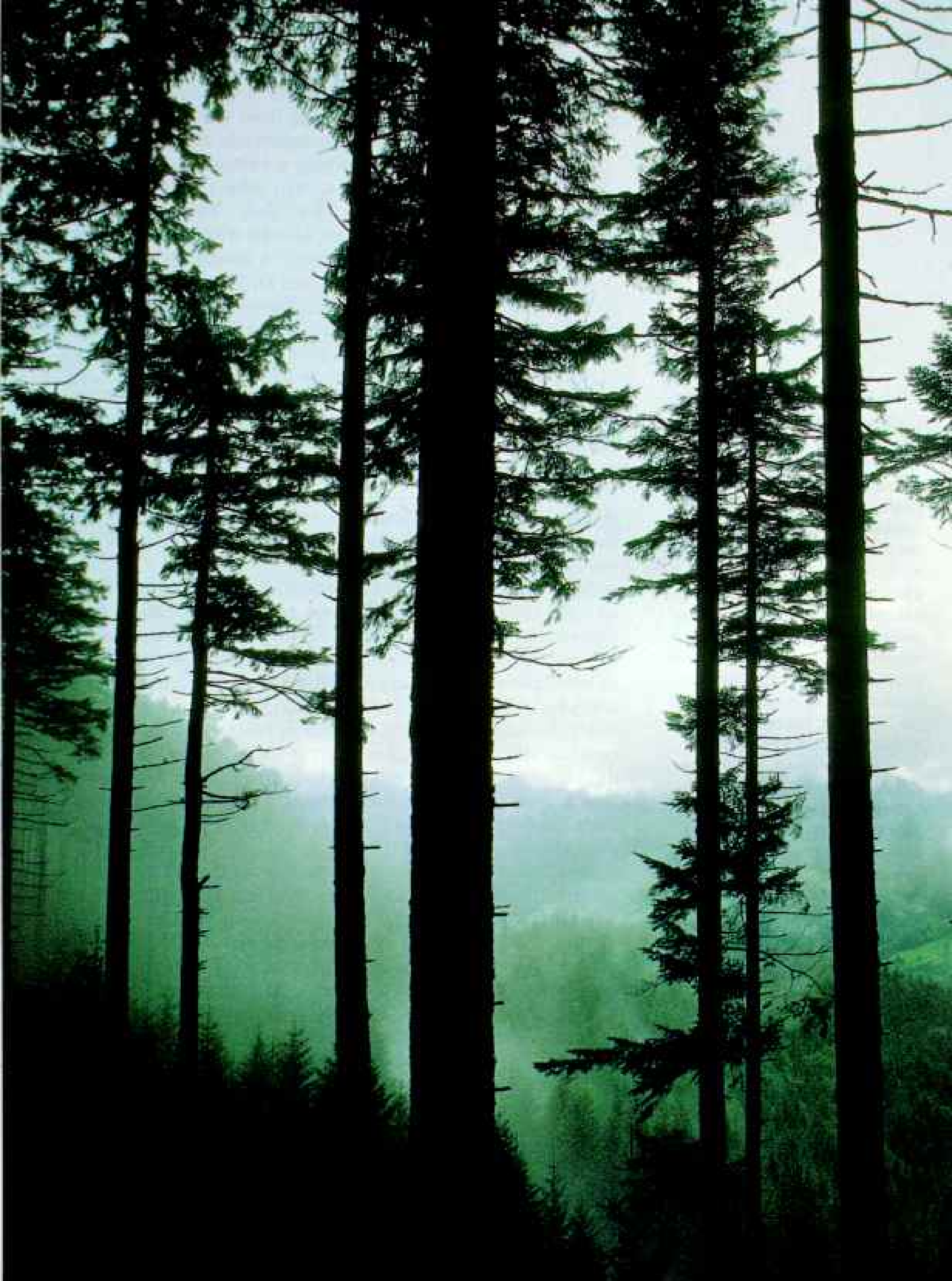
In other areas dirty air is held even more culpable. Man-made monuments that have endured for thousands of years are now being rapidly eaten away. In the American West spectacular vistas are fading behind an aerosol haze. Ozone resulting from automobile emissions annually reduces crop yields significantly, sometimes by as much as 20 percent of the soybean harvest.

What is not known about air pollution may be even more disturbing. We are in the midst of a chemical revolution in which some 65,000 commercial compounds enter our environment each year. Some are proven carcinogens—cancer-causing substances—and many more are suspected of being so. Yet only eight chemicals are listed as hazardous and are regulated at their source by the U. S. Environmental Protection Agency (EPA).

In a quiet valley near California's coast I watched a protest rally unfold in a school yard that has been emptied several times by nauseating fumes. A mile and a half north of the little town of Casmalia, population about 200, a toxic waste dump lies hidden by rolling foothills. For several years cast-off cyanide, oil-field acids, and industrial solvents were hauled there and left in open lagoons to evaporate. Local residents began complaining of

With no place to hide, boys in Cubatão, Brazil, cover their faces as they try to avoid breathing a cloud of lung-searing fumes from a fertilizer plant. Called the "valley of death" by residents, Cubatão may be the most polluted community on earth. Scores of plants including a petrochemical complex pump at least 75 pollutants into its frequently stagnant air, raising contamination levels in parts of town to twice those considered safe for humans. "Some days it is so bad you can't breathe," says one resident. "If you go outside, you will vomit."

During the past two years, São Paulo state health officials report major reductions in particulates and other pollutants. But globally, new threats appear as fast as known pollutants are reduced. Deadly dioxins and other toxics, identified in some fish in the Great Lakes, are believed transported by air over great distances. Pesticides and herbicides found recently in alarmingly high concentrations in fog have been added to the list of potential culprits in forest dieback.



Trees are dying in West Germany's Black Forest. The needles of firs, spruces, and pines are turning yellow and falling off, leaving thin, scruffy crowns (left). Among the possible causes: oxides of sulfur and nitrogen from distant power plants and factories, nitrogen oxides from motor vehicles, and ozone from the interaction of airborne chemicals in sunlight. These and other pollutants may damage the needles' cell membranes, allowing nutrients to escape. They may also acidify the soil, destroying organisms necessary to the nutrient cycle, as well as injuring the trees' fine root systems. Weakened trees become more vulnerable to drought, frost, fungi, and insects.

At a research center in Essen-Kettwig (above), visiting American scientists inspect damage to trees exposed to ozone and acidic fog under controlled conditions in the chambers in the background. Tests so far have found no simple cures. Says the mayor of one Black Forest village: "There is no reason for optimism."

A filthy haze chokes Mexico City on a winter morning in 1986 (below). Vehicle exhaust, factory smoke, and smoldering refuse heaps befoul the air inhaled by 17 million people. Breathing this air has been compared to smoking two packs of cigarettes a day.

By contrast, the sky was clear in September 1985 (right) when winds washed out the city's vast bowl-shaped valley. Even the peaks of nearby volcanoes were visible—a cause for celebration.

noxious smells and respiratory problems. Soon all unusual ailments loomed large in the community's consciousness—nosebleeds, chronic diarrhea, a baby's birth defect, a young teacher's death by leukemia.

"On November 25, 1985, I had a metallic taste in my mouth and a queasy stomach," said Ken McCalip, principal of the two-teacher Casmalia Elementary School. "The other teacher told me she was too sick to teach. We dismissed for the day."

"When the wind died and the fumes lingered in town, it kept us like prisoners in our homes," said Debra Vaudrin, who later fled with her family.

BOTH BY GUILLERMO ALDANA E.

The county health office urged closing the dump. "Though we have no definitive proof that it is harmful," an official told me, "we also don't have proof that it is not."

Dumping of liquid wastes was stopped, but the solids continued. Casmalia residents believed the county supervisors were reluctant to give up revenue—nearly three million dollars annually—received in fees from the dump. The supervisors answered that state law preempted them from closing it over a health issue. I called the director of state health services, Dr. Kenneth Kizer, who said, "Nobody wants toxic wastes nearby, but we have a limited number of sites in which to dispose of them. Until we get additional sites, we'll have to base our decision on the information we gather."

This past January Dr. Kizer's department decided that the dump posed no imminent danger to citizens and would remain open, although more closely monitored. "Clearly there have been problems," Dr. Kizer said, "but we need more information before closing the dump."

WHERE OUR AIR is concerned, in Casmalia as in the rest of the world, we live in an age of uncertainty. As damage from our aerial soup concerns us more and more, an alarmed public clamors for answers and action. Both are slow in coming.

For example, the Carcinogen Assessment Group (CAG), an arm of EPA, was formed in 1976 to determine what chemical substances pose high cancer risks. Out of the thousands of commercial substances released to the atmosphere, "we've reviewed the data on about 200 of them," said Dr. Roy E. Albert, former CAG chairman, "those that have been identified as possibly carcinogenic and worthy of further study."

His voice grew steely: "The record of EPA regulation is abysmal. But research is expensive, and the funding we are now getting for research is inadequate."

Yet the air pollution picture is not totally bleak. Continuing research offers some hope of improvement. In late 1986 two scientists reported a chemical process capable of eliminating nitrogen oxides from diesel exhaust gases and coal-fired boilers. The hot gases, passed over a nontoxic chemical

A deadly soup

RARELY *does a city suffer from just a few air pollutants. Most, like this symbolic U. S. metropolis (below), generate a complex brew. Some chemicals (black labels) are emitted directly from identifiable sources. Others (red labels) are formed indirectly through photochemical reactions in the air. A glossary of major pollutants follows (right).*

What worries protestors demonstrating at Casmalia, California (facing page), is what they don't know. They suspect that a nearby toxic dump has flooded the town with hazardous fumes, causing headaches, scratchy eyes, and nausea.

As (arsenic): *from coal and oil furnaces, glass manufacturing; long-term exposure may cause lung and skin cancer.*

C_6H_6 (benzene): *from refineries, motor vehicles; long-term exposure may cause leukemia.*

Cd (cadmium): *from smelters, burning waste, coal and oil furnaces; long-term exposure damages kidneys and lungs, weakens bones.*

Cl_2 (chlorine): *from chemical industries; forms HCl; irritates mucous membranes.*

CO (carbon monoxide): *from motor vehicles, coal and oil furnaces, smelters, steel plants; starves body of oxygen; damages heart.*

F^- (fluoride ion): *from smelters, steel plants; high concentrations mottle children's teeth.*

HC (hydrocarbons): *from unburned gasoline vapors; combine with nitrogen oxides in sunlight to form smog.*

HCHO (formaldehyde): *from motor vehicles, chemical plants; irritates eyes, nose.*

HCl (hydrogen chloride): *from incinerators; irritates eyes, lungs.*

HF (hydrogen fluoride): *from fertilizer plants, smelters; irritates skin, eyes, mucous membranes.*

Hg (mercury): *from coal and oil furnaces, smelters; causes tremors, behavioral problems.*

HNO_3 (nitric acid): *formed from NO_2, a major component of acid rain; causes respiratory diseases.*

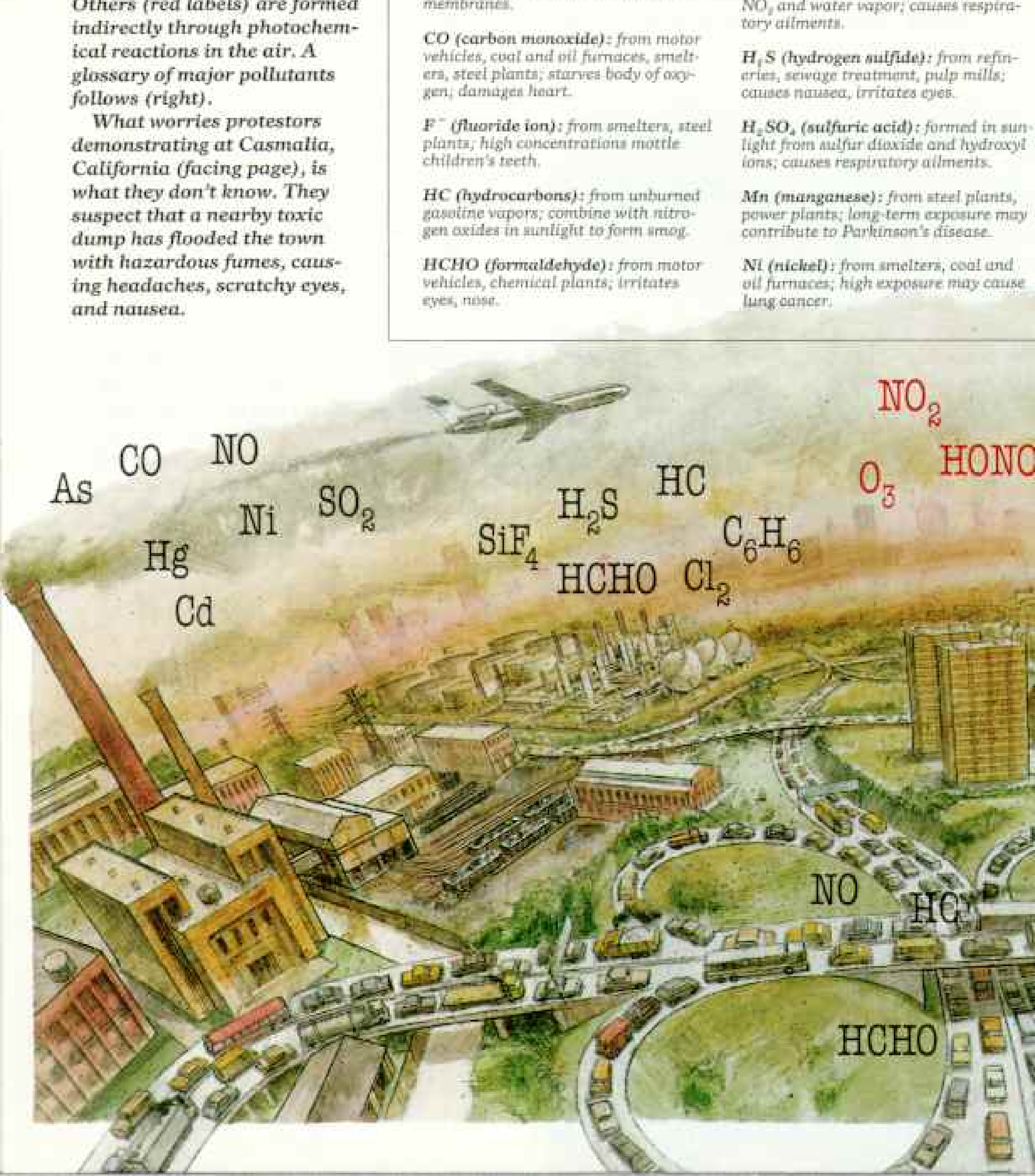
HONO (nitrous acid): *formed from NO_2 and water vapor; causes respiratory ailments.*

H_2S (hydrogen sulfide): *from refineries, sewage treatment, pulp mills; causes nausea, irritates eyes.*

H_2SO_4 (sulfuric acid): *formed in sunlight from sulfur dioxide and hydroxyl ions; causes respiratory ailments.*

Mn (manganese): *from steel plants, power plants; long-term exposure may contribute to Parkinson's disease.*

Ni (nickel): *from smelters, coal and oil furnaces; high exposure may cause lung cancer.*



NO (nitric oxide): *from motor vehicles, coal and oil furnaces; readily oxidizes to* NO_2.

NO_2 (nitrogen dioxide): *formed in sunlight from NO; produces ozone; causes bronchitis, lowers resistance to influenza.*

O_3 (ozone): *formed in sunlight from nitrogen oxides and hydrocarbons; irritates eyes, aggravates asthma.*

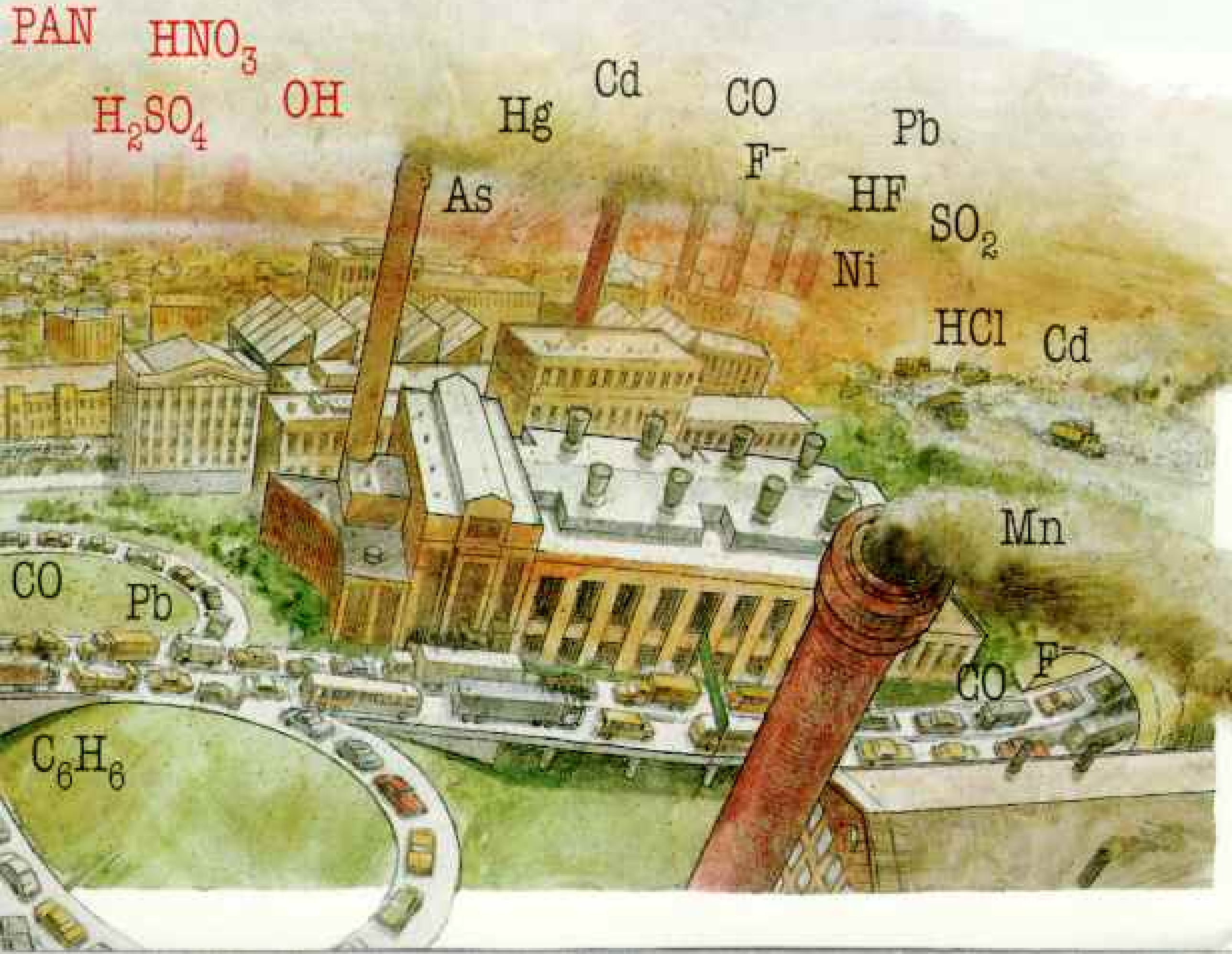
OH (hydroxyl radical): *formed in sunlight from hydrocarbons and nitrogen oxides; reacts with other gases to form acid droplets.*

PAN (peroxyacetyl nitrate): *formed in sunlight from nitrogen oxides and hydrocarbons; irritates eyes, aggravates asthma.*

Pb (lead): *from motor vehicles, smelters; causes brain damage, high blood pressure, impairs growth.*

SiF_4 (silicon tetrafluoride): *from chemical plants; irritates lungs.*

SO_2 (sulfur dioxide): *from coal and oil furnaces, smelters; obstructs breathing, irritates eyes.*



TOMASZ TOMASZEWSKI

Fear of fallout from Chernobyl caused Warsaw citizens to post this playground off-limits. The city is only 400 miles from the Soviet power plant where a nuclear reactor exploded on April 26, 1986, but Polish officials were not told of the accident for more than two days. By then a radioactive cloud had drifted over Poland, Finland, and Sweden. Restrictions were later put on water, milk, meat, and vegetables in 25 countries.

called cyanuric acid, break down into harmless nitrogen and water. If later research supports the findings, a giant step could be taken toward eliminating a major contributor to acid rain and man-made ozone.

Perhaps the most controversial environmental issue of the decade is acid rain, but that too is clouded in mystery.* "We are in the infancy of understanding the full effects on an atmosphere acidified by burning fossil fuels," Dr. Chris Bernabo, an air-quality expert, told me. "In order to really understand it, we must conduct years of research."

The federal Clean Air Act of 1970, amended in 1977, expired in 1981. As of this writing it continues on extensions, outdistanced by the growing knowledge about air pollution.

We live on a forgiving planet, with mechanisms to deal with natural pollutants. Decay, sea spray, and volcanic eruptions annually release more sulfur than all the power plants, smelters, and other industries in the world. Lightning bolts create nitrogen oxides just as automobiles and industrial furnaces do, and trees emit hydrocarbons called terpenes. Their release triggers a bluish haze that gave the Blue Ridge its name.

For millions of years the ingredients of such substances have been cycling through the ecosystem, constantly changing form. They pass through plant and animal tissues, sink into the sea, return to the earth, and are vaulted aloft in some geologic event to begin the cycle again. An atom of oxygen completes the cycle approximately once every 2,000 years. A portion of the next breath you take could have last been breathed by Jesus.

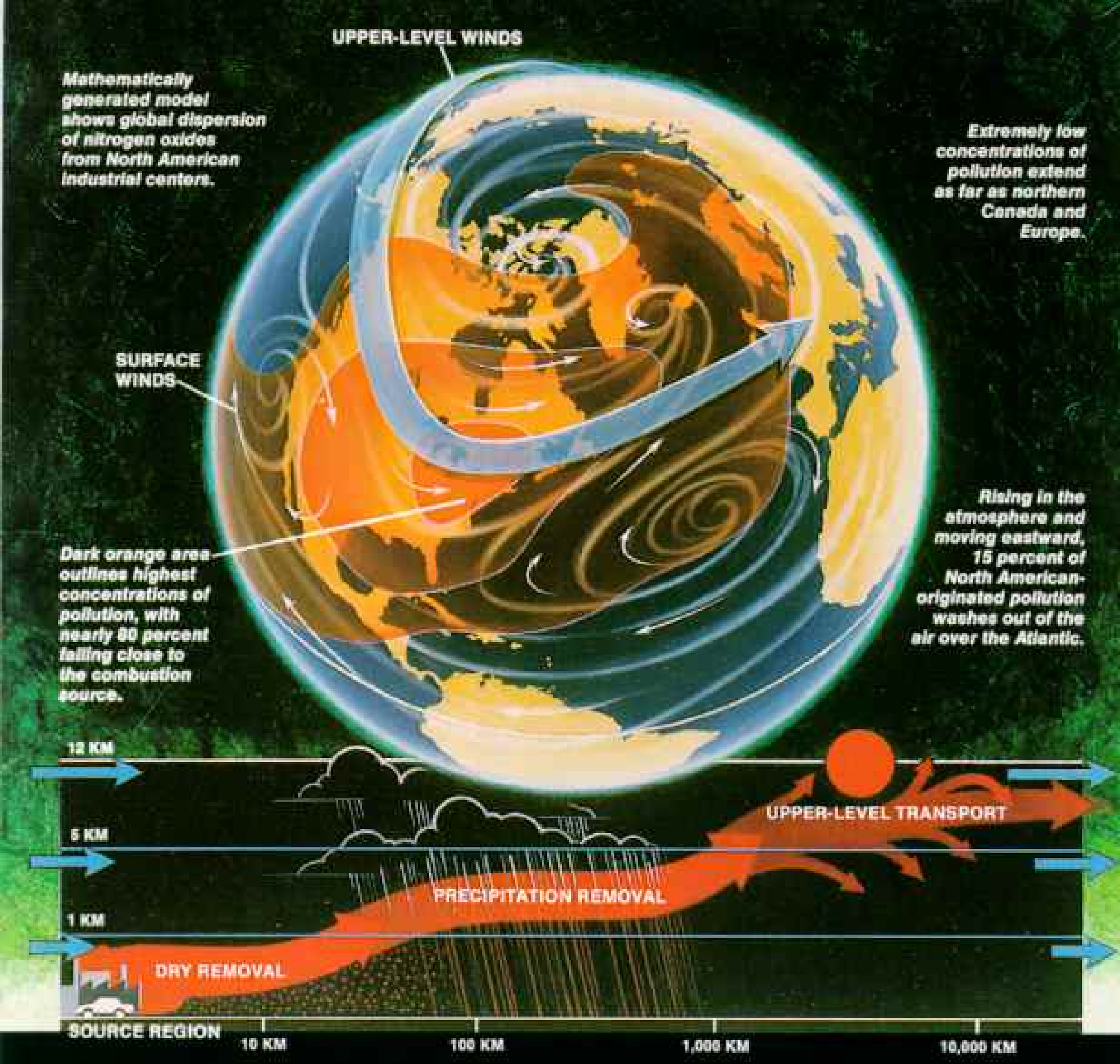
Can earth assimilate the additional 70 million tons of sulfur that we release each year? What happens to plants that absorb the additional nitrogen oxides (NO_x) we create with our miniature lightning bolts inside car cylinders? Can the atmosphere take on the extra load of carbon dioxide (CO_2), methane, man-made ozone, and chlorofluorocarbon refrigerants that scientists say could raise global temperatures by the greenhouse effect (pages 514-15)?

SUCH CHEMICAL INCREASES can be accommodated somehow, over time. Earth has plenty of that, but do we? The current overloading has the potential to alter life on this planet. Physically, our bodies may already be showing the stress.

Take lead, for example. Most of us do, from paint, plumbing, and principally automobile exhausts, despite reductions in the lead content in gasoline (page 523). Peruvian skeletons 2,700 years old were found to contain a thousandth of the lead levels that we consider typical.

True, lead levels in the U. S. have declined significantly in the past decade. But

*Anne LaBastille wrote "Acid Rain—How Great a Menace?" for the November 1981 GEOGRAPHIC.

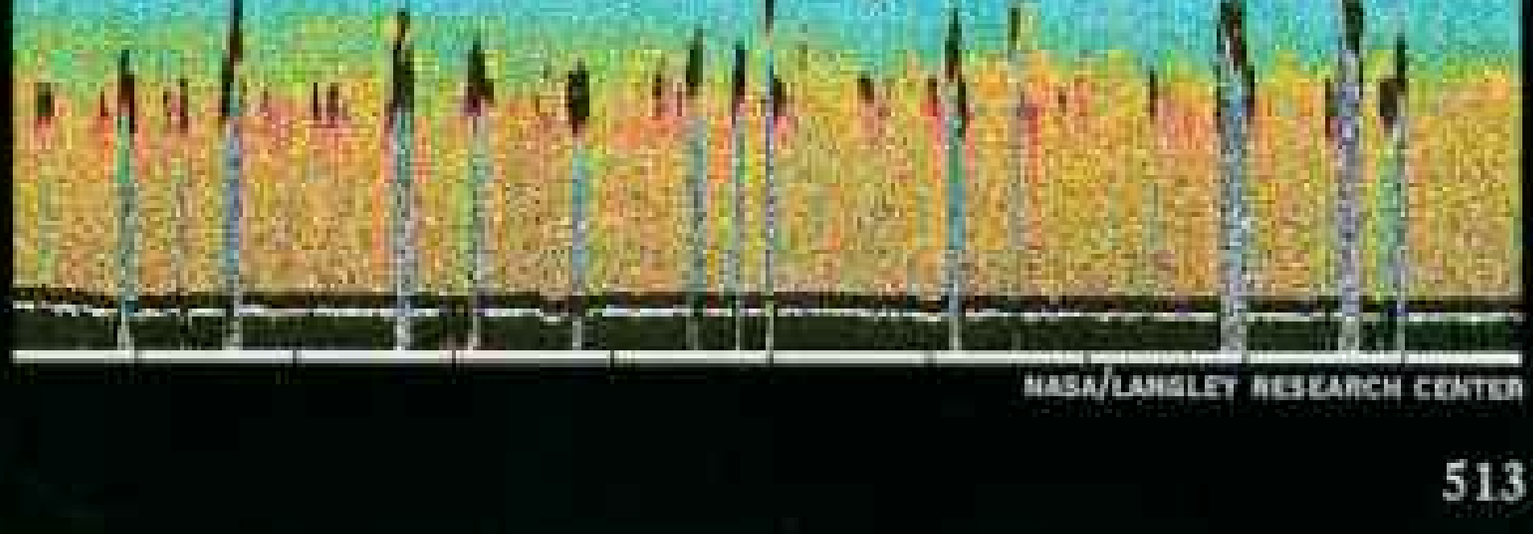


Careless neighbors

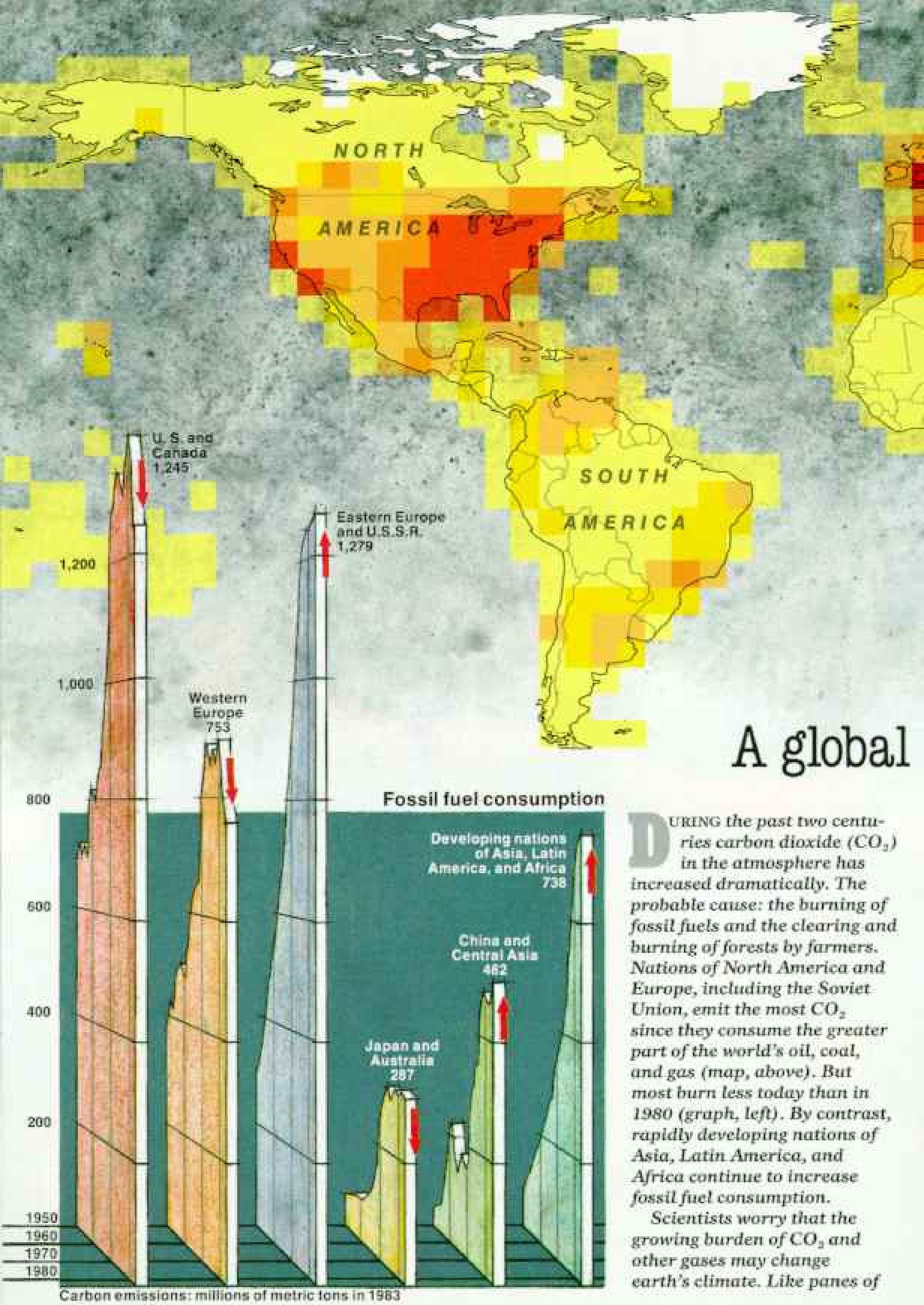
ONE NATION'S *pollution may become another nation's problem. Most emissions from North America's industrial heartland fall nearby on the northeastern U. S. and eastern Canada, as seen in a global model (top). A small percentage rises high enough to be carried long distances.*

Near their sources, some gases and particles may drop directly to earth (diagram, above). Others are washed from the sky later by rain, snow, or mist. But chemicals such as chlorofluorocarbons that do not dissolve or recombine at lower levels may contaminate the stratosphere.

Clouds over the Amazon in Brazil are profiled in a lidar image (below), made by bouncing a laser beam off particles in the air. Thunderstorms can gather smoke and other organic particles near the surface and pump them higher into the atmosphere.



NASA/LANGLEY RESEARCH CENTER

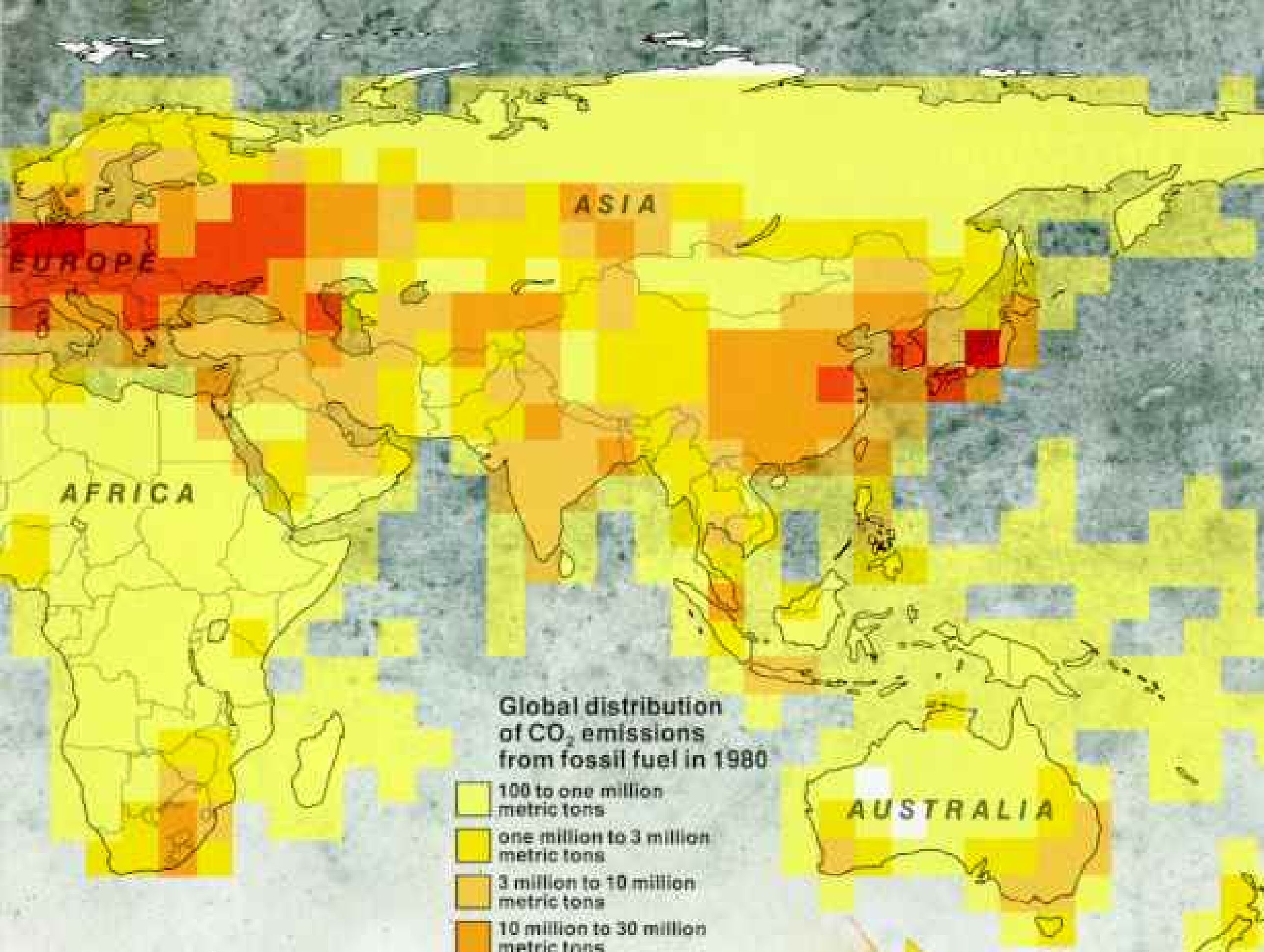


A global

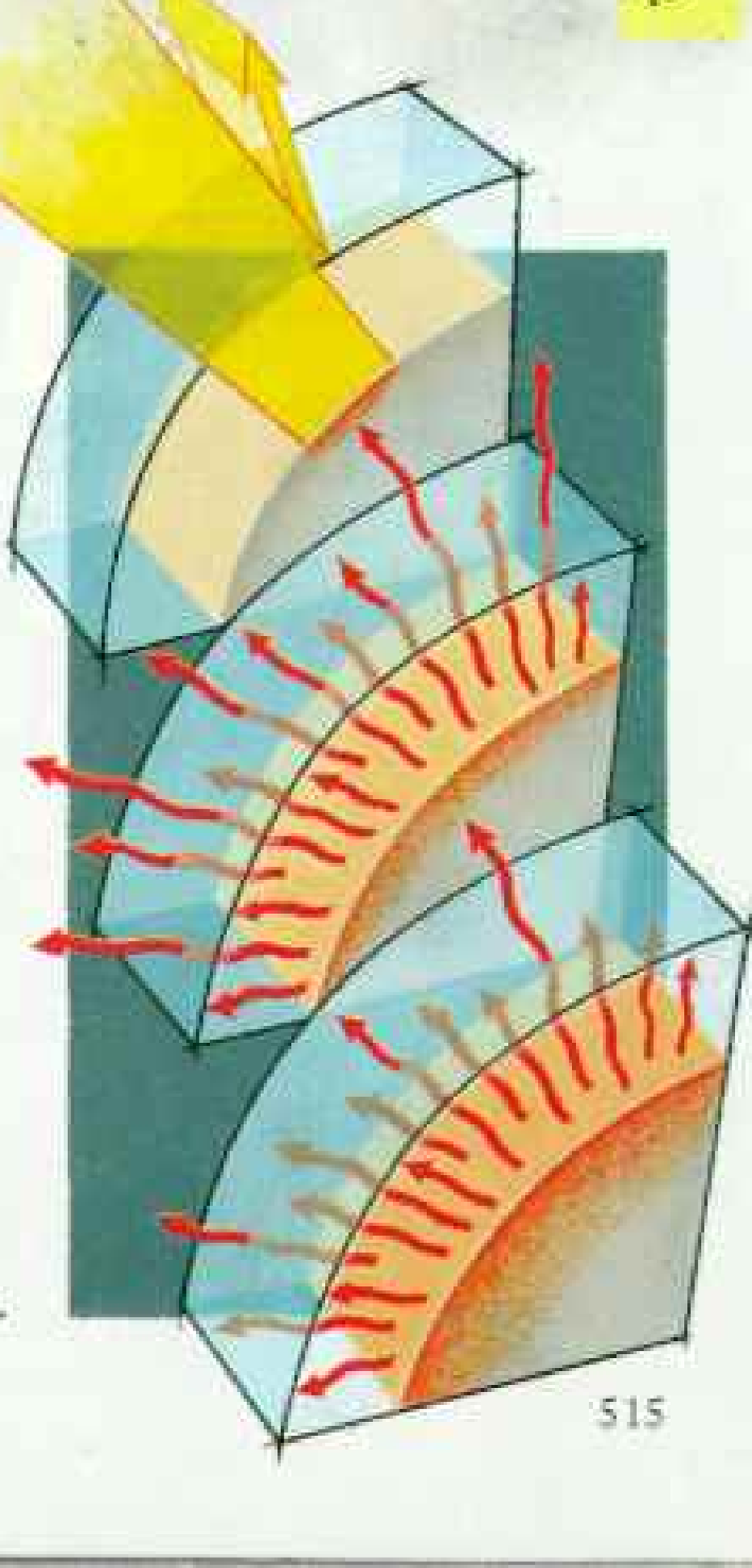
DURING the past two centuries carbon dioxide (CO_2) in the atmosphere has increased dramatically. The probable cause: the burning of fossil fuels and the clearing and burning of forests by farmers. Nations of North America and Europe, including the Soviet Union, emit the most CO_2 since they consume the greater part of the world's oil, coal, and gas (map, above). But most burn less today than in 1980 (graph, left). By contrast, rapidly developing nations of Asia, Latin America, and Africa continue to increase fossil fuel consumption.

Scientists worry that the growing burden of CO_2 and other gases may change earth's climate. Like panes of

National Geographic, April 1987



greenhouse



glass in a greenhouse, CO_2 allows most solar radiation to penetrate the atmosphere (right, top) but prevents part of the heat reradiated by land and bodies of water from escaping into space (right, middle). As CO_2 accumulates, enough heat may be trapped to gradually warm the atmosphere (right, bottom).

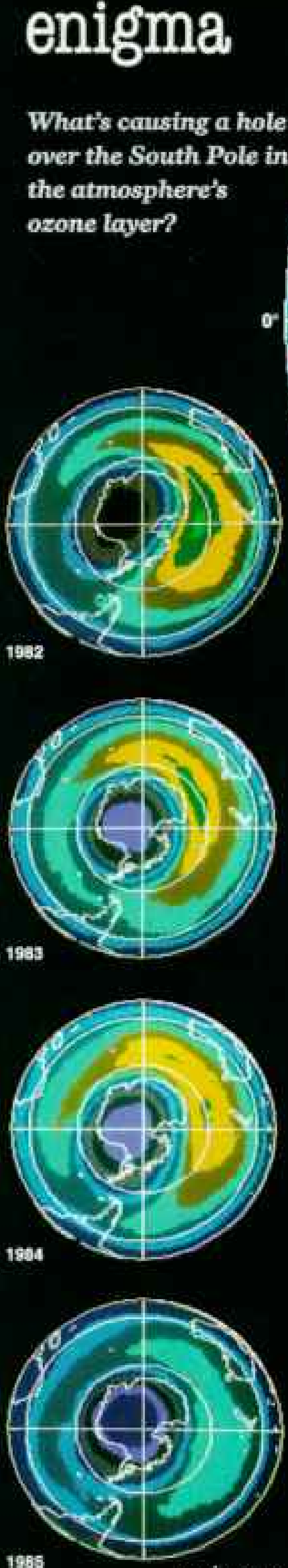
Researchers estimate that the earth's mean temperature could rise 1.5°C to 4.5°C (2.5°F to 7.5°F) by the middle of the next century if greenhouse gases continue to increase at the current rate. That would make the atmosphere warmer than it has been at any time during the past 100,000 years. Global rainfall patterns could shift, bringing heavy rains to previously arid regions such as the Sahel and droughts to productive farmlands such as the U. S. Midwest.

The impact could be even greater at the Poles, where mean temperatures might rise as much as 10°C (18°F). If the West Antarctic ice sheet melted, as it did during a previous period 120,000 years ago, ocean levels could gradually rise as much as 15 or 20 feet, flooding many cities and farm regions.

So far there has been no clear evidence that a warming trend has begun. But scientists warn that the atmosphere would require thousands of years to recover from a mean global warmup of 1.5° to 4.5° C.

The ozone enigma

What's causing a hole over the South Pole in the atmosphere's ozone layer?



ANOXIOUS form of oxygen, ozone impairs vision and breathing when it occurs in smog. But in the upper atmosphere, 12 to 30 miles above the ground, it protects life on earth by intercepting the sun's damaging ultraviolet radiation. During the past eight years this protective layer of ozone has become thinner each spring over the South Pole, as seen in these images (left) from the Nimbus 7 satellite. From 1979 to the present, a hole (shaded dark purple) has deepened, within which ozone concentrations have fallen by 40 percent. A color bar (above) identifies concentrations from lowest, at left, to highest, at right. Some scientists believe the ozone was attacked by chlorine released by chlorofluorocarbons, widely used industrial chemicals. Others theorize that the ozone was destroyed by nitric oxide produced in the atmosphere by the sun during an active solar cycle, or that the ozone was pushed aside by upwellings of air from lower levels of the atmosphere. Whatever the cause, the potential effects could be serious: If the ozone continues to disappear, skin-cancer incidence could rise sharply.

NASA/GODDARD SPACE FLIGHT CENTER

excess lead in the human body from a variety of sources can increase blood pressure. An EPA investigator calculates that "if you lowered everybody's blood lead levels by a third, there would be 60,000 to 70,000 fewer heart attacks over a decade."

Humanity releases many other elements to the air—mercury, chromium, vanadium, selenium, arsenic. As with lead (and radiation from such incidents as the Chernobyl disaster) man's concentrated effluents often pose more danger than those from nature.

OUR MISTAKES are costly. Americans spend more than ten billion dollars a year on medical problems caused by outdoor pollutants. Researchers now suggest that gas and wood-burning stoves exude harmful compounds inside buildings. These indoor pollutants, along with cigarette smoke, asbestos, toxics released from building materials, and radon gas trapped by tight insulation, may exact an annual health bill of a hundred billion dollars (pages 528-9).

Aside from monetary losses, air pollution eats at beloved cultural treasures. In Athens I sat on a stone and contemplated what has been called the most beautiful building in the world. Acid deposition has caused more erosion on the marble Parthenon in the past 24 years than had occurred in 24 centuries.

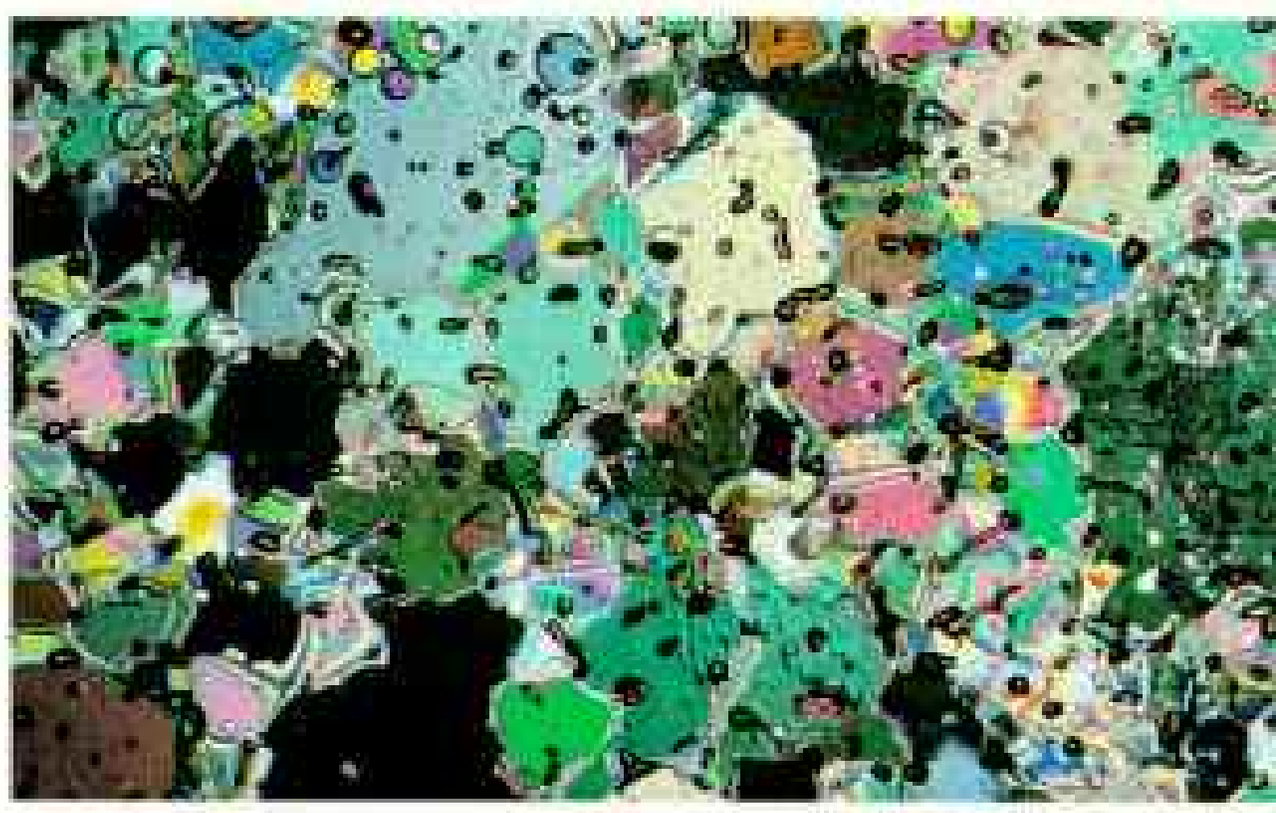
The Roman Colosseum, Westminster Abbey, and the Taj Mahal are suffering similar damage. At Chartres, as with other cathedrals, stained-glass windows dating from the 12th and 13th centuries have corroded to barely recognizable images. Is combustion our contribution to the arts?

The sources of damage are not easily removed. Legislation lags because fumes come from industries badly needed for national economies, from automobiles prized for private transportation, and from high-sulfur heating oils. Besieged by budget-conscious citizens and profit-conscious industries, politicians fiddle with regulations while their Romes burn.

The problem goes far beyond buildings and cities. Our entire troposphere is a blue balloon from which there is little escape. Some pollutants degrade or change form, but others may drift for years.

For a portrait of our atmosphere, U. S.

NATIONAL GEOGRAPHIC PHOTOGRAPHER GEORGE F. MOBLEY (ABOVE)



Like time capsules of the atmosphere, ice cores from a Yukon glacier contain information about air quality before the industrial revolution. By analyzing trapped air bubbles, a research team including Dr. Gerald Holdsworth (top) has learned that carbon dioxide levels in today's atmosphere are 27 percent higher than they were before 1850.

An ice sample from a glaciated plateau on Mount Logan (above) seems to bubble like club soda. Individual ice crystals take on different colors according to the angle at which polarized light strikes them.

scientists sample the air at four "clean" locations in a federal program called Geophysical Monitoring for Climatic Change.

What sweeter air than atop one of Hawaii's volcanoes, 13,680-foot Mauna Loa? Meteorologist Elmer Robinson drove me up its bare shoulders through lava fields sometimes jagged as cinders, sometimes smooth as swirled chocolate. In bright sunlight we looked down at clouds raining on the town of Hilo, far below.

On Mauna Loa's dry, primordial landscape nothing sprouts but technological wizardry. The air is tasted with tongue-twisting nephelometers, transmissometers, and spectrometers to better understand the aerial porridge that now surrounds us. The heavens are probed with laser light to see what particles are drifting. Dust from China reaches here, and a mystery cloud once appeared whose source was never identified, the stuff of science fiction.

For a view more mesmerizing than any fantasy, I mounted a ladder to a telescope aimed at the morning sky. A large, black obscuring disk loomed in the eyepiece to protect my retina, but at its edges flickered the light of hidden energy—the burning sun. Here, seemingly within arm's reach, was the engine that drives this planet, hurling gases thousands of miles into space. Is that life-giving heat now perilously altered on earth?

"One of the longest continuous records of CO_2 content of the air is kept here," said Mr. Robinson, director of the Mauna Loa Observatory. "We find an increase of 27 percent since the mid-19th century. CO_2 holds heat close to the earth, so the greenhouse effect is not a wild idea, it's pretty basic physics."

The greenhouse effect, with potential for altering climate, melting the polar ice caps, and raising ocean levels, has been called one of the most serious long-range environmental issues. Suddenly, it's short-range.

"The most significant thing we've seen in the past few years has been the increase in other greenhouse gases—methane and the chlorofluorocarbons," said Mr. Robinson.

"With the addition of these gases we may begin to see the effects around the turn of the century," says climatologist J. Murray Mitchell, Jr., of McLean, Virginia, who analyzes data sent from Mauna Loa.

All gases thickening the greenhouse are believed due to human activities. Combustion gives off CO_2. Methane, escalating by 2 percent a year, is attributed to gases from livestock manure, additional rice fields, and digestion of termites proliferating on dead wood left by worldwide clearing of forests.

The chlorofluorocarbons are a two-edged sword. Used as refrigerants and, in some places, still used as spray-can propellants, they add to the greenhouse as they drift upward. When they reach the stratosphere, they are believed to react destructively with the gauze of ozone that protects us from excessive ultraviolet rays. A sharp rise in ultraviolet rays would increase melanomas and other malignant skin cancers and reduce crops. Melanomas have doubled worldwide in recent years, but scientists are unable to connect that fact directly to ozone depletion. It may be simply that people are spending more time outdoors.

A warmer, wetter earth, or one more seared by sun? We are not just polluting, as bad as that may be, we are tampering with basic weather-making components of our atmosphere without knowing the outcome.

THERE IS mounting evidence that our whole planet is involved. The South Pole seems fairly clean because 90 percent of earth's population lives in the Northern Hemisphere. Yet in late 1985 scientists monitoring the stratosphere detected a major hole in the protective ozone screen over Antarctica (page 516). A result of natural activity, or man's? So far science has more questions than answers.

The North Pole, on the other hand, at times resembles a turn-of-the-century coal town. For in winter, when the Arctic is tilted into constant night and the sun cannot generate cleansing winds and precipitation, the largest single mass of pollution sits atop the globe like a dirty cap.

Wearing bulbous boots and mittens as thick as down comforters, I rode with two technicians to the Barrow Observatory in Alaska. Atop stark huts where we looked at solar-radiation instruments, the wind reached down the tunnel of my parka hood to stab my cheeks.

It was early November, and at 8 a.m. a full moon still shone like a bright dime, and

Tree rings tell the story: Something's killing red spruces in New York's Adirondack Mountains. A core taken near Mount Marcy by Dr. Edward Cook (left) of the Lamont-Doherty Geological Observatory shows normal growth rates until the mid-1960s, when rings start to narrow (below). Some scientists believe air pollution may have contributed to this decline. Dr. Cook theorizes it may have resulted from abnormally hot summers and cold winters. A similar weather pattern coincides with massive red spruce losses during the 1870s. An infrared view of Mount Marcy in 1984 (bottom) shows dying spruces as blue-gray instead of a healthy red.

An unwelcome guest, Denver's "brown cloud" of smoke and smog returns to the city each winter as heavy, cold air holds pollutants close to the ground. The cloud's dismal color is created by sunlight reflected off dustlike particles of wood smoke, diesel exhaust, and factory emissions. From mid-November to mid-January, when

atmospheric inversions often occur here, Denver also suffers the nation's highest concentration of carbon monoxide. To combat this problem, motorists during the past three years have been asked not to drive on one working day a week, using a voluntary system of rotation based on license plate numbers.

Trapped inside the combustion chamber instead of being released into the atmosphere, coal ash forms a crust of slag inside a burner developed by TRW, Inc. As much as 90 percent of the ash is caught by the burner system, which also reduces emissions of nitrogen oxides and sulfur oxides. The system was designed to adapt gas or oil furnaces to burn powdered coal.

the aurora borealis looped a ghostly scarf across the sky. By late November the sun would not rise at all. When it reappeared in late January, it would shine on a haze of sulfates and soot that would remain until spring storms flushed them out.

Eight nations touch the Arctic—the United States, the Soviet Union, Canada, Finland, Iceland, Norway, Sweden, and Denmark (Greenland). Who soils it? Air masses are mixtures of numerous gases and particles unique to their places of origin. The Arctic pollutants showed a "signature" unknown to Western scientists.

Dr. Kenneth Rahn of the University of Rhode Island found they included arsenic, selenium, antimony, and indium, in a combination that pinned most of the pollution to a mineral-rich smelting area in the Soviet Union's Ural Mountains. Other investigators found dry-cleaning Freons and degreasing solvents used commonly by the Russians but rarely by Western nations.

This method of tracing pollution to its source sprang from the ability to examine smaller and smaller samplings—now as little as one part per trillion parts of air.

Tracing pollutants is becoming a political necessity because air is no respecter of boundaries. On the acid rain issue alone the Scandinavians are angry at the British, the Canadians are impatient with the United States, and the Northeast blames the Midwest for dead trout and dying trees. From the accused the answer has become a familiar refrain: "You can't prove that my emissions are killing your. . . ."

With fingerprinting and tracking of particles with lasers (page 513), the disclaimers become less convincing. But the dying continues, and we've made the ammunition for these killing fields all too available, says meteorologist Volker Mohnen, who gathers cloud data from atop Whiteface Mountain in upstate New York.

"Water droplets in clouds become little chemical converters," he explained. "In a normal ecologically balanced system, ammonia from decaying matter is present in the air along with natural oxides of sulfur and nitrogen. Ammonium sulfate or ammonium nitrate are therefore created, falling to the ground to become natural fertilizer.

"That's the regular cycle—living things on the ground die, decay, and release ammonia that nurtures more living things. What we are now doing is to inject additional sulfur, nitrogen, and hydrocarbons into the atmosphere, altering the cycle."

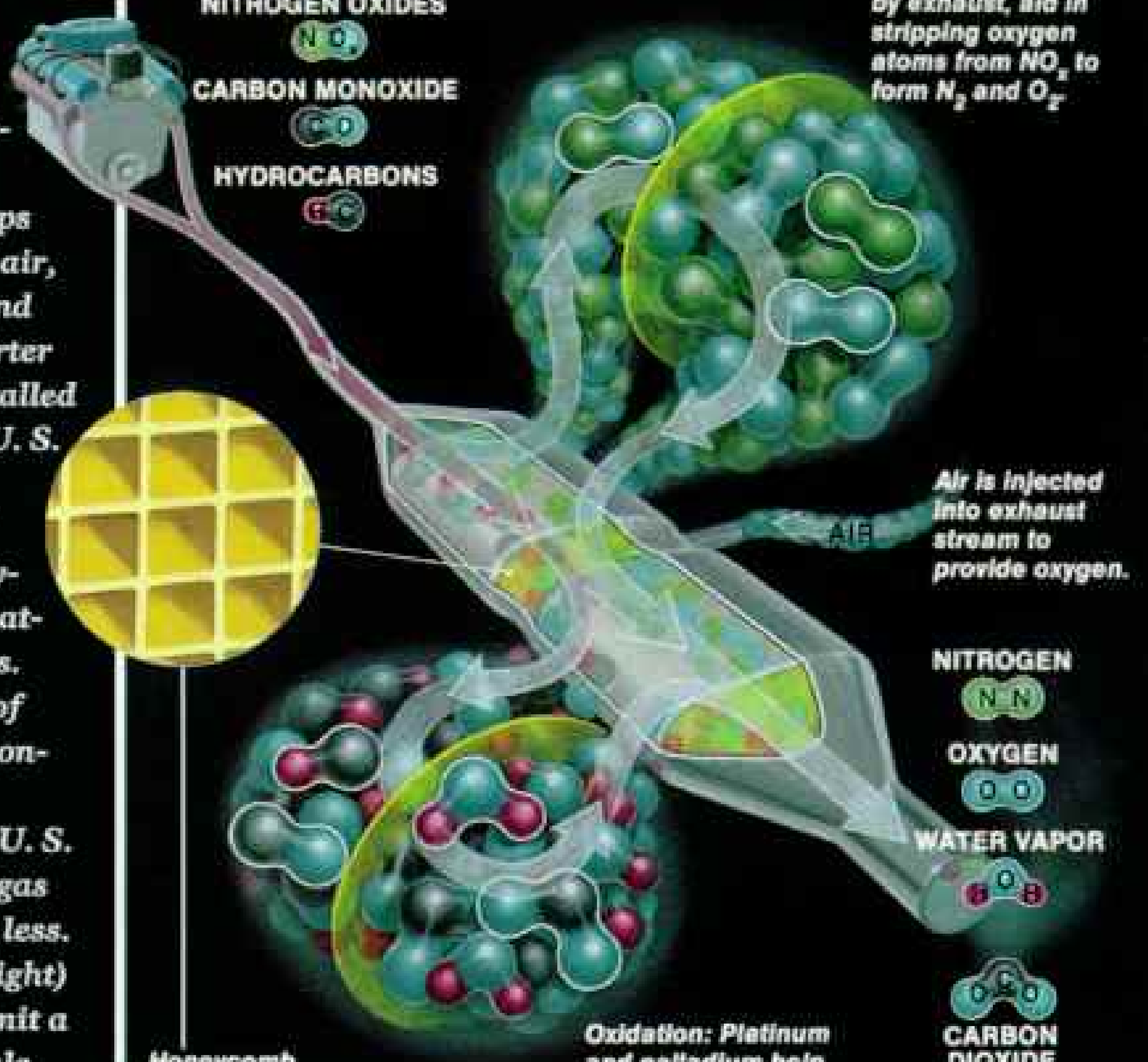
IF THE MECHANICS of acid rain formation are becoming better understood, the effects are less clear. Something is killing trees, but scientists are finding that the deeper they look, the more complex the picture. There are multiple theories about forest damage.

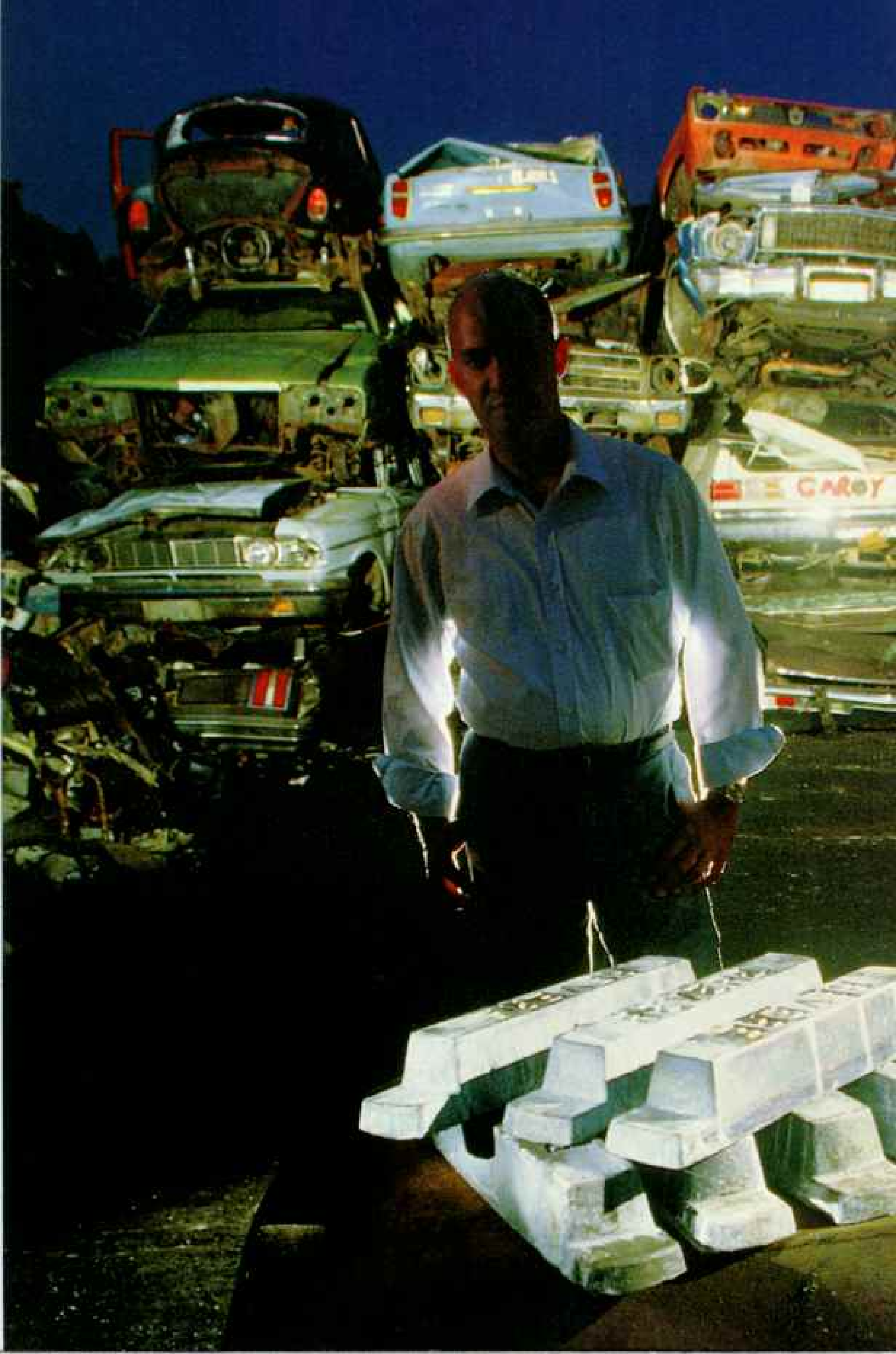
Dr. Bernhard Ulrich of the University of Göttingen in West Germany first sounded

Getting the lead out

USING unleaded gasoline pays off in three ways: It keeps lead from poisoning the air, reduces maintenance, and allows a catalytic converter (right) to do its job. Installed on new cars sold in the U. S. since 1975, converters eliminate 90 percent of carbon monoxide and hydrocarbons and now greatly reduce nitrogen oxides. But only a few tankfuls of leaded gas can destroy converter effectiveness.

One in ten cars in the U. S. is thought to use leaded gas illegally because it costs less. A tank opening (below right) has been enlarged to admit a leaded gas nozzle. Telltale pink on treated paper (below) reveals lead in car exhaust checked during an annual survey by the Environmental Protection Agency.





Paying the price for lead, a young girl and a middle-aged man symbolize victims of a lead-polluted environment. The 20 automobiles stacked behind them – including many "lead sleds" built before 1975 – without catalytic converters would have spewed out the equivalent of 525 pounds of lead in exhaust fumes during their average life span of ten years.

Between 75 and 95 percent of the lead inhaled or ingested accumulates in bones and other tissues, threatening to cause irreversible brain and kidney damage. Young children are most vulnerable because their nervous systems are still developing. Excessive lead can decrease a child's intelligence, shorten his or her attention span, create learning disabilities, or cause hyperactivity. Perhaps 20 percent of all preschool children have excessive blood lead levels.

Elevated blood lead levels in adult males have been linked to high blood pressure. An EPA researcher estimates that 60,000 to 70,000 heart attacks per decade might be prevented if the mean blood lead level of all Americans was reduced by a third. The phasing out of leaded gasoline has already helped. From 1976 to 1980, when production of lead additives dropped by more than half, the mean blood lead level in the U. S. fell by a third.

an alarm when his tests of German soils in the early 1970s showed high acid inputs from the atmosphere. The result, he predicted, would be forest damage as acids leached nutrients from leaves and soils and as trees pulled aluminum and heavy metal ions into their systems. Both aluminum and heavy metals are present but immobile in many soils, but acid solutions mobilize them.

The role of prophet might have seemed due the energetic, almost sprite-like biologist had not a blizzard of other theories emerged. Damage to ponderosa pines by ozone had been demonstrated near the Los Angeles area in the U. S. in the 1960s, and the same pollutant has been embraced by many as a major cause in Germany.

Others felt that air pollutants merely weakened trees so they could be killed by drought and pathogens. Excess nitrogen from emissions of nitrogen oxides also gained popularity, on the theory that trees rich in nitrogen were not hardening for protection from winter.

Problems in pinning the culprit stem from our own basic ignorance of the environment. Time and time again I was told by scientists on both sides of the Atlantic that the search for causes of forest dieback has shown how little we know about how trees grow.

"There is no generally accepted step-by-step process demonstrating that a pollutant affects trees," said Dr. Arthur Johnson, soil scientist at the University of Pennsylvania. "We just don't know enough about the exact mechanisms of tree growth to do that. The only pollutant on which there is a consensus

Where there's smoke, there may also be toxic pollutants. At a warehouse fire in Elizabeth, New Jersey, firefighters (left) put on breathing units to protect themselves from dangerous gases. A special team had earlier identified hazardous chemicals in the fire. Detonations hurled explosive aerosol paint cans at the firefighters like hand grenades.

Airborne toxics can also escape in much quieter ways. At a petroleum refinery in Marcus Hook, Pennsylvania, environmental engineer George Keegan (above) tests valves for leaks of benzene, as required by federal law. Thousands of other chemical compounds in the United States—many suspected of causing cancer—remain unregulated.

as to its injuring trees at a distance is ozone, in the case of California's ponderosa pines and in white pines in the East."

Searching historical records covering more than a century, the University of Pennsylvania team has found consistent red spruce dieback following either an extremely warm summer or a cold winter, with a combination of the two being especially deadly. Perhaps, Dr. Johnson says, trees weakened by climate variations are then finished off by air pollution.

"That's why you see so little action on controls right now, because it's such a complex picture," said Volker Mohnen, the Whiteface Mountain cloud chaser. "Should we reduce the emissions by 10 percent, 20 percent, or 50 percent to correct problems not fully understood? This would constitute a major interference with human activities."

And human pocketbooks.

REDUCING the emissions of sulfur dioxides by half in this country, using current technology, could require refitting large power plants with flue-gas scrubbers. The cost has been estimated at two to seven billion dollars a year, for a total of 50 billion dollars over a decade. Who would pay for it?

Would it be power plants like those of the Ohio Valley, source of much of this nation's sulfur dioxides? Or should the entire country pay through an electrical usage tax, which would mean the polluter, polluted, and the pristine share equally in the cost?

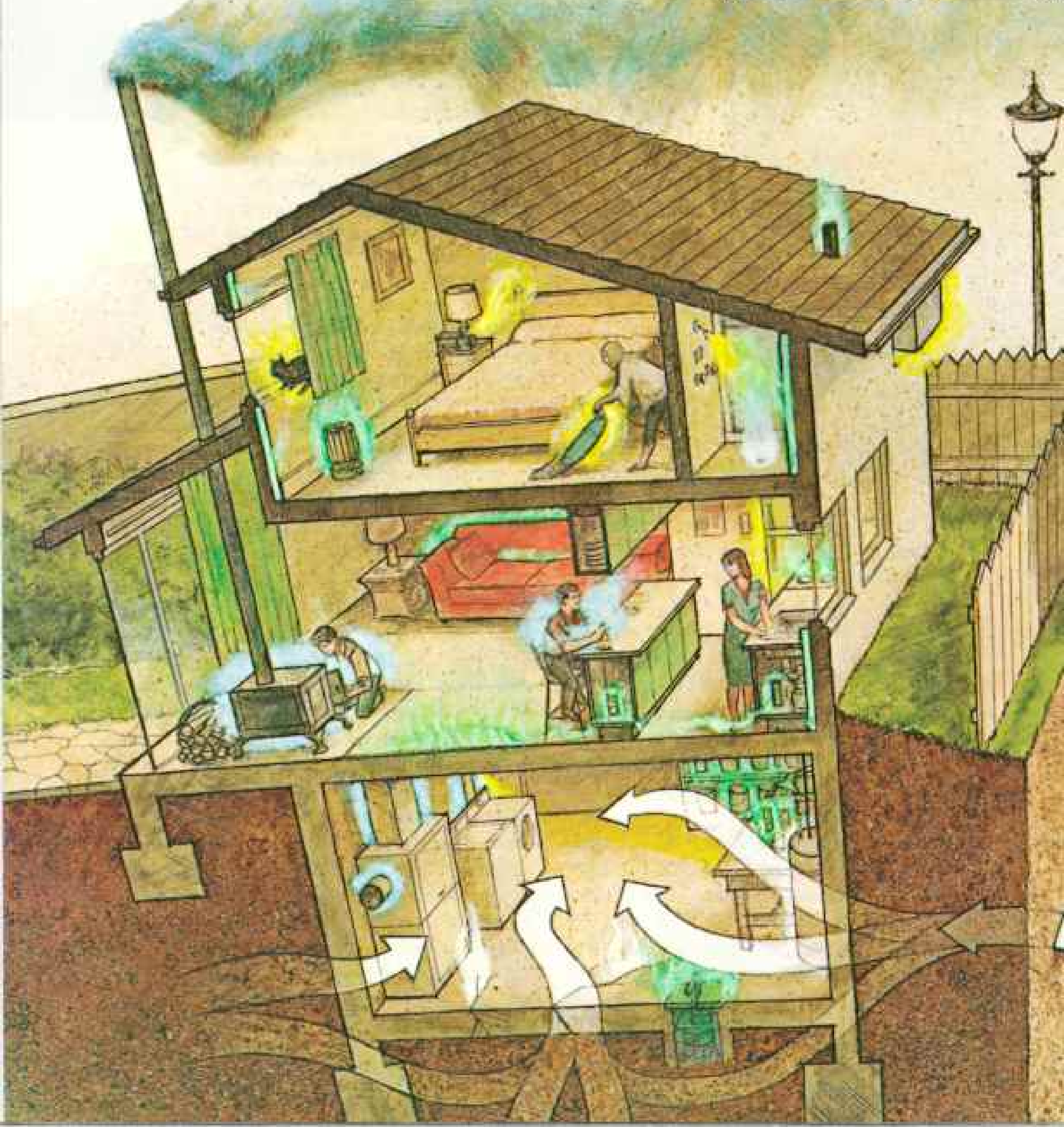
Perhaps Midwest plants should switch to low-sulfur coal mined in the West. But that

The enemy within

THERE'S *no place like home—or the office—for contaminated air. Pollution levels indoors, especially in buildings that have been "tightened" for energy conservation, can be ten times higher than those outdoors.*

Radon, a colorless, odorless, naturally occurring radioactive gas (white, below) seeps into basements from decaying uranium in soil. A million families in the U. S. are thought to be exposed to radiation levels higher than those faced by uranium miners.

Larry Kaplan of Clinton, New Jersey, with his wife, Joan, and daughters Amy and Heather (left), are surrounded by fans, meters, research data, and graphs they used in their fight against radon. When it was discovered inside their house, Larry installed



fans beneath the foundation to safely vent it outside.

Toxic fumes (green) enter the home or workplace in many ways. Newly installed carpets, furniture, plywood, and some foam insulation give off formaldehyde, causing headaches, impairing breathing, and irritating eyes, nose, and throat. Poorly vented kerosene heaters, gas ranges, and wood stoves put out unhealthy amounts of carbon monoxide and nitrogen dioxide. Copying machines emit noxious ozone. Dry-cleaning fluids, disinfectants, paints, and pesticides leak chemical vapors.

Hazardous particles (blue) fill the air from cigarettes, wood stoves, dryers, and asbestos insulation.

Biological pollutants (yellow) add other worries. Bacteria may be drawn into air-conditioning systems from rooftop puddles or breed in kitchens, baths, bedside humidifiers, or spaces above office ceilings. Pets give off allergy-inducing dander. Fungi grow in cellars.

Some remedies: Ventilate when cooking with gas; never use unvented kerosene heaters; open fireplace dampers fully; filter pollen from air; stop smoking.

Children of smokers suffer more bronchitis and pneumonia during infancy than those of nonsmokers. In a smoking-habits survey, a University of North Carolina team found cotinine, a metabolite of nicotine, in the urine of this baby (below) and others who live with smokers. In rural Nepal (facing page) a cooking fire can fill a poorly ventilated house with heavier pollution than the worst urban smog, increasing risks of respiratory disease—the Third World's leading killer.

would idle 20,000 or more miners in Illinois, Ohio, Kentucky, and West Virginia.

And what if that multibillion-dollar solution is the wrong one, outdated the moment it is completed? "Technology is already available to burn fuel more cleanly and efficiently, and within 15 or 20 years many existing plants will be ready for retirement," admitted Dr. Mohnen.

Can the environment wait 20 years for better technology?

"Not at current emission levels," he replied, "but perhaps with conservation. A 20 percent reduction in fossil fuel use is possible, through conservation measures for automobiles and electric power users."

For the past half decade the U. S. government has answered calls for controls on industrial emissions by saying more research was needed. In early 1986 a joint U. S.-Canadian report called for a five-year industrial emission control project costing five billion dollars. The report heartened some Canadians; others remained skeptical that the U. S. would appropriate the money in an era of tight budgets. So far, it has not.

In the U. S., acidification has long been seen as a problem of the eastern states, but the West may also be vulnerable. Many eastern soils are underlain with limestone and contain calcium carbonate that can neutralize acids. Western alpine soils are commonly on top of granite, which provides little neutralizing alkalinity. So far no significant changes in western acidity have been detected, but increased exposure to power plants, smelters, and motor vehicles could change that picture rapidly.

German trees have shown how rapid that change can be. The now familiar signs of German forest dieback were noticed in the 1970s in the Black Forest. By 1986 more than half the nation's trees were afflicted. "German forests as we know them may never exist again in our lifetime," said forest historian Dieter Deumling.

Elsewhere, witnesses in several eastern European countries, heavy users of high-sulfur coal, report whole forests turned to stump-studded meadows. Tree losses on Swiss Alpine slopes have been blamed for a rash of avalanches, some of them fatal.

The possibility of fatalities by air pollution spurred Japan to action. Two decades ago economic and industrial expansion had spawned a dangerous success. From cities around Tokyo Bay came nightmarish images of citizens wearing masks, breathing from oxygen vending machines.

"Around 1970 children were collapsing on school playgrounds from the effects of photochemical smog, and there were numerous victims of a respiratory disease known as Yokkaichi asthma," I was told by Kazuo Matsushita, deputy director of the planning division in Japan's environmental agency.

Facing me across a table in a government

building in Tokyo was a battery of Japanese bureaucrats. At 35, Mr. Matsushita was the eldest. Ties loosened, shirt sleeves rolled above their elbows, they exuded the same kind of energy with which the nation has attacked world auto and electronic markets.

"The public was clamoring for cleaner air," said Mr. Matsushita. The government offered tax breaks to companies that met clean-air standards early. And the industrial community was reminded of the benefits of a healthy population.

"To make money, you need good productivity, and if the workers are feeling good, you get it," said 30-year-old Jun Masui, chief of auto-emission controls. "So, it is cost-effective to clean up the air."

Japan's problems are far from over. I glanced out the window and noted that buildings were disappearing behind smog. Nitrogen oxide emissions from Tokyo traffic are still high.

Reduction of industrial emissions has been more dramatic. In Kawasaki, the industrial hub, sulfur dioxide has been reduced 96 percent by installing scrubbers and switching fuels. A central monitoring system tattles on plants exceeding pollution limits, but such high-tech sentinels are costly. Each of 18 stations measuring ambient air costs half a million dollars, more than most countries are willing to pay.

LESS THAN a decade ago Mexico City was sliding toward prosperity on an oil-lubricated national income. But long before the 1985 earthquake devastated hundreds of its buildings, the collapse of world oil markets had left its economy in a shambles. The hard-pressed government could not afford to clean up air extravagantly dirtied. Raw sewage dries and is wafted aloft to mix with heavy concentrations of fossil fuel emissions. Even so, air over Mexico City takes a backseat to what may be the most polluted corner on earth—Brazil's "valley of death."

An hour's drive south of São Paulo the land drops away suddenly to a coastal plain more than 2,000 feet below. Between the plateau and the sea less than 15 miles away, industrial plants belch thousands of tons of pollutants a day, some of them extremely toxic, some as common as dust from a cement factory. Sharing the valley with the industries are about 100,000 people in the municipality called Cubatão.

Normally our respiratory systems defend against solid particles like dust with filters of mucus and hair, but smaller specks from combustion and manufacturing invade bronchial tubes. Inflamed, the tubes narrow, restricting breathing. Within an hour of my arrival a dull ache nagged in my chest.

In the downtown core population of some 40,000, nearly 13,000 cases of respiratory disease were reported in one recent year. Other health statistics about Cubatão are more frightening. The air holds high levels of benzene, a known carcinogen. One in ten workers in a Cubatão factory unit showed low white-blood-cell counts, perhaps a precursor of leukemia. Infant mortality is 10 percent higher here than in São Paulo state as a whole. Environmental officials blame it on poor sanitation and malnutrition.

STRUCK down by mesothelioma, a rare form of cancer caused by exposure to asbestos, Dan Pasquinucci (right) of Parlin, New Jersey, is comforted on his deathbed by his wife, Alyce. A former president of Local Union 28 of the Sheet Metal Workers International Association, Dan was exposed to airborne asbestos fibers on construction jobs decades ago. Until they were banned in the 1970s, materials containing asbestos were commonly applied to buildings for insulation and fire protection.

Union instructor Jack Looney looks on (below) as Deborah Nagin of Montefiore Medical Center in New York City sprays an irritant smoke into a plastic enclosure to test the fit of a mask provided for an apprentice sheet-metal worker. Even small amounts of asbestos fibers may increase a person's chances of developing cancer 15 to 40 years later. So workers use extreme caution as they wet, scrape, and bag asbestos-laden material for removal from an office interior (facing page). Tubes from outside the sealed area carry fresh air to the workers.

Surprisingly, I could find few who would complain about the pollution, including those who live in its heart, a ragged cinder-block and sheet-metal neighborhood known as Vila Parisi. Villagers there breathe fumes but smell jobs. They are wary of industry offers for their property and government offers of free homesites on a landfill.

"The refinery wants our land for expansion, and they offered us 500,000 cruzeiros [then $200] for it," said a young woman with an infant dabbling in mud at her feet and another perched on her hip.

"Yes, the children are often ill and sometimes can barely breathe. We want to live in another place, but we cannot afford to."

Dr. Oswaldo Campos, a university professor of public health, says the dirty air in Cubatão is a case of economic priorities, not deliberate callousness. "Some say it is the price of progress, but is it?" he commented in a São Paulo coffee shop. "Look who pays the price—the poor."

A lesser price for all is hinted in recent São Paulo state statistics on Cubatão's air: In a two-year period, particulates down by 80 percent and varying reductions in other pollutants. The remedial program is showing results, but there is far to go.

THE AGONIES of a developing nation? Cubatão has its counterpart in Ironbound, New Jersey. Flanked by Newark's commerical district and surrounded by train tracks that inspired its name, Ironbound appears as a faded, faintly depressing industrial enclave, barely rating a glance from the New Jersey Turnpike. But I found a hard-working, close-knit community that is angry and confused about the air it must breathe.

In or near Ironbound are dozens of plants whose emissions join fumes from the turnpike and busy Newark International Airport, in sight of New York City. On a clear calm day the region gives off a brownish urban plume that marks the mouth of the Hudson River like a biblical pestilence. And it is equally perplexing. Chemicals released in an industrial area number in the thousands, and science is still identifying them.

"We can detect substances we never even knew existed in the air five years ago," said Dr. Ron Harkov, researcher with New Jersey's Department of Environmental Protection. "Some have cancer-causing properties and other health hazards, but at what levels, we don't know."

New Jersey's cancer death rates led the nation during our century's middle decades, and the state's industrial complex became known as "cancer alley." A bad rap, officials say, noting that national cancer rates have since overtaken New Jersey's, and the fact that industry is blamed for a minority of cancers. New Jersey now has pollution laws as tough as any in the U. S.

Laws, however, must be tighter than pipe fittings to stop all the leaks.

"Think of a single refinery and all the valves, pipes, and flanges in it," said researcher Harkov. "Nothing is sealed perfectly, and when a company is making 75 different substances, there's no way they can tell you every second of the day what is leaking out of their pipes."

Spills and leaks in the chemical age have spawned a new breed of patrolmen, those of hazardous materials, or "hazmat," units. Prowling industrial areas, they snoop and sniff for suspicious gas fugitives. Clad like spacemen and armed with detection instruments, they precede fire fighters into curtains of smoke to warn of dangerous fumes.

New Jersey requires a hazmat unit in each county. I joined one in hard-pressed Middlesex, where potentially serious chemical accidents occurred ten times in eight weeks in 1985. A tank of the pesticide malathion exploded, for example, and some 200 people received treatment at hospitals for vomiting and shortness of breath. A seal on a pump failed at another plant, and 40 painters collapsed on a bridge a mile away from breathing another pesticide ingredient.

Rich Kozub, 30, grew up in Middlesex County before taking a degree in environmental science. As we patrolled his old neighborhood in an unmarked car, the radio crackled with reports of chemical peril: A railroad tank car holding chemicals had slipped its rails and was leaning dangerously. Fumes lingered from a paint-factory explosion and fire that had killed two men.

As we neared a metal smelter in Port Reading, a dark cloud from the plant billowed over a horizon of row houses. "Smoke plume!" barked Kozub and accelerated

Erasing the beauty of classical Greece, sulfur oxides in the smog over Athens chemically transform marble into gypsum, causing it to crack and flake off. A frieze panel on the Parthenon (left) has lost much of its detail, compared with another panel (right) preserved at the British Museum since the early 19th century.

down a side street for a look. It was gone by the time we gained a close view, but complaints were pouring in. Mrs. Diane Pitz, young, blond, clad in a running suit, answered her doorbell and acknowledged phoning in a report.

"I opened the window to let in some fresh air and noticed the smell right away," she said. "It happens almost every day."

(Since then the plant has shut down, precluding a court fight to close it.)

So what does one do, flee to some remote isle? Even flying might be hazardous to your health. A report by the National Academy of Sciences to Congress in mid-1986 included 19 recommendations on improving the air quality for airline passengers confined in close quarters for hours. "A noteworthy suggestion was that smoking be banned on all commercial flights," said James A. Frazier, a member of the study group. "We also suggested that ventilation systems on planes be used to optimum advantage at all times."

Ventilation systems are driven by air bled from the engines, and sometimes part of the system has been shut down to save fuel. On newer planes as much as half the air is filtered and recirculated instead of being bled from the engine, an engineer with Boeing explained to me. Clean air at last? Not exactly. Bacilli from a sick passenger, he admitted, could pass through the filter and reenter the passenger cabin.

ARE WE DEEPER in jeopardy with every breath we take, every automotive move we make?

Nationally, says the EPA, air quality has improved since 1975 in the commonly known and regulated criteria pollutants—particles, sulfur dioxide, carbon monoxide, nitrogen dioxide, ozone, and lead. And yet, in the introduction to its *National Air Quality and Emissions Trend*

Certified victims of air pollution, Machi Kuramochi (facing page, seated), Tokuji Maehara (standing at left) and Kiyoharu Yamamoto of Kawasaki, Japan, show government papers authorizing payments for asthma treatments. Sashes bear the name of their pollution-victims advocacy group.

Once one of Japan's most polluted cities, Kawasaki has reduced sulfur dioxide emissions by 96 percent since 1970. Helping to keep up the good work, controllers (below) check air-quality data from remote sensors.

Report, the agency points out that nearly 80 million people live in counties where ozone levels exceed air-quality standards, 61 million breathe too much carbon monoxide, and 32.6 million share air space with too many particles.

Progress in criteria pollutants can be measured in numbers. In newer, more mysterious toxics it is best measured in attitudes.

"Fifteen years ago chemists were dealing with London's sulfurous smog in one camp, photochemical smog in another, and the toxic chemicals people didn't talk with the other two camps," said Dr. James N. Pitts, Jr. His recent book *Atmospheric Chemistry*, coauthored with Dr. Barbara Finlayson-Pitts, is a major reference. "It is clear that we must look at trace species such as nitrate and hydroxyl radicals present in concentrations thousands of times lower than SO_2 and NO_x. They are now known to be linked with acid rain, photochemical smog, and the reactions of toxic chemicals in air."

"It's like the medical profession," meteorologist Elmer Robinson told me on Mauna Loa. "It solved infections like smallpox and scarlet fever and now it tackles long-term effects like cancer. In the case of pollution, we have dealt with acute local problems, and now we are addressing the longer-term atmospheric problems."

Throughout history humans have lived with perils over which there seemed little control—stronger creatures, hostile elements, mysterious diseases. One by one such threats have been tamed and replaced by one of our own making.

Air pollution is modern man's wolf at the door, said Dr. Irving J. Selikoff, called by some the father of pollution health effects. In a Mount Sinai Hospital office in New York City, amid stacks of research data, he told me: "It is a public problem as well as a science problem. Regulation is up to the government, but government bases decisions on its reading of what people want."

Since costs are high and truth is elusive, regulation may be slow in coming, says Dr. Selikoff. With patriarchal calm he folded his hands before saying carefully: "If you look at the studies and the experiments with guinea pigs and mice, it looks like we should all get off the face of the earth. But we don't really know what many of the substances in the air do to people. It may take 50 years to know that. Can we wait that long?"

As Roger Revelle, University of California professor of science and public policy, once stated, "Mankind is in the process of conducting a major, unintentional experiment, that of feeding back into the atmosphere in a short space of geological time the fossil fuels that have slowly accumulated over the past 500 million years. . . ."

Now that the chemical era has joined the age of combustion, that experiment has expanded. Almost breathlessly we await the outcome. We are our own guinea pigs. □


川崎公害裁判原
川崎公害裁判原

The Antarctic Challenge

By SIR PETER SCOTT

A ghostly moon and summer's dying light illuminate Mount Erebus and the hut built by Capt. Robert Falcon Scott at Cape Evans in 1911. Scott's courageous journey to the South Pole inspired three men to set out on his path 74 years later.

SINCE THE DAWN of history man has felt an urge to explore the unknown. It is the basic drive in most fields of endeavor. The excitement of discovery—of seeing what few people, if any, have ever seen before, the sense of achievement and of comradeship—provides the moving force for exploration.

During the 19th century exploring the planet we live on was a widespread undertaking. By the turn of the century most of the world had been mapped, but the huge continent of Antarctica, half again the size of the United States, remained largely unexplored and unknown. To that time no man had ever stood at either end of the earth's rotational axis.

The most important results of my father's two Antarctic expeditions—more important by far than standing at the Pole itself—were the priceless data collected by his scientific colleagues on the geology, glaciology, meteorology, and natural history of the region. The Antarctic plays a vital role in the earth's environmental systems, including its

ROGER WEAR

climate and weather patterns.

I was two and a half years old when my father died. In his farewell letter to my mother, found with his body eight months after his death, my father wrote: *Make the boy interested in natural history if you can; it is better than games; they encourage it at some schools. I know you will keep him in the open air. Above all, he must guard and you must guard him against indolence. Make him a strenuous man. I had to force myself into being strenuous as you know—had always an inclination to be idle.*

He forced himself quite successfully, and few people ever knew of that inclination. There can be no doubt that the members of his expedition held him in high regard, notwithstanding recent attempts in print and on television to suggest otherwise.

Robert Falcon Scott set himself high goals and blamed only himself on the rare occasions when those goals were not met. His immediate reaction to the discovery that Amundsen had reached the South Pole before him was one

of concern for his teammates.

It is a terrible disappointment, he wrote in his diary, *and I am very sorry for my loyal companions. Many thoughts come. . . . To-morrow we must march on . . . and then hasten home. . . . All the daydreams must go; it will be a wearisome return.*

None of the five men survived. My father and two companions made it to within 11 miles of safety—a depot of supplies known as One Ton Camp some 150 miles from their base camp (map, page 546). They had walked more than 1,600 miles, to the Pole and almost back. There, frightful weather pinned the team down, and on March 29, 1912, my father wrote in his diary: *Since the 21st we have had a continuous gale from W.S.W. and S.W. We had fuel to make two cups of tea apiece and bare food for two days on the 20th. Every day we have been ready to start for our depôt 11 miles away, but outside the door of our tent it remains a scene of whirling drift. I do not think we can hope for any better things now.*

Nearly a year later my mother received my father's last request with regard to my upbringing. Through the years that followed she put me in the way of famous naturalists of the day—Sir Ray Lankester, Sir Arthur Shipley, and Sir Julian Huxley, who was to become a lifelong friend. These men took a great deal of trouble to teach me. I am indebted to my father, to them, and to many others for steering me toward a career in natural history.

I am no less indebted to my mother, a professional sculptor of some distinction, for involving me in the arts, particularly in painting, which has been my principal source of income for the last 54 years. My deep concern for Antarctica is an outgrowth of both those interests.

LT. H. R. BOWERS, POPPERFOTO, LONDON

A hard-won triumph *was celebrated January 17, 1912, as Scott, second from right, and his party raised the Union Jack at the South Pole after a torturous 78-day journey from Cape Evans. But sweet success was soured by evidence that they were not the first in history to reach the Pole. A team led by Roald Amundsen had beaten them by five weeks, leaving behind the flag of Norway.*

HERBERT PONTING, FOTOFOTO, LONDON

Less arduous aspects *of the expedition occupy Scott in his book-lined quarters at Cape Evans. For homey touches, Scott kept a picture of his wife, Kathleen, on his desk, right, and installed a pipe rack on the wall at left. On the bed lies his naval jacket, which he carried with him for good luck.*

Like Scott, the 1986 team also overwintered in the comfort of a hut, from which members made short though grueling training forays before the run for the Pole.

SINCE my father's day Antarctica has become a vast natural laboratory for the study of our planet. What a breathtakingly beautiful laboratory it is, too. I have been privileged to visit the Antarctic five times, first as a guest of the United States and later in the cruise ships *Navarino* and *Lindblad Explorer*. I find Antarctica one of the most majestic regions on earth. The continent's sheer size is stunning. It covers some 5.4 million square miles, an area that doubles in winter due to increases in the surrounding ice pack.

I have three times visited my father's overwintering hut at Cape Evans, which has been cleared of snow and maintained by the New Zealanders precisely as it was when he left it 76 years ago. I have also twice visited Sir Ernest Shackleton's hut at Cape Royds, from which he launched his historic expedition that took him within 112 miles of the South Pole in 1909 before he had to turn back.

Traveling by air, I spent three days as a guest of the Americans at their Amundsen-Scott South Pole Station. The base is a marvel of huts constructed within chambers set into the polar snowfield, with every imaginable convenience, including the most southerly flush toilet in the world.

These visits to Antarctica have underscored for me the peril which that unique wilderness faces today. Even before my father's time commercial sealers and whalers had begun the overexploitation of Antarctica's rich stocks of seals and whales. The slaughter stopped only when dwindling numbers of some species became uneconomical to hunt.

When I contemplate such terrible waste and lack of foresight, I am reminded of an old Portuguese proverb that runs: "Architects cover their mistakes with creepers, cooks with sauces, doctors with earth."

By contrast, I would suggest that man covers the earth with his mistakes, and in few places is the damage as lasting as in Antarctica. When one considers that a mere footprint in the Antarctic moss may remain visible for decades, one begins to appreciate the extreme fragility of that environment.

Yet we seem slow to learn. Even now the 18 nations known as consultative parties to the Antarctic Treaty are discussing how mining will be carried out for platinum, coal, oil, and other minerals if commercial deposits are found underground or beneath the sea.

All parties acknowledge the high risks of oil spills, pollution, and the harmful effects of industrial activity on the Antarctic environment. Yet many consider these risks perfectly acceptable in exchange for a few years'

The author is the son of British polar explorer Capt. Robert Falcon Scott, who died with four companions after reaching the South Pole on January 17, 1912—five weeks later than the Norwegian team led by Roald Amundsen. **Sir Peter Scott** is a distinguished naturalist, painter, and co-founder of the World Wildlife Fund-International, the first person to be knighted for services to conservation.

additional supply of raw materials.

Antarctica's isolation has been no defense against contamination by a distant world. Traces of DDT have been found in Adélie penguin eggs and in the flesh of seals. Plastic rubbish washes ashore on the continent's beaches, perhaps from sources thousands of miles away.

WHAT IS TO BECOME of this last great wilderness on earth? A growing number of people throughout the world believe that the Antarctic should be declared the first truly international park in history. It is an exciting concept that some of us have been thinking about for years.

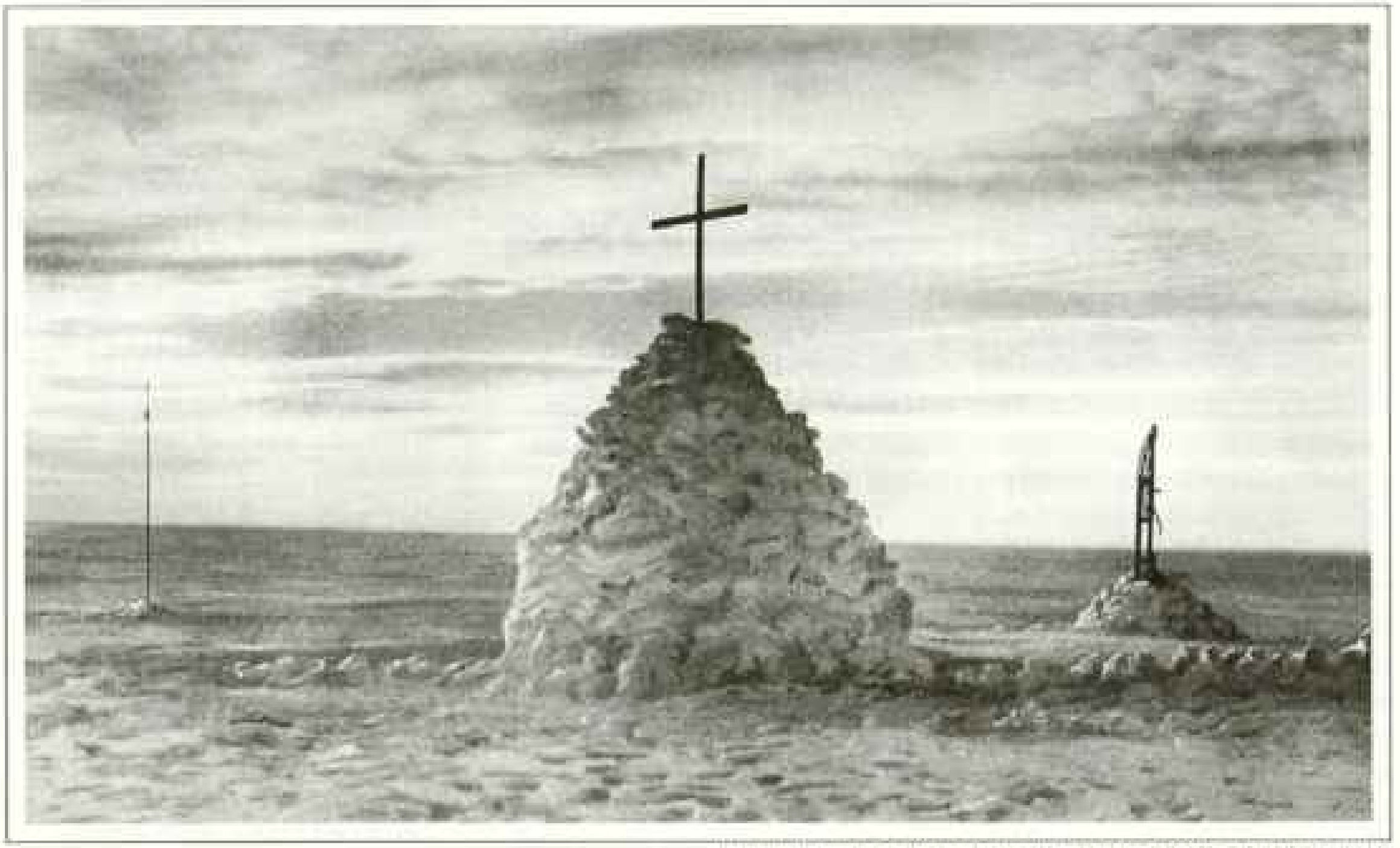
Antarctica's natural resources, including its incredible beauty, must be given the very highest priority. Designation as a world park could guarantee that priority by forbidding development, mining, or the harvesting of any living creature within the continent's boundaries.

Perhaps such a concept is too advanced for our day, but time will tell. The optimist says, "We live in the best of all possible worlds," while the pessimist is rather afraid that he may be right. My own philosophy lies somewhere in between. I do not believe we live in the best of all possible worlds, but there is certainly no case for allowing people to make it worse.

My father devoted the last 12 years of his life to Antarctica and greatly expanded our knowledge of that vast, dangerous, and unbelievably splendid continent. The three young men who recently retraced his footsteps to the South Pole and whose story follows are men of similar character. Such was their regard for the pristine purity of Antarctica that they carried their rubbish with them rather than contribute unnecessary pollution.

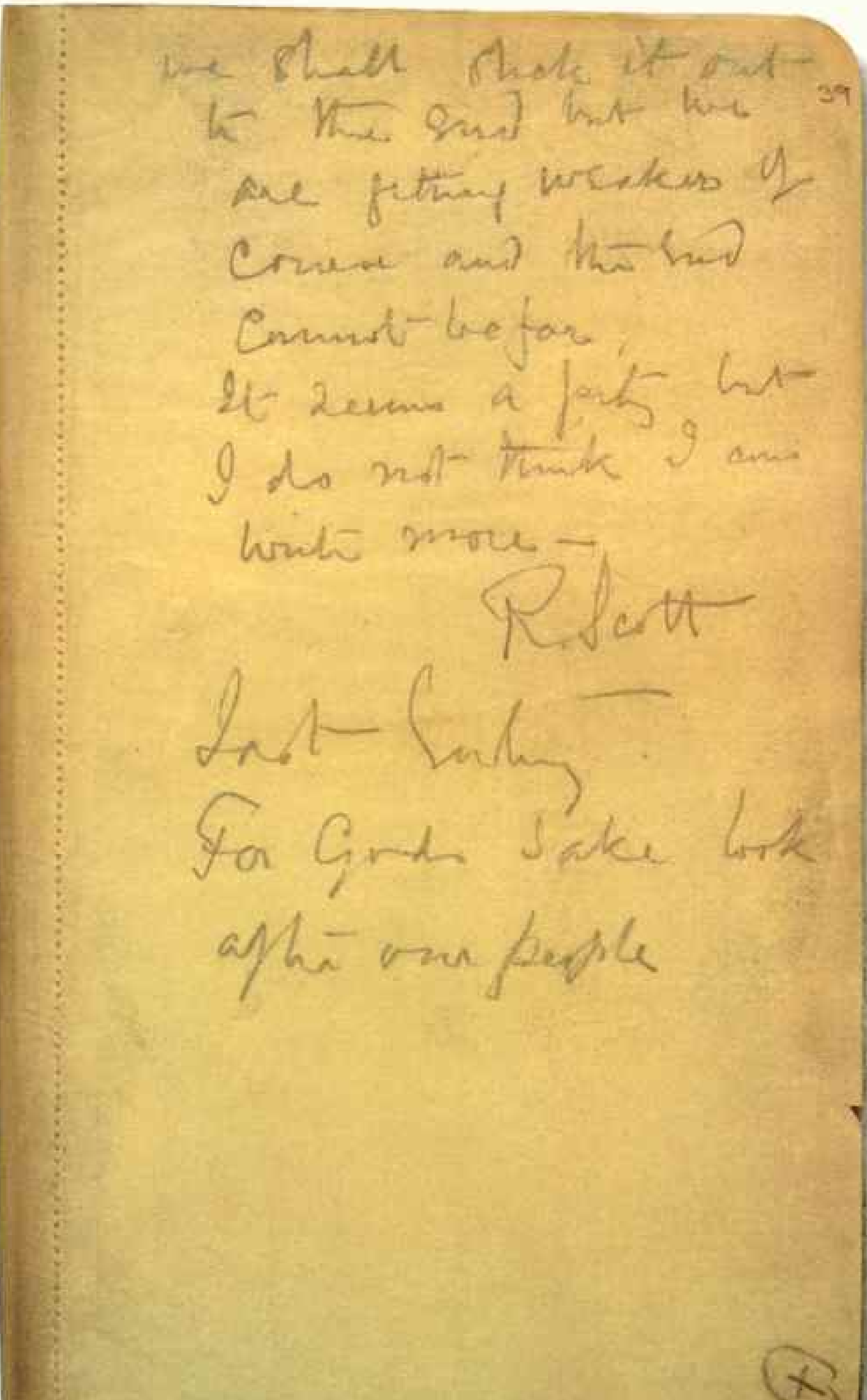
I have unreserved admiration for Robert Swan, Roger Mear, and Gareth Wood. Their journey was most ably organized and was, in my view, enormously worthwhile. They made a number of significant refinements in the techniques of polar travel and contributions to the study of human physiology at low temperatures—advances that will be of benefit in future years.

I am proud to have been a patron of this undertaking to commemorate Robert Falcon Scott's last expedition. * * *



PHOTOGRAPH BY SEARCH PARTY, POPPERFOTO, LONDON (ABOVE); THE BRITISH LIBRARY

Shrine to adventurers, *a cross-topped cairn was erected on the spot where the bodies of Scott and two companions were found by a search party in 1912. The other two members of Scott's group had died earlier on the trek back from the Pole. Scott's concern for others, even as he foresaw death, is reflected in his last diary entry* **(right)**, *found with his body, which lay only 11 miles from a supply depot.*


we shall stick it out
to the end but we 39
are getting weaker of
course and the end
cannot be far.
It seems a pity but
I do not think I can
write more —
R. Scott
Last Entry
For God's sake look
after our people

In the Footsteps

# of Scott

By ROBERT SWAN

ROGER MEAR

IT WAS A SIMPLE ACCIDENT but a costly one. As I towed my sledge across the glacier, the vehicle suddenly slewed around, wedging my foot in a crack in the ice. As I went down, I heard the ligaments in my knee snap and thought simply, "This time you've had it."

Far ahead I could make out the tiny figures of my partners, Gareth Wood and Roger Mear. Even if they noticed me, there was little they could do: Although we were a close-knit team, on the trail it was every man for himself.

As I sat motionless, the pain and an icy polar wind closed in on me like a pack of wolves around an injured animal. For perhaps the first time in my life I was truly frightened, and fear acted like a shot of adrenaline. Despite the searing pain, I forced myself to stand and discovered that the knee would hold me. Leaning into my waist harness, I inched slowly forward against the massive weight of the sledge.

Somehow that day—Sunday, December 15, 1985—I managed to keep moving and caught up with my partners as they were making camp. It was a grim conversation that night in our sleeping bags inside the tent as we discussed my situation.

We were 471 miles from Antarctica's Cape Evans, the starting point of our expedition to the South Pole in the footsteps of Robert Falcon Scott. With 424 miles still to go, we had passed the point of no return and must now continue toward the Pole. Like Scott 74 years before us, we carried no radio and thus could not summon help. I must somehow make it on my own.

"Don't worry, it'll be OK," Roger said, perhaps with more confidence than he felt.

***In a supreme test** of self-reliance, author Swan and his men—like Scott—took no radios or dog teams on their trek. Not as alone as he'd hoped, Swan shows dismay at finding five men at a temporary research camp. From there on they met no other humans until they reached the Pole.*

In Scott's Footsteps

Their journey took the team to the heart of a land nearly twice as large as Australia. Though traveling during the southern summer, the trio encountered high winds, blinding snow, and temperatures as low as minus 20°F. Except for a slight deviation on Beardmore Glacier, the team followed Scott's route and arrived five days ahead of schedule. Equally inspirational was the journey of Sir Ernest Shackleton, who came within 112 miles of the Pole in 1909.

Merciless winds *in the Ross Sea spit spray onto the ice-coated Southern Quest, the team's support ship. True to Scott's route, the ship called at Cardiff, Wales; Cape Town, South Africa; and Lyttelton, New Zealand, before arriving at Cape Evans.*

Swan became interested in Antarctica while studying ancient history at the University of Durham in England. Working with the British Antarctic Survey, he met Roger Mear, one of Britain's foremost mountaineers. Together they hatched the idea for the expedition, teaming up with Canadian Gareth Wood, a mountaineering instructor.

"You'll just have to crack on at your own pace. Do your best, and we'll never separate too far from you. But we can't slow up at this point. . . ."

I agreed completely. Through the sleepless hours that night I thought of Scott's brave but despairing words, entered in his diary weeks before he and his two remaining companions died of exposure and starvation on their return from the Pole.

"We cannot help each other," he had written, "each has enough to do to take care of himself. . . . We mean to see the game through with a proper spirit, but it's tough work. . . . One can only say 'God help us!' and plod on our weary way. . . ."

My own situation was serious but far from hopeless; like Scott and his men I must simply plod ahead and not lose spirit. Roger and Gareth and I had long ago agreed what we would do if one of us became totally incapacitated. The other two would drag him on a sledge, though at far greater risk to their own survival. If two men became incapacitated, the third would have to attempt to tow one and leave the other to die.

Fortunately I could still move, as could Gareth, who was suffering terribly from a foot blister that would not heal. Though the injuries didn't immobilize us, they were a constant reminder of the narrow line we walked between success and disaster.

My accident occurred on the 43rd day of our trek. We had departed Hut Point on November 3, at the start of the Antarctic summer, after nearly a year of training for our attempt on the Pole. At the outset we hauled 42-pound sledges, each carrying 311

REBECCA HARD

pounds of equipment and supplies, which had been stripped down even to the point of removing the protective wrapping around our high-energy chocolate bars.

OVER the nearly 900-mile journey we would consume an average of 5,100 calories a day in food, though experts at home had assured us we would need at least 8,000 calories daily. Once on the trail our loads gradually lightened as we consumed food and cooking fuel. We took the daily ration in turn from each of the three sledges. The weight loss was only six pounds at a time, but it seemed more like 20 when one's own sledge was involved.

What little rubbish we generated we carried with us, for we refused to add to the pollution of Antarctica.

Our first great obstacle was the Ross Ice Shelf, an immense plain of floating ice some 400 miles in width and roughly the area of France. Though seemingly level, the shelf is an endless labyrinth of ice ridges, small crevasses, and treacherous snow crusts that crumble under the slightest weight. It's often said that the Eskimos, or Inuit, have dozens of ways to describe snow and ice surfaces, but from my experience with the Ross Ice Shelf I'd say that's not nearly enough.

By the end of our second week we were roughly a third of the way across the ice shelf, near the point where Scott and his two companions were trapped in their tent by a blizzard and starved to death. Had they been able to travel only 11 more miles, they would have reached one of their major supply depots and perhaps survived.

As we set up our own tent that night, I thought of a line from Scott's "message to the public," penciled during his last days. It was a simple, moving passage that perhaps more than any other single thing had inspired our expedition in his footsteps:

"We are weak, writing is difficult, but for my own sake I do not regret this journey, which has shown that Englishmen can endure hardships, help one another, and meet death with as great a fortitude as ever in the past."

At age 19 **Robert Swan** bicycled 6,000 miles from Cape Town to Cairo in seven months. Later expeditions took him to Iceland and Antarctica.

REBECCA WARD (ABOVE); GARETH WOOD

***Last link** to the outside world, the Southern Quest lies off Cape Evans **(above)** preparing for the trip to Sydney, Australia, where she waited out the winter before returning. The team's headquarters, at right, named Jack Hayward Base in honor of an expedition benefactor, lay 200 yards from Scott's hut, left. Swan busied himself **(below)** by writing thank-you letters to more than a thousand other sponsors.*

Nearing the point *of no return, Gareth Wood follows Swan across Beardmore Glacier toward the Cloudmaker, peak at right, the halfway mark. A wheel on the sledge measures distance traveled; the team averaged 12.5 miles a day.*

AFTER OUR THIRD WEEK we were halfway across the ice shelf and had developed new respect for the brutal weather that plagued Scott and his men. One entry in my journal sums it up:

November 24, 215 miles out. Stiff head wind developed to Blizzard from South. Going rough, not able to see. The surface is hell. Each mile has to be fought for and won.

ROGER MEAD

As the days and miles passed, we developed a standard routine. Wake-up was at 6:30 a.m., followed by a breakfast of oatmeal and a mug of hot chocolate, both heated over a tiny gas stove and eaten while we were still in our sleeping bags. Then came the business of rising, dressing, and breaking camp.

Though we were in top condition—I at age 29 and Roger and Gareth in their 30s—getting under way was always a chore. Slowly and stiffly, like rusted old machines, we would collapse the tent, pack the sledges, harness up, and begin our standard nine-hour daily trek on skis.

After the first three hours on the trail we would stop for a lunch of salami, biscuits, butter, and chocolate, then trek for another

three hours. After a second break we would trudge the last three hours, then make camp and cook our freeze-dried meal. By then we were usually so exhausted that we acted more like zombies than men, and it was all we could do to tend the day's minor aches and injuries and make notes in our diaries.

Hunger and boredom were constant companions. To relieve the latter, each of us had his own special trick. Mine was to imagine the daily trek from one campsite to another as a stroll across London. One day, for example, I would walk from Hampstead Heath to Euston Station, and on another from the Barbican to Westminster Abbey. Along the way I would visualize every landmark and feature I could recall. But there was a problem. Despite my best efforts, I would also picture every restaurant, café, and food shop en route, and I invariably finished my stroll hungrier than ever.

To guard against discouragement at difficult times, we followed a cardinal rule: Every day was treated entirely separately and on its own, not as another step nearer our ultimate goal. Still, we couldn't help celebrating occasional milestones. On December 10, our 38th day, we reached the end of the Ross Ice Shelf and confronted the next challenge, an ascent of the great Beardmore Glacier—a climb of 9,000 feet spread over a distance of 120 miles. Beyond the glacier lay the Polar Plateau and a straight 356-mile shot to the South Pole.

To traverse the glacier, we exchanged our skis for crampons and kept constant watch for deep crevasses. The danger was not confined to us alone, for to lose a sledge with its vital food and equipment was nearly as serious as losing a man.

ALMOST AT ONCE the Beardmore dealt us an unexpected blow. Near the base of the great ice formation Roger climbed a small ridge to film Gareth and me as we began our ascent. Suddenly from a distance of 50 yards I sensed something very wrong with Roger. He had turned to glance behind him and simply froze in an attitude of total shock.

"What's wrong?" I shouted. "Roger, what is it?" No answer, and then as Gareth and I joined him on the ridge, we followed his gaze toward higher ground and instantly understood. There, dotting the pristine snow like droplets of oil on a clean bed sheet, lay a cluster of tents.

The shock was stunning. We had never expected to encounter other humans in the course of our trek to the Pole. We had planned the expedition retracing Scott's route carefully so as to face the same challenges, dangers, and isolation that he and his men had endured three-quarters of a century earlier.

Now, through no one's fault, that isolation had been compromised. For a moment we considered simply ignoring the fact and going on our way, but that would not change matters. Instead, we approached the tents and introduced ourselves.

The men in the camp were American geologists led by Dr. Donald DePaolo and Dr. Scott Borg of the University of California at Los Angeles. The team was collecting samples of granite from the central Transantarctic Mountains for clues to the action of plate tectonics on the earth's crust some 500 million years ago.

Dr. DePaolo introduced us to his colleagues: John Goodge, also of UCLA, Dr. James Mattinson of the University of California at Santa Barbara, and a Russian scientist, Dr. Eugene Mikhalsky of Leningrad's Institute of Oceanology.

"Join us for dinner," Dr. DePaolo generously offered, and we were soon enjoying a meal of steak and lobster. The food was delicious, but after weeks of plain if nourishing fare, our stomachs later rebelled with severe cramps.

When we left on December 13, Eugene pressed a small chocolate bar on us as a gesture of Soviet goodwill. "Good luck," Jim added, and with handshakes all around we turned to the Beardmore Glacier.

Our shift from skis to crampons for the ascent may have put me off stride, for it was on the third day of the climb that I tore the ligaments in my knee.

Within hours the knee swelled to ghastly size, though miraculously it still functioned. The injury meant I would take longer to cover the same distance than Roger and Gareth, but there was no alternative.

"Nurse it as much as you can, Robert," Gareth said of the knee. "I'm certain it will heal once we're back on skis."

REBECCA WARD

Triumph and misfortune *came hand in hand for expedition members. At the very moment they arrived at the Pole, the Southern Quest was sinking after being crushed by ice off Beaufort Island, where she awaited the team's return. Although there were no injuries, the adversity that so closely followed success was, to Swan, a final and unfortunate parallel to that of the Scott expedition.*

DESPITE Gareth's and my injuries, we scaled the Beardmore in remarkable time: seven days, compared with the 12 it took Scott and his men. At the head of the glacier we skirted the infamous Shackleton Icefalls, a great frozen battlement named for the British explorer Sir Ernest Shackleton, who came within 112 miles of the South Pole in January of 1909—three years before either Amundsen or Scott reached it. Bad weather and dwindling supplies forced Shackleton's party to turn back almost within sight of their goal, a blow perhaps as cruel as that suffered by Scott when he discovered that the Norwegian Roald Amundsen had reached the Pole five weeks before him.

Once atop the Polar Plateau we felt an unspoken conviction: We were going to make it after all. We had less than 350 miles still to go, most of it easier than the terrain we had covered. Like Scott, however, we concentrated on our day-to-day progress rather than on the possibility of success. Gareth summed it up in his diary:

December 20. 500-odd miles down. Nine hours a day, day after day we have marched. It feels like being on a train, a slow-moving one, but to leave that train would mean death. . . .

At almost this same point Scott, too, had reflected on the endless marching:

"There have been some hours of very steady plodding today; these are the best part of the business, they mean forgetfulness and advance."

True to Gareth's prediction, once we were back on skis, my knee and his blister

GARETH WOOD (ABOVE); ROGER HEAR

***Tea for three** makes for a modest Christmas treat (**left**) as Mear coaxes ten cups from just two tea bags, the entire supply. Because of tea's low food value, the men devoted precious cargo space to high-calorie beverages such as cocoa.*

*A barber pole marks the "bottom" of the earth (**facing page**), where Swan, Wood, and Mear display Britain's Union Jack and the flag of a BBC children's program amid the flags of other nations. Opus, the penguin featured in the Bloom County cartoon strip, stands in comical witness to the celebration of a daring challenge successfully met.*

gradually healed. In other respects the Polar Plateau was less kind to us. During our ascent of the Beardmore Glacier the weather had been almost balmy for Antarctica. Temperatures near zero had caused us to strip down to a mere layer or two of clothes. But at an altitude of 10,000 feet on the Polar Plateau the combination of wind and severe cold became a constant, dangerous factor.

Yet there was beauty as well. Atop the plateau one felt an incredible sense of space, and the quality of light was extraterrestrial. Silver particles of ice floating in the air gave rise to startling phenomena. The sun poised above us within a great milky halo, and in the course of the earth's revolution one's shadow would creep playfully round one like a mischievous wraith from the past.

We celebrated Christmas Day with the one luxury we had allowed ourselves—two tea bags we had brought along for a special occasion. We managed to extract ten cups from the two bags before we conceded we were merely drinking hot water.

"It was delicious," Roger observed, "and after all, this expedition wouldn't be really British without at least one cup of tea on the way to the Pole."

For dessert we carefully divided Eugene Mikhalsky's chocolate bar into three tiny but equal portions and wished him well wherever he was on this Christmas Day.

We had 277 miles still to go, and despite our Christmas feast, hunger still dogged us like an unrelenting beggar. I no longer took my imaginary walks across London. Instead I had fantasies of sitting at an empty table in a restaurant while all around me the most sumptuous dinners were being served and eaten with the greatest relish. I watched and waited, but no waiter ever came to my table.

AS WE NEARED THE POLE, I thought more and more of Scott. At this stage of his trek he had become a seasoned pessimist, as an entry in his diary reveals:

"At present everything seems to be going with extraordinary smoothness, and one can scarcely believe that obstacles will not present themselves to make our task more difficult. Perhaps the surface will be the element to trouble us."

Prophetic words across three-quarters of a century, for as it had done to Scott in 1912, Antarctica now played its penultimate trick on us. When we were only 145 miles from the Pole, it ushered in 1986 with a New Year's Eve gift of sastrugi, or wind-scoured snow ridges, averaging two feet in height, which continued for 56 unending miles of purgatory. New Year's Day was conspicuous in that the sastrugi almost doubled in height.

To make matters worse, a strong, steady wind blew up from the south, whipping the snow directly into our faces. No horizon, no contrast, no surface definition. But with our compass and sextant we were a match for the elements. Still, even the smallest navigational error now could cause us to miss the U. S. Amundsen-Scott South Pole Station. Though we carried 88 days' worth of food

and 90 days' fuel, we were now in our 68th day and the margin was growing thinner.

As we neared our goal, my thoughts turned increasingly to the tragedy that had befallen our predecessor. On January 9 I made one of the last entries in my diary:

Two more good marches and we'll be there. Scott is with me now. Oh, how that Norwegian flag must have broken his heart.

TWO DAYS LATER—January 11, 1986—we reached the South Pole, five days ahead of our original schedule. In the full light of an Antarctic summer evening I spotted a domed structure off to our right, and we made for it. Along the way we passed a small marker flag, and I fingered the frayed material, as perhaps Scott had touched the Norwegian flag. For him that flag symbolized defeat. This flag was our symbol of victory.

Lee Schoen, manager of the Amundsen-Scott South Pole Station, and his crew came toward us across the snow, and suddenly we were engulfed in a jubilant crowd.

"You made it!" Lee exclaimed. "A great trek, you guys. Everyone's proud of you."

And then, in our moment of triumph, Antarctica played its last cruel trick on us.

"I'm sorry, I have bad news for you," Lee added when the congratulations were over. "We've had a radio message that your support ship, *Southern Quest*, was trapped in the ice off Beaufort Island and is sinking. The crew is safe and your plane was gotten off intact, but I'm afraid the ship's gone."

The news was a heavy blow, for we had planned all along to conduct our expedition without any outside help. Although our plane could still fly, the Americans preferred to airlift us to McMurdo Sound themselves, and we felt obliged to accept.

We paid all expenses requested of us, and Gareth and two members of our ship's crew remained another year at the Cape Evans camp to remove all traces of our expedition. We felt it important in the spirit of those who had gone before us to complete our expedition in a proper manner.

We had followed in Robert Scott's footsteps and perhaps in doing so had called the world's attention once again to a historic achievement whose tragic ending in no way diminishes the spirit and courage for which it will always be remembered.

There can be no finer tribute to Scott and his men than the line on his memorial in Antarctica, taken from Tennyson's "Ulysses":

"To strive, to seek, to find, and not to yield." □

A British team following the route of Robert Falcon Scott approaches

ANTARCTICA

The great white continent still beckons explorers intrigued by the unknown, be they adventurers testing their mettle or scientists seeking answers in a pure environment. The future of Antarctica, with its vast resources locked in an icy vault, is guarded by an international treaty.

By PRIIT J. VESILIND
NATIONAL GEOGRAPHIC SENIOR WRITER

ROGER RICH

the U. S. Amundsen-Scott Station at the South Pole on January 11, 1986.

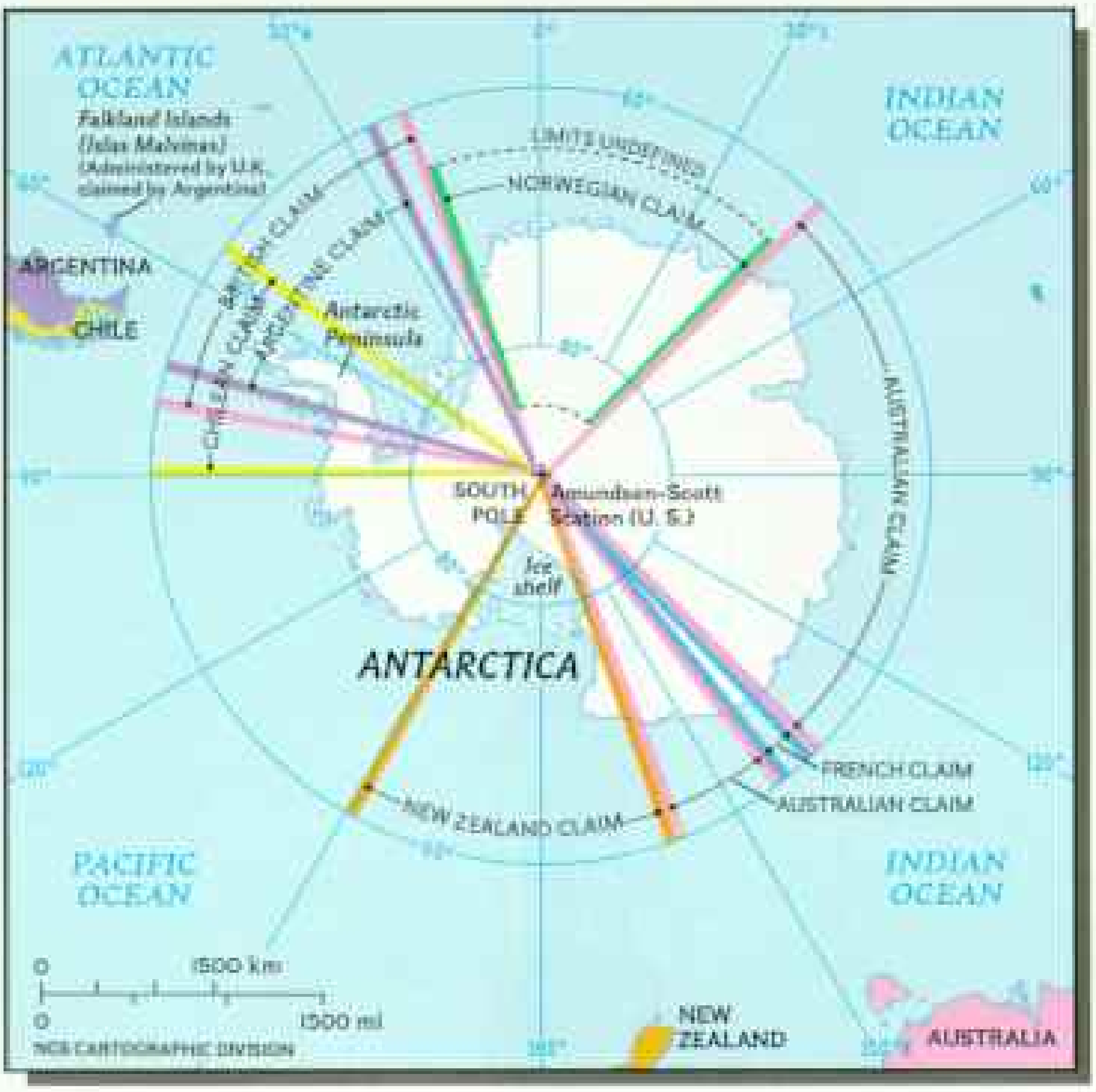
ANTARCTICA, that bleak, white place, still defies full understanding. Man, earth's most meddlesome creature, has reached the moon but has yet to explore the frozen continent into submission.

But the face of the continent is swiftly emerging. The map accompanying this issue shows dozens of new features—ridges, elevations, details of coastline—added since the GEOGRAPHIC's last Antarctic supplement map in 1963. Says map consultant Guy Guthridge of the National Science Foundation, "Thirty years ago only one-third of the Antarctic had been seen. Now the world has a good understanding of its topography. This map is a celebration of the progress."

A thousand tourists visited the continent on cruise ships in 1986, but serious exploration of any sort has come at great cost. Most of Antarctica is covered by ice and clawed by howling winds, a landscape as blank and hostile as the moon. Darkness prevails for six months each year, temperatures near minus 90°C (-129°F), and ice shelves 120 meters (400 feet) thick spread into the surrounding ocean. Humans who winter over live like rodents in burrowlike stations. Outside work is often impossible.

Yet, as earth's other natural resources dwindle, nations eye the Antarctic as a final repository. Who wants Antarctica? And what right do they have to pursue it?

The continent surrounding the South Pole



Who owns *this land with no native population? Seven nations press often conflicting claims* (**above**), *but a 1959 treaty forbids new claims and calls for free access for scientific purposes. However, the treaty is not universally recognized.*

A supply ship sits off the tip of the disputed Antarctic Peninsula (**right**), *where children of personnel stationed at Argentina's Esperanza research base go sightseeing.*

constitutes nearly a tenth of the world's land but is owned by no one. It has no indigenous people to press land rights, as has the Arctic. Pie-slice sections are claimed by seven nations—the United Kingdom, Argentina, Chile, Australia, New Zealand, South Africa, and Norway. Neither the United States nor the Soviet Union, prime players on the southern stage, claims Antarctic territory nor honors the claims of others. But both consider the continent politically important. A multitude of developing countries clamor in the United Nations for their share of . . . whatever is there.

FOR NOW, science is king, thanks to the Antarctic Treaty of 1959, a highly successful international agreement among 12 scientifically active nations—Argentina, Australia, Belgium, Chile, France, Japan, New Zealand, Norway, South Africa, the Soviet Union, the United Kingdom, and the United States.

In the 1986-87 austral summer, with constant light and higher temperatures, 57 scientific stations operated on the continent, manned by scientists from 18 nations. The United States sponsored 255 researchers and 74 experiments, ranging from studies of variations in cosmic-ray intensity to the measurement of energy expended by emperor penguins.

The Antarctic Treaty grew from the International Geophysical Year (IGY) of 1957-58, a scientific assault on the Antarctic, and called for scientific stewardship of the world south of latitude 60 degrees. It froze territorial claims, banned military

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activity, and established Antarctica as a nuclear-free zone. It provided all nations freedom of scientific inquiry but obligated them to share the results. The question of resources was avoided, but timely resolutions have kept research from crossing the line into prospecting.

The treaty has evolved through regular meetings of its consultative parties, originally the 12 nations who conducted the IGY. Since then, six other nations who have carried out substantial scientific research in Antarctica—East Germany, Poland, Brazil, India, China, and Uruguay—have been accepted into the "club." Sixteen more nations have agreed to abide by its terms.

"The Antarctic Treaty is one of the most important postwar arms-control and antinuclear agreements," asserts R. Tucker Scully, Director of Oceans and Polar Affairs in the U. S. Department of State. It has worked so smoothly that an Australian representative suggested, wistfully, that it should be extended ten degrees in latitude each year until it covered the globe.

The treaty does not interfere with historical claims, as long as claimant nations do not interfere with the science. The fact that British, Chilean, and Argentine claims overlap has been ignored. Even during the Falklands (Malvinas) crisis in 1982, Britishers and Argentines sat side by side in Wellington to discuss Antarctic projects.

Australia, Chile, and particularly Argentina have been most active in keeping their claims alive. Argentina has set up a post office and in 1978 flew a pregnant woman to its base at Esperanza, where Emilio Marcos

Palma was born and promptly declared an Argentine citizen.

Most claimant nations seem content with the treaty, but 1991 draws near. In that year any consultative nation will be able to ask for a review of the treaty and possibly withdraw from it. Yet few Antarctic experts feel the date will be significant. Says Mr. Guthridge, "As far as I can see, 1991 will slide right on past. We have pretty much of a consensus among the treaty nations that they have a lot more to lose by abandoning the treaty than they have to gain."

The most pressing issues of the Antarctic relate to resources. The southern waters are fertile, supporting a short, delicate food chain: great whales, seals, penguins, and their primary diet—squid, fish, and shrimplike crustaceans called krill.

Whales have been randomly hunted for more than a century. With the depletion of some species, krill have amassed in spectacular swarms, and fur seals have prospered on the excess food. Krill have been ballyhooed since the 1960s as a major new source of protein for a hungry world, but large-scale commercial krill fishing, led by the U.S.S.R. and Japan, has scarcely begun.

To regulate commercial harvesting and protect the continent's environment, the consultative parties have adopted two conventions. One, ratified in 1978, protects Antarctic seals. Another, to protect "marine living resources," took effect in 1982.

ANTARCTICA has always inspired grandiose schemes. It has been proposed as a dump for nuclear wastes and as cold storage for the world's excess food. The Antarctic contains three-quarters of the world's fresh water locked in its ice, and dry nations have dreamed of dragging icebergs home to Australia, Saharan Africa, and the Middle East.

But world thirst for oil, gas, and other minerals will probably determine the continent's future, even though today's recovery technology seems inadequate. Minerals are locked under an immense, year-round sheet of moving ice as much as five kilometers (three miles) thick. Even if needed resources lie beneath, most researchers contend that the cost of extraction would be staggering.

Oil, tapped from offshore rigs, would be more accessible. But there is no proven potential, despite encouraging core samples and much speculation. The U. S. Geological Survey states flatly: "No known petroleum resources occur in Antarctica."

Major oil companies, already curbed by environmental regulations, are staying away. Says Nahum Schneidermann, supervisor of basin studies for Chevron Overseas Petroleum: "The fact is, the world now has a surplus of hydrocarbons that could last for the rest of the century. But in the next hundred years, who knows? Antarctica may become an important frontier, simply because it will be the last frontier."

OVER THE PAST six years the treaty's consultative parties have begun to hammer out a farsighted minerals regime that will examine if, when, and how the extractions of the future should proceed. But talk of mineral wealth, even in potential terms, has excited strong reaction. Environmental groups such as Greenpeace, whose members paraded in penguin costumes outside a recent Antarctic Treaty meeting in Brussels, distrust the motives of the consultative nations. They push to preserve Antarctica as a world park, the last unsullied continent.

Meanwhile, more than a hundred developing nations have denounced the treaty organization as unfair. In 1983 they raised the "Antarctic question" in the United Nations, borrowing a phrase from the 1982 Law of the Sea Convention that labels unclaimed deep-sea beds "the common heritage of mankind." In their view the treaty organization is self-appointed and thus arbitrary, secretive in its meetings and thus arrogant.

Treaty nations, led by the United States and the Soviet Union, answer that they have spent great sums of money and many years in the interest of science, and that the condominium has maintained peace and stability. What would be the alternative? If oil were found in great quantities, for example, would there be a chaotic land rush?

For now, the Antarctic Treaty protects the common interest. National claims are frozen; their boundaries (page 558) are relegated to a small inset on our supplement map. Exploration continues, but without the exploitation that usually follows. □

NATIONAL GEOGRAPHIC SOCIETY

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NATIONAL GEOGRAPHIC MAGAZINE

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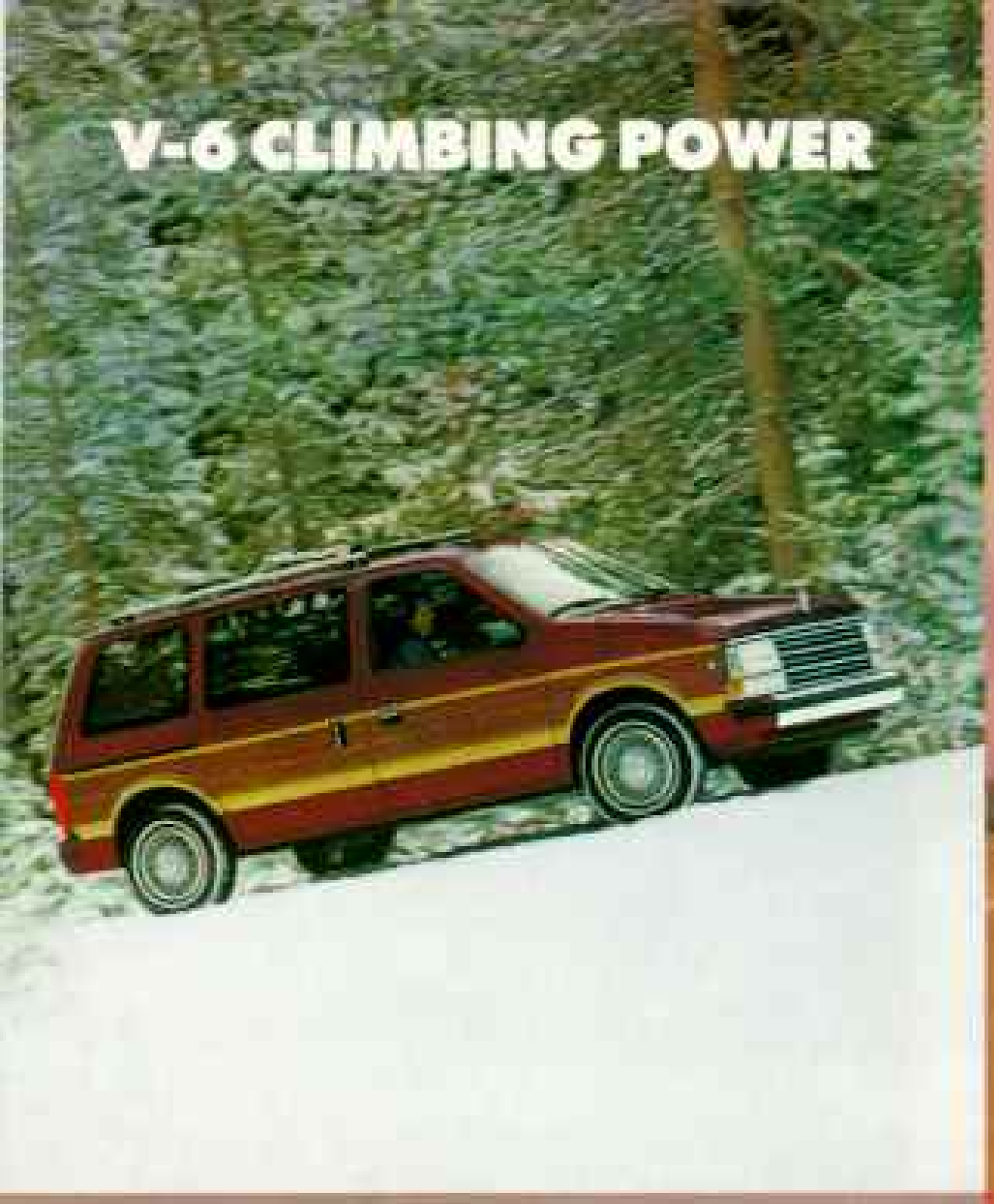
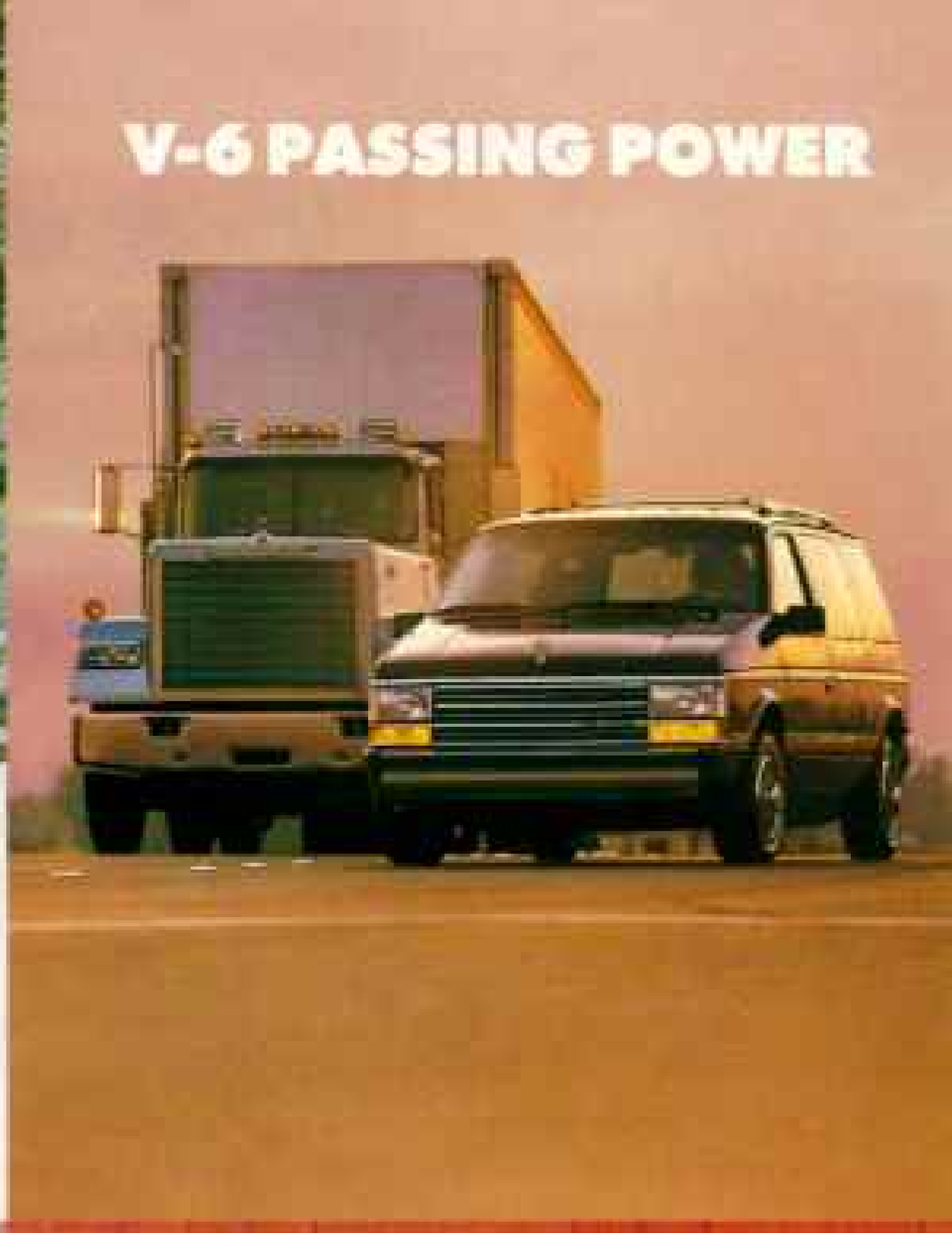
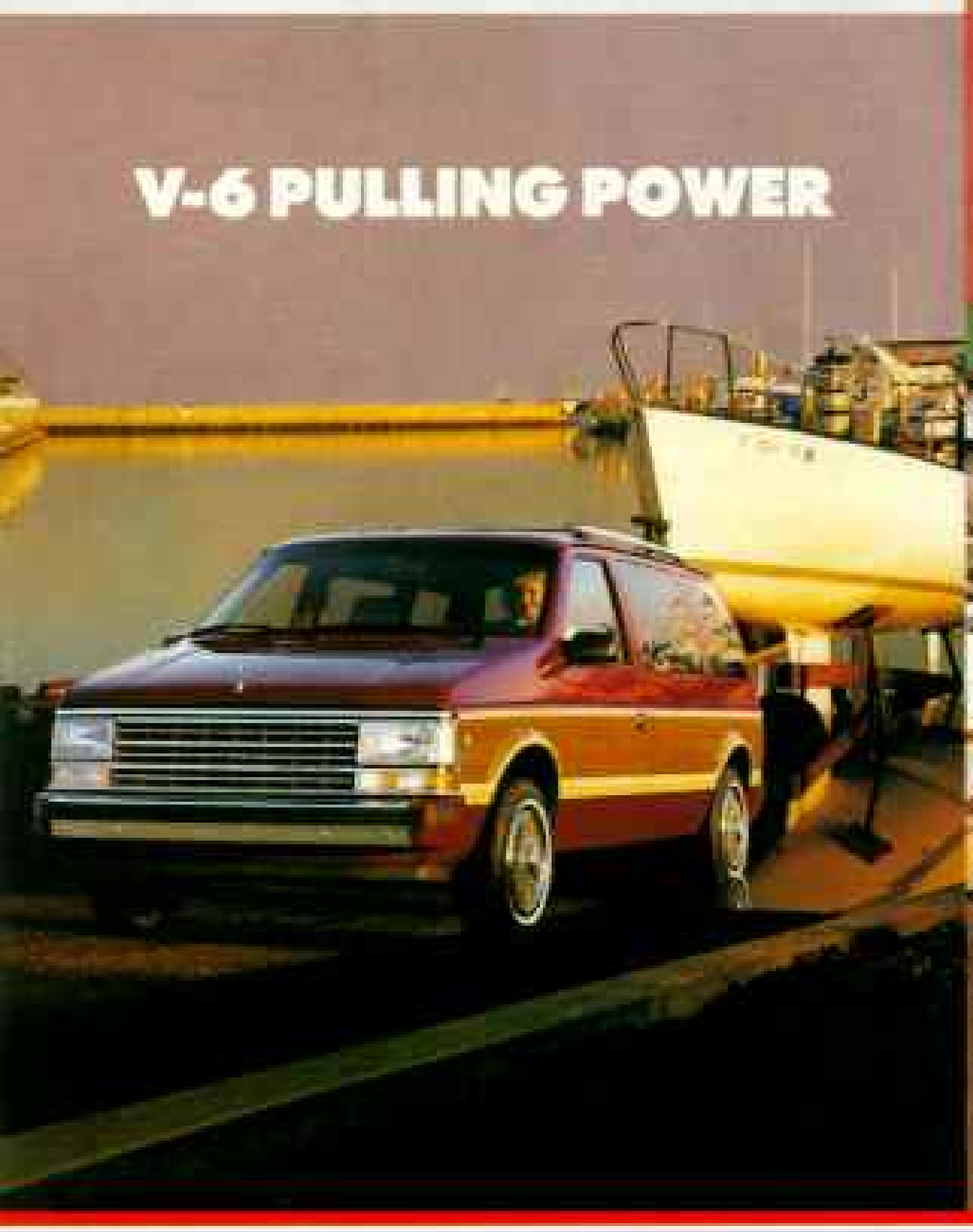
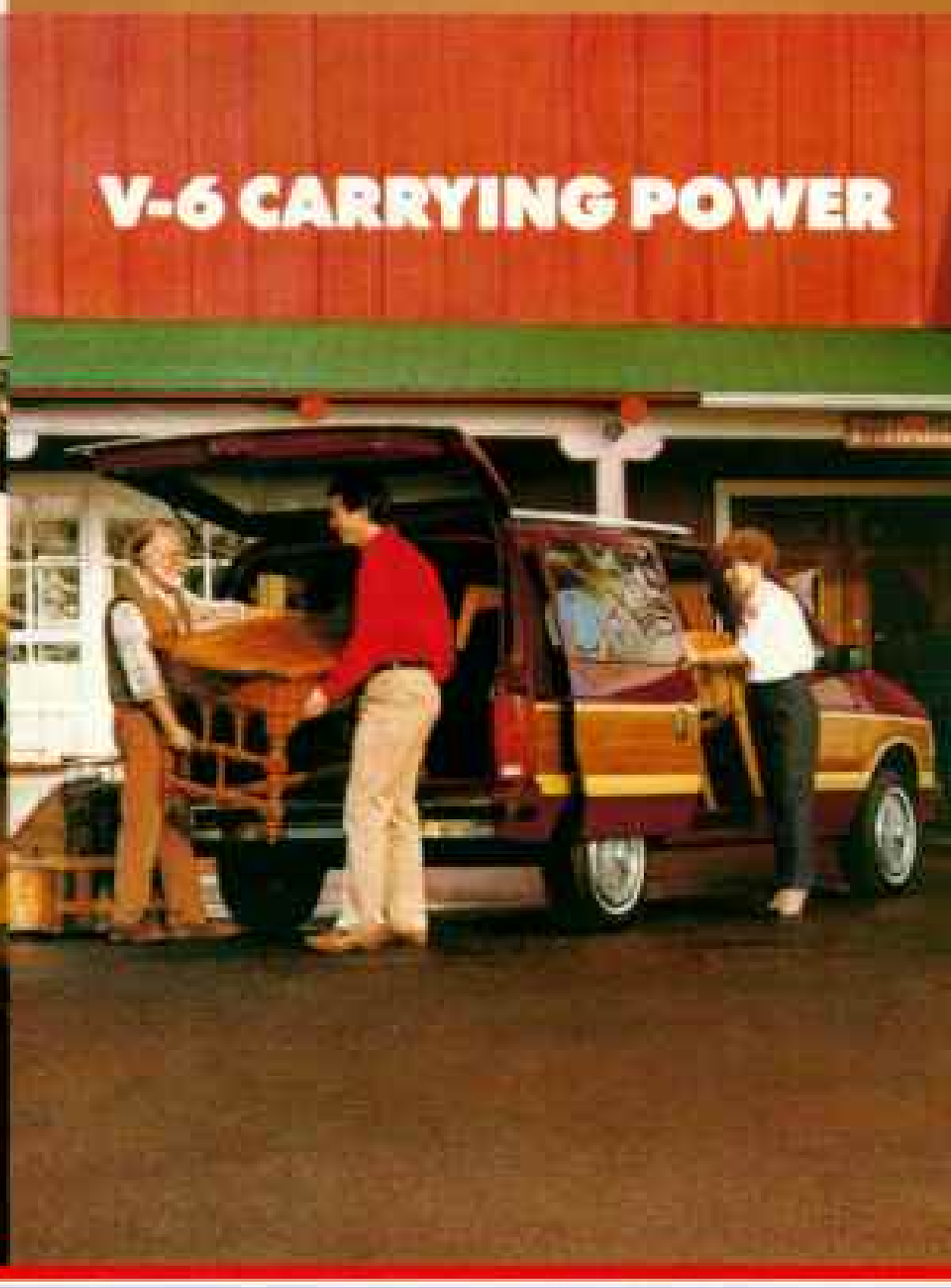
*Optional. **Protects engine and power train for 7 years or 70,000 miles and against outerbody rust-through for 7 years or 100,000 miles. See limited warranty at dealer. Restrictions apply. †Based on survey of owner problems with '85 cars and light trucks (combined) sold Oct.-Nov. '85 (5 month avg. usage) and a warranty comparison of competitively priced models for vehicles designed and built in N. America. BUCKLE UP FOR SAFETY.









VOYAGER V-6

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Under way: the National Geographic Kids Network

"SCIENTISTS HAVE BEEN DOING this for five million years, and, just think, we're only kids, and we can do it."

At the age of 12, Jeff in California had made a debatable assumption (that there were scientists five million years ago) and an important discovery (that students his age could do real, if basic, science—investigate levels of acid in rain and compare data).

"I couldn't believe the results!" said Ryan in Nebraska, who found that rain near his rural, one-room school was more acid than rain where his New York City and California colleagues lived.

Jamie in Nebraska commented: "You can understand better when you have someone else's data along with your own."

Exactly. Jamie and his fellow fourth-through-sixth-grade experimenters at nine schools across the country had worked together recording and comparing the range of acidity or alkalinity of common liquids including rain. It was the pilot project of what will eventually become the full-fledged National Geographic Kids Network.

The NGS Kids Network is designed to help students do research on issues of scientific, social, and geographic significance—such as climate variations, comparative botany, and air and water quality. Having gathered information in their communities, they will channel data from their schools' microcomputers through a telecommunications network to a topic scientist, who, using a powerful central computer, will receive and store the data. The topic scientist will then process the information into charts, maps, or other forms for student analysis. Finally, the students—like scientists everywhere—will compare and share their results nationwide.

We are now moving from pilot project to major program—from nine participating schools to the potential for 10,000 participating schools within five years. This is not

JOSEPH H. BAILEY, NGS

ERICH BLOCH, AT LEFT, DIRECTOR OF NSF, REVIEWS THE NGS KIDS NETWORK PILOT PROJECT WITH GILBERT M. GROSVENOR AND ARTHUR NELSON, PRESIDENT OF TERC.

an undertaking to be assumed lightly—or alone. Our principal partner will be the nonprofit educational research and development corporation Technical Education Research Centers (TERC), assisted by Dickinson College in Carlisle, Pennsylvania.

The National Science Foundation (NSF) will be a major source of funding, through TERC, for the National Geographic Kids Network. Without NSF's farsighted commitment, it would have been almost impossible to have moved from pilot stage to program stage.

Working together—and with teachers across the nation—I am confident that all of us involved in the NGS Kids Network will develop techniques and materials to truly engage students in science and geography.

In California, Matthew summoned his 12-year-old wisdom and put his experience with the pilot network this way:

"We are sharing among the other schools, and we are helping the United States. It's not just for schools." I agree.

Gilbert M. Grosvenor

PRESIDENT, NATIONAL GEOGRAPHIC SOCIETY

At Bret's Skysailing, you can't soar without a little daring, and you can't soar at all with American Express.

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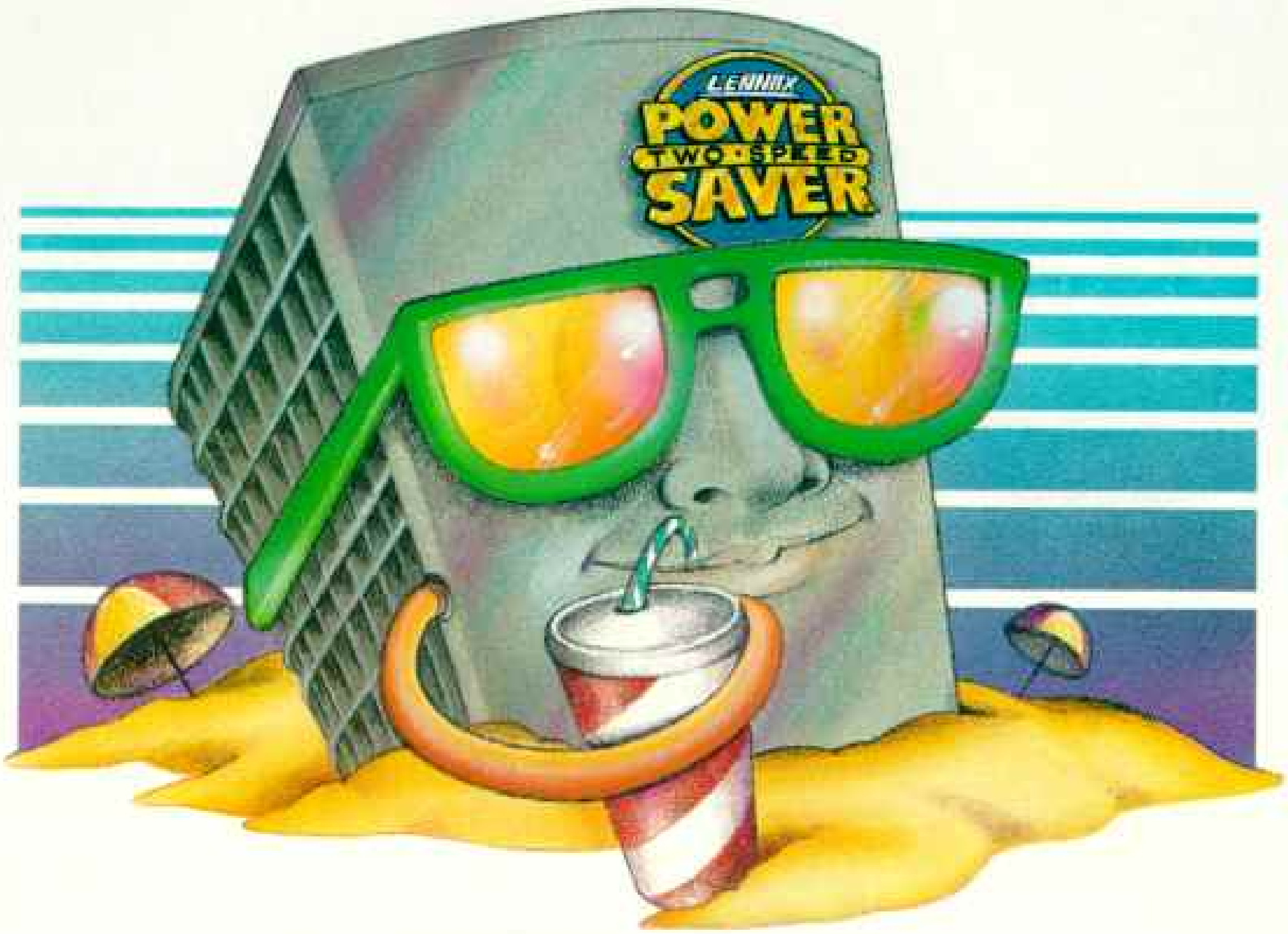

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Gavin MacLeod, Panama Canal *British Registry*

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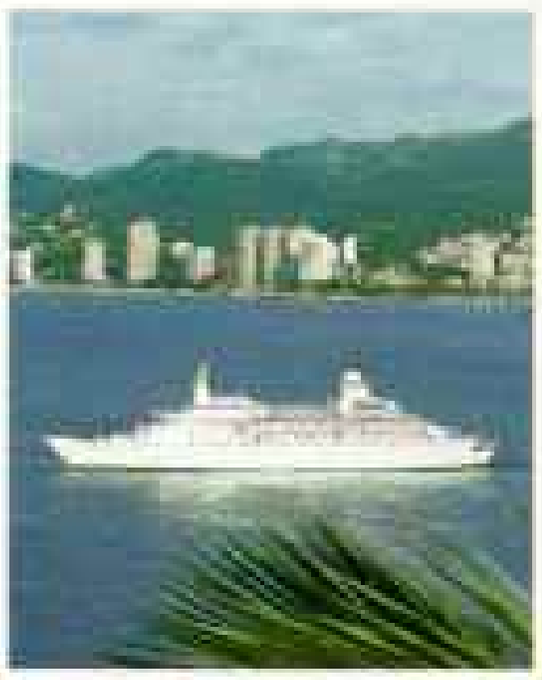

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Once, a phone was a phone and a computer was a computer.

And anybody could tell the difference.

Today, however, telephones routinely boast computer memories, computer intelligence, even computer screens.

And computers are discovering the power of networking, as telephones already have.

The name of the game is getting the right information to the right people at the right time.

Because being able to do that easily will make our work more productive and our lives less hassled.

And that's what AT&T is all about today.

Our goal is to do for information what we have already done for conversation.

To accomplish that, the people at AT&T Bell Laboratories are working to combine everything you like about telephones with everything you expect from computers.

So computers will finally deliver what they have been promising for decades.

Consider some examples: Some day soon, instead of being limited to the new cars available in a dealer's inventory, you'll be able to sit down at a computer terminal in the dealer's showroom and enter the model you want, the engine, the options, the color, etc.

A data network will automatically translate your order into instructions to dozens of suppliers and plants in the production process. The result is a custom-made car delivered faster than you ever thought possible.

In banking, powerful and versatile data networks could mean loan approval in minutes instead of weeks. And account balances that are always current.

In retailing, a chain whose stores employ a data network could always have hot-selling items in the stores where they're selling hottest. Pleasing both the customer and the company controller.

The idea is networks which not only move information instantly, but which also interpret it, rearrange it and apply it in the most useful way. All automatically.

Just as the AT&T long distance network handles a telephone call, instantly, intelligently, automatically.

Which is to say, we're very close to the day when you won't be able to tell a phone from a computer, and won't even care.

But until then, the phone cord is the one on the top.

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The right choice.

Members Forum

Custer

"Ghosts on the Little Bighorn" (December 1986) gives new data on the events of 1876. Past experience apparently was not a teacher for Custer, because in 1868 he attacked Black Kettle's camp on the Washita with 500 men. Six thousand Southern Plains Indians were camped nearby, and only the usual "Custer's Luck" prevented him and his men from being annihilated at that time.

Joseph C. Webb, Jr.
Austin, Texas

At least ten Canadian troopers in the Seventh Cavalry were killed at the Little Bighorn, including Lt. William Cooke, Custer's adjutant, whose written message to Benteen for help is the last word we have from Custer's doomed command. Cooke is buried in Hamilton, Ontario, which has an energetic group of Little Bighorn buffs.

Dan Bjarnason
Toronto, Ontario

Being of American Indian descent, I read the article with interest and sadness. It's about time the Indian was given some respect and the real truth told. Why make Custer out to be such a hero when his intent was to kill innocent women and children as well as the warriors? I am so tired of Indians being depicted as murdering savages. Thank you for not being biased.

Arlone Weitkamp Moreno
Fort Thomas, Kentucky

We have made another exciting discovery at the battlefield. Dr. Clyde Snow, forensic anthropologist, identified skull fragments including teeth from a marker excavation as those of a 35-to-45-year-old man of mixed racial heritage who smoked a pipe. The only man killed in the battle to fit that description is Mitch Boyer, Custer's half-Sioux scout, who warned him against entering the valley. To test this circumstantial evidence, we used television cameras to superimpose a picture of the bones on our photograph of Boyer. We had a precise match. The fragments' sharp edges indicate the skull was crushed, probably by a war club.

Douglas D. Scott
National Park Service
Midwest Archeological Center
Lincoln, Nebraska

The "silver" five-cent coins on page 801 are actually composed of 75 percent copper, 25 percent nickel and were commonly referred to as "shield

nickels" because of the shield design on the obverse. They were minted from 1866 to 1883.

George W. O'Neal
Elkins, Arkansas

Many knowledgeable members have written about these coins. For all collectors, Mr. O'Neal is right. The shield nickels were confused with silver "half dimes," minted as late as 1873 but not commonly used because of their small size.

Like the North and South in the Civil War, Americans fought each other at the Little Bighorn. That battlefield is a monument to American war heroes, white and red. It should not be named after the winner or loser.

Thomas V. Rotole
Camdenton, Missouri

The Custer Battlefield is the only national memorial to the soldiers who gave their lives for the U. S. during the Indian Wars of the last century; it should remain so. If we must have balance between factions at this battlefield, then we should for all: the Japanese at Pearl Harbor, the Mexicans at the Alamo. I do not denigrate the Indians, but their memorial should be on their own reservation at Lame Deer or Wounded Knee.

William M. Pond
Carmichael, California

The Sioux were not merely defending a "way of life." They were defending land that had been pledged to them in the last treaty between the Sioux nation and the U. S. in 1868—a treaty not abrogated to this day.

John Koster
Glen Rock, New Jersey

It doesn't seem reasonable that the Sioux could call the Black Hills their "sacred ground." Minnesota and the Great Lakes would seem more appropriate. The Sioux were woodland Indians forced out of their homelands by pressure from the east. Their migration west was slow, until they acquired horses. The Black Hills were originally occupied by the Crow and Cheyenne tribes and the Kiowa before them. The Sioux drove out other tribes in the 1820s. They occupied the Black Hills no more than 60 years before they were driven out by the gold seekers.

Medwin W. Mitchell
Parachute, Colorado

Custer's last stand, the *Titanic* disaster ad nauseam! However often retold and examined by archaeologists, the stories remain—one of monumental arrogance and the other of compounded stupidity. What's next, the charge of the Light Brigade at Balaklava or Mrs. O'Leary's cow in Chicago?

J. W. Stiffi
Tabb, Virginia

Titanic

The eerie images of the sunken liner (December 1986) were spontaneously studied by my fifth-grade class. The public would be surprised at the genuine depth of student interest (even from ten-year-olds) in past historical events, be it the unearthing of King Tut's tomb, the exploits of magician Harry Houdini, or the Apollo moon landings. A dramatic presentation such as your magazine provided can help children *and* adults imagine what it must have been like to be there *live*. Your portrayal of the great ship's tragedy was sensitively handled and unforgettable.

John J. Karolewsky
Carol Stream, Illinois

The 1,500-plus people who stood on the stern that cold April night awaiting death would not have considered the ship "a symbol of an age long past." It was and is a symbol of failed technology and man's failure to provide for the welfare of fellow human beings. The *Titanic* should be removed from the depths and displayed so that this and future generations can understand the anguish and bravery of those who perished.

Steve A. Foster
Piedmont, South Carolina

I feel as if I had been along on Robert Ballard's journey. Is there a possibility that a collection of the videotapes will be made available for purchase? I believe that if Dr. Ballard narrated them, they would be treasured items for many, many years.

Buddy G. Moore
Pincoining, Michigan

We agree and have produced an hour-long video, "Secrets of the Titanic," *available from the Society for $29.95 or at videotape outlets.*

For all the credit Ballard deserves, I sharply disagree with one of his conclusions that deep-sea research can be done "faster and better *without* man's physical presence in the sea." This does immeasurable harm to the future of ocean science. Man's "mind in the sea" is our greatest asset. To contemplate replacing it with a machine is not a progressive view for the future.

Richard W. Grigg
Department of Oceanography
University of Hawaii
Honolulu, Hawaii

The article was fascinating. However, the measurements used were meaningless to me and many colleagues. The majority of the world's population functions with the metric system. Could you not accommodate us by listing both units of measurement in *all* your very interesting articles?

R. Saba
Toronto, Ontario

Tsetse Fly

Having hunted big game all over Zimbabwe, I can assure you that, as stated in the December 1986 issue, when the fly goes, so will the game. After aircraft sprayed our hunting area, we found many dead or dying snakes, toads, small animals, and fish. The worst indirect effect of the fly-control program is poaching. Once an area is partially cleared, human occupation literally explodes and poaching becomes rampant. Not a day went by during the two months I hunted in fly-controlled areas but that at least half a dozen snares were found. The locals make these snares from the high-tensile stainless wire they cut from the fly-control fences. In addition, controls over chemicals are so lax, locals barter for them to use to kill river fish. While cattle and goats are despoilers of the African bush, their owners are the most vicious threat to its wildlife.

Emil A. Furlane
Joliet, Illinois

Westminster

"The Palace That Became Parliament" (December 1986) was very interesting and informative—among the best articles of 1986. Congratulations to Patrick Cormack and Adam Woolfitt.

Spyros S. Veliotis
Athens, Greece

It is not true that a constitutional monarch has the right to consult and to advise. The monarch has the right to be consulted, to encourage, and to warn. It is the Queen's ministers who advise her, and a constitutional monarch must accept such advice. They are answerable to Parliament, which is ultimately answerable to the electorate.

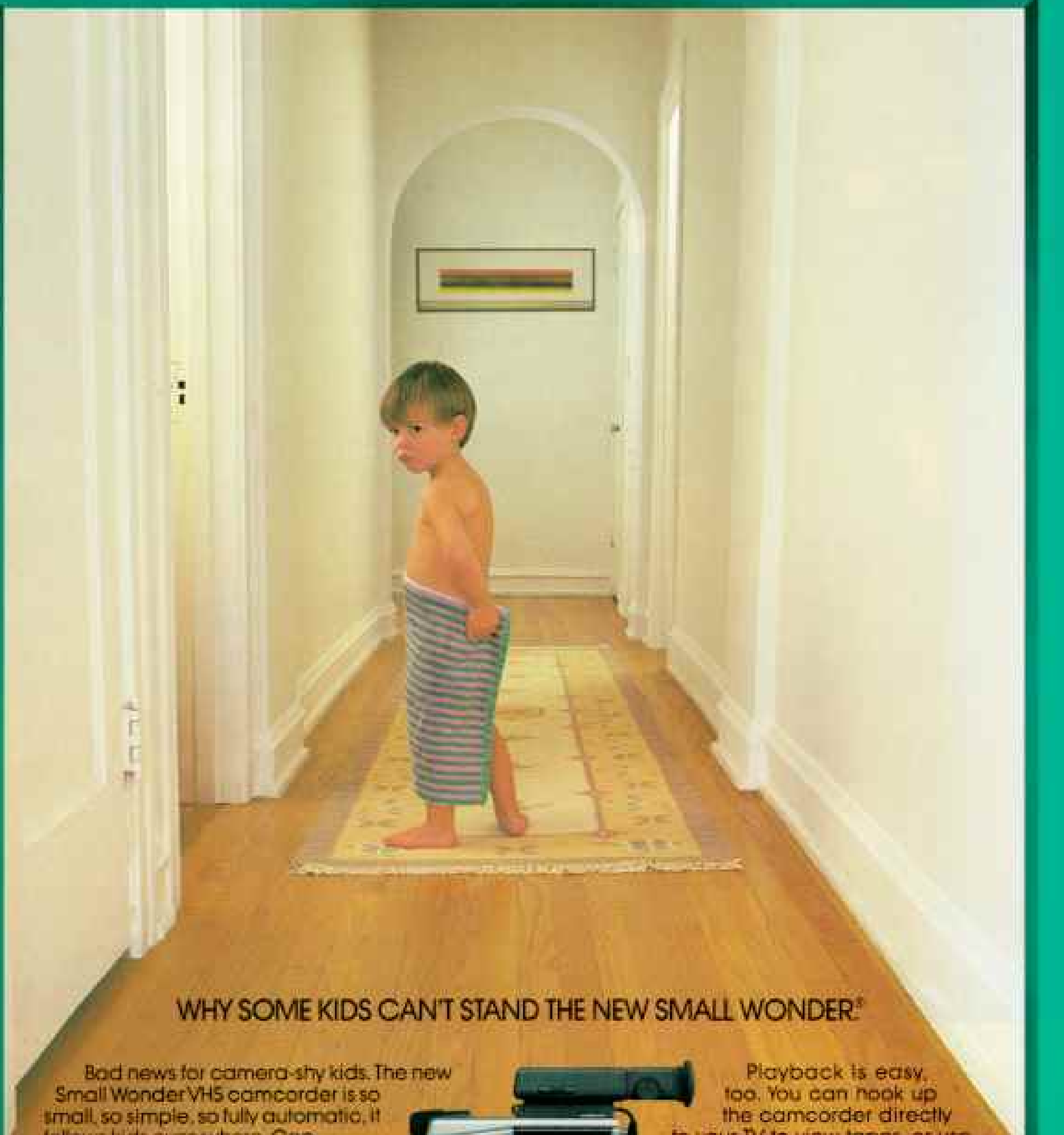
Bernard Black
St. John's College
Southsea, Hampshire

Although such articles provide a vivid and accurate reflection of historical and cultural Britain, the Society appears oblivious to the problems faced in both rural (e.g. agricultural quotas, urban sprawl, declining services) and urban (e.g. unemployment, housing, racial tension) society here. Coverage of such subjects in conjunction with more pleasant aspects would not only provide balance and diversity but also reflect a lifestyle more recognizable as that of the vast majority of contemporary British people.

Joseph Nicholson
Prudhoe, Northumberland

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.*

S M A L L



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The new Small Wonder from RCA makes it easy to enjoy great video memories. In fact, it just might be the world's easiest camcorder. Sorry, kids.

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Golden-shouldered Parrot **Genus:** Psephotus **Species:** chrysopterygius **Adult size:** Length, 26cm **Adult weight:** 54-56g **Habitat:** Semi-arid savannah woodland and open forest, where termite mounds are prevalent, in southern Cape York Peninsula, Queensland, Australia **Surviving number:** Unknown

Photographed by Hans and Judy Beste

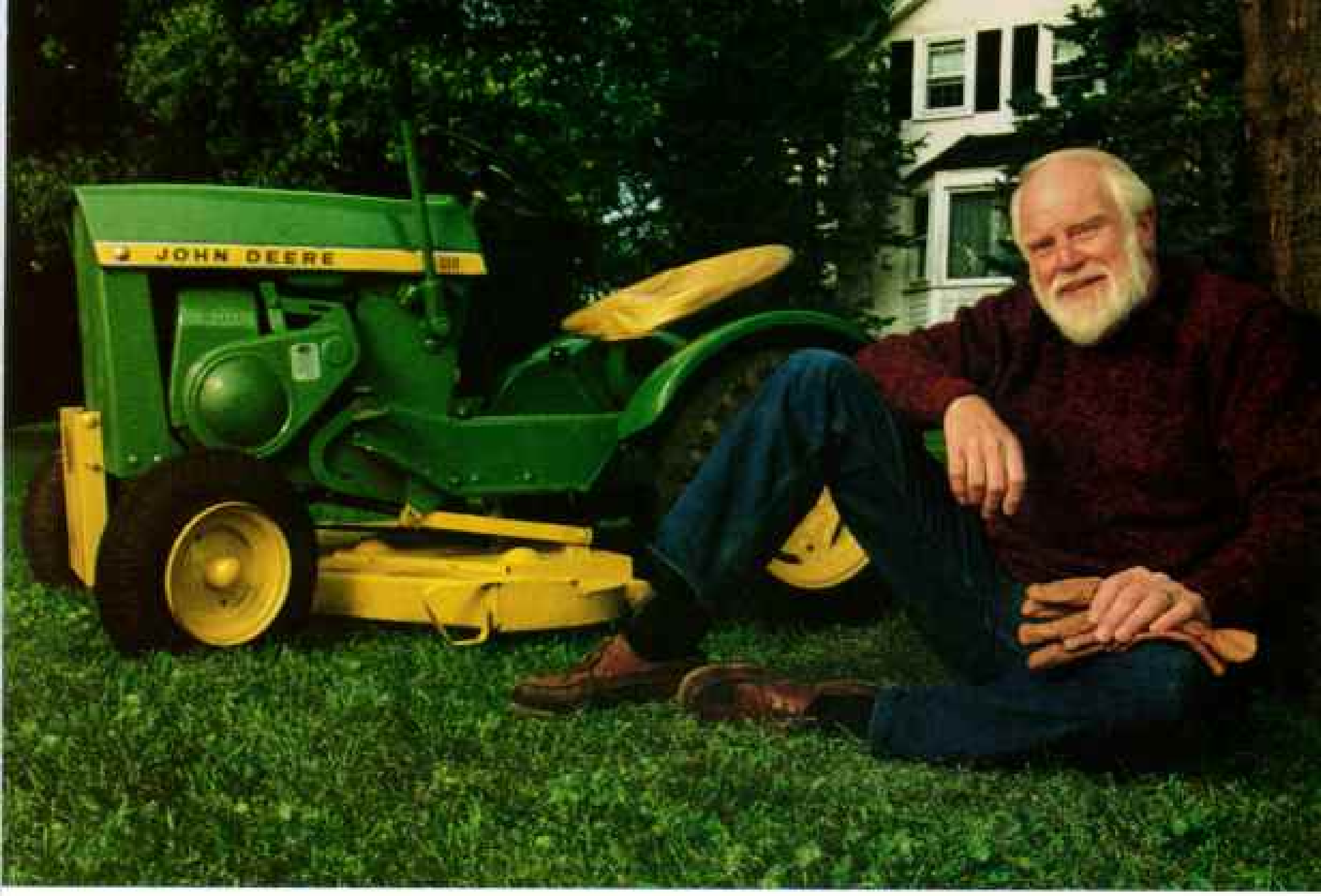
Wildlife as Canon sees it

One of the greatest roles of photography is to record and preserve images of the world around us worthy to be handed down as a heritage for all generations. A photograph of a pair of golden-shouldered parrots has a unique power to capture the elegance of this colorful bird.

Native to Australia, the golden-shouldered parrot nests in active termite mounds, burrowing an entrance to a chamber where it lays four to six eggs on a bed of crumbled earth. Gone from many areas of its original range, this parrot survives only in fragmented groups, leaving the species particularly vulnerable. Trapping for the bird trade and the disturbance of its habitat by agricultural activities are further contributing to the decline of the species.

An invaluable research tool, photography can also play a vital role in preventing the demise of the golden-shouldered parrot by enhancing our knowledge and understanding of this magnificent bird.

And understanding is perhaps the single most important factor in saving the golden-shouldered parrot and all of wildlife.



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• Power Steering	• Power Steering	• Power Steering	• Power Steering
• Electronic AM/FM Stereo Radio	• Electronic AM/FM Stereo Radio	• Electronic AM/FM Stereo Radio	• Electronic AM/FM Stereo Radio
• Electronic Digital Clock	• Electronic Digital Clock	• Electronic Digital Clock	• Electronic Digital Clock
• Tinted Glass	• Tinted Glass	• Tinted Glass	• Tinted Glass
• Interval Wipers	• Interval Wipers	• Interval Wipers	• Interval Wipers
• Reclining Bucket Seats	• Reclining Bucket Seats	• Reclining Bucket Seats	• Reclining Bucket Seats
• Tilt Steering Wheel	• Tilt Steering Wheel	• Tilt Steering Wheel	• Tilt Steering Wheel
• Rear Window Defroster	• Rear Window Defroster	• Rear Window Defroster	• Rear Window Defroster
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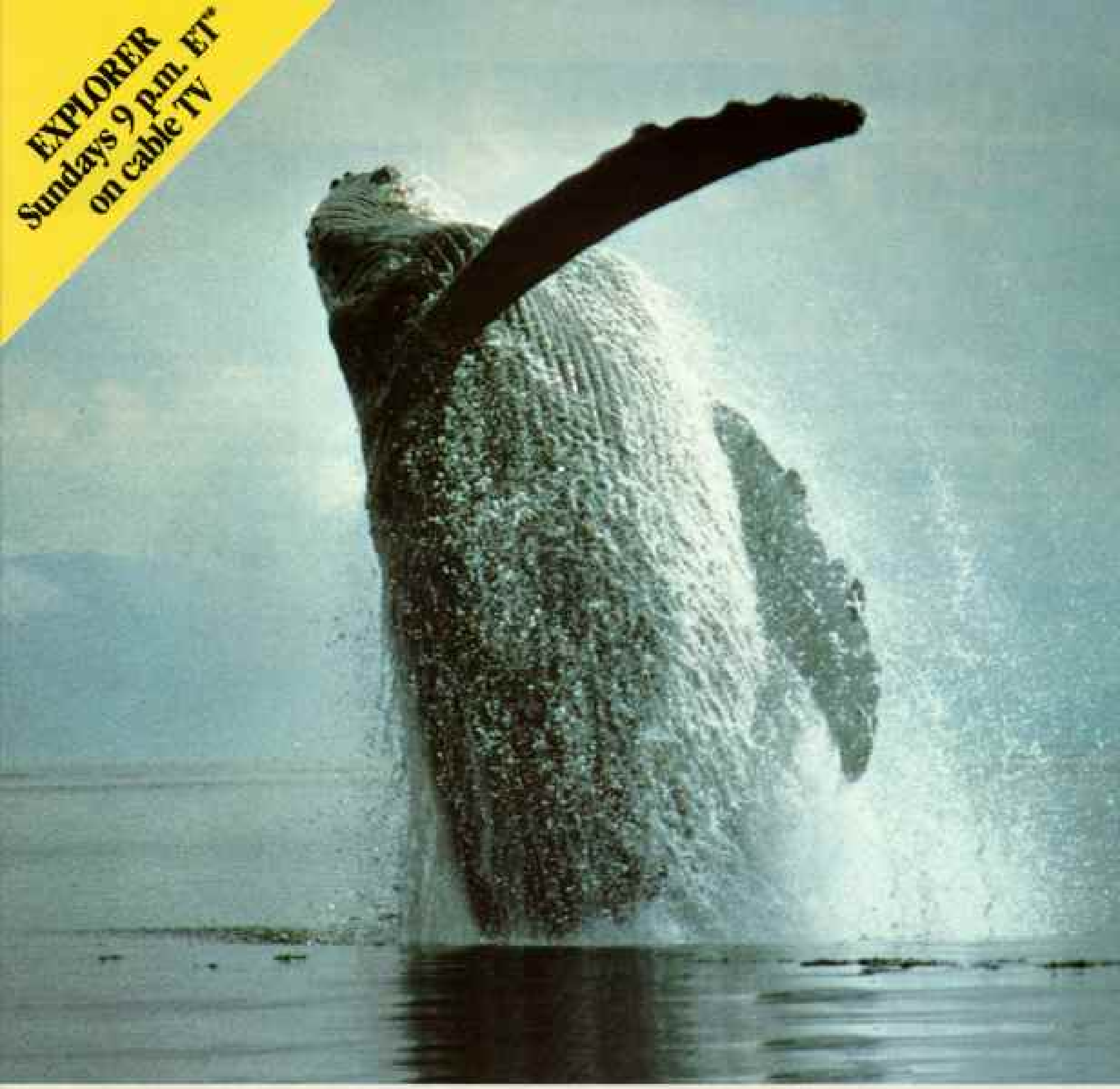
*Based on comparably sticker-priced Ford Escort, Honda Civic, Toyota Corolla and Nissan Sentra models. Escort model includes special value package 255A and selected individual option items.

FORD ESCORT

WORLD'S BEST-SELLING CAR FOUR YEARS RUNNING.



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On Assignment

BY GENE SHOOP (LEFT) AND ZBIGNIEW BZDAK

AMAZING is the word heard most often at NATIONAL GEOGRAPHIC headquarters to describe ***Loren McIntyre,*** who surmounts all obstacles with ease, as in the mountains of eastern Peru (***above***). A fitting tribute for his 70th birthday this March, his Andes article caps a 21-year string of GEOGRAPHIC assignments that began with a 1966 look at Bolivia, where he served for five years as a U. S. foreign-aid officer. At age 51, Loren retired to launch a new career in writing and photography, specializing in two of South America's most physically demanding regions: the Amazon and the Andes. Fluent in Spanish, passable in Portuguese, he is at home wherever his assignments take him, from the Caribbean to Cape Horn. Alarms were sounded in our halls in 1982, when Loren "disappeared" in Venezuela while researching his biography of Alexander von Humboldt (September 1985). It turned out he had been "detained" for two weeks in a grimy frontier cell, following an imbroglio over documentation. His ordeal ended when a U. S. Embassy plane came to his rescue.

In 1971 Loren led an expedition that traced the Amazon to a tiny lake on the slopes of Mount Mismi in southern Peru. In this issue, whitewater expert ***Piotr Chmielinski*** (***above,*** holding kayak) details his record-breaking journey from a frozen waterfall on Mount Mismi to the mouth of the great river. Chmielinski and his party survived not only extraordinary hazards of the upper Apurimac River but also nerve-testing encounters with Peru's Maoist guerrillas. Supporting himself as an industrial-hygiene engineer in Washington, D. C., the 34-year-old Polish expatriate has run 23 rivers in North and South America, 13 never before conquered, and plans to tackle Asian rivers next.