SPECIAL PLACES OF THE WORLD: THE HOLY LAND

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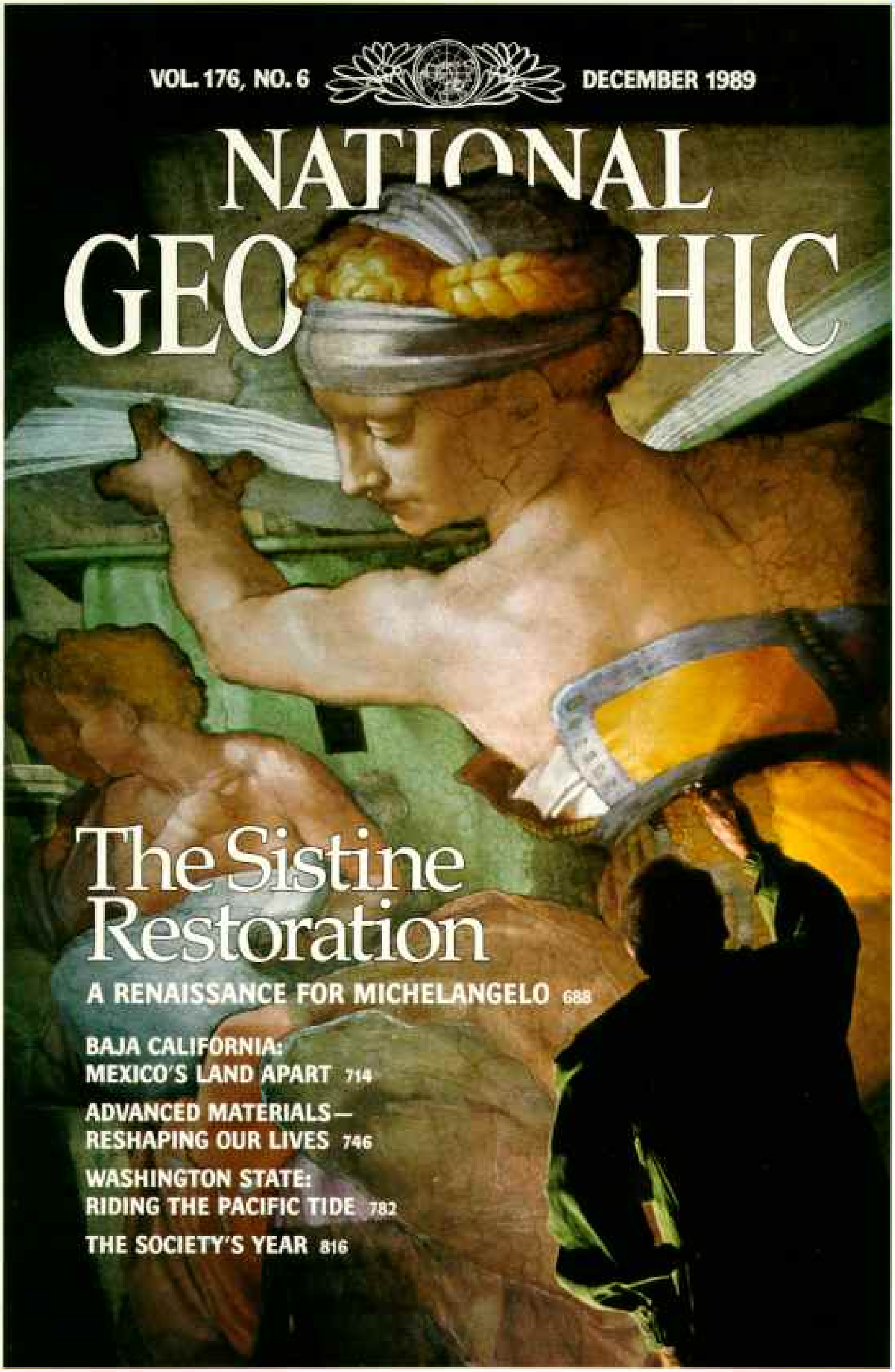

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OFFICIAL JOURNAL OF THE NATIONAL GEOGRAPHIC SOCIETY WASHINGTON, D.C.

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DECEMBER 1989

CLEANING THE SISTINE CEILING

A Renaissance for Michelangelo 688

For nine years restorers have been removing the grime of centuries from the artist's frescoes in the Vatican's Sistine Chapel. The results are literally brilliant. David Jeffery describes the restoration project, photographed by Victor R. Boswell, Jr., and Adam Woolfitt.

Double Map of the Holy Land

The latest in the Special Places of the World series charts the area sacred to Jews, Christians, and Muslims, relating historical events and scriptural passages to actual sites.

THE BAJA 1000 OFF-ROAD RACE

Baja California: Mexico's Land Apart 714

Once a seldom traveled hinterland, this desert peninsula has been discovered by tourists drawn to the beauty and bounty of the Sea of Cortés and by Mexican workers in search of jobs. The deluge of visitors has brought a bloom of prosperity, along with new problems. Don Belt reports, with photographs by Annie Griffiths Belt.

A THALLIUM-BASED SUPERCONDUCTOR

Advanced Materials— Reshaping Our Lives 746

Man's increasing ability to create new materials by manipulating the atoms or molecules of existing ones is spurring an international scientific race that is transforming our material world. Thomas Y. Canby and photographer Charles O'Rear describe recent developments in plastics, ceramics, composites, and alloys.

SUNDOWN OFF THE OLYMPIC PENINSULA

Washington State, Riding the Pacific Tide 782

A rising wave of Asian commerce brings economic benefits to the Evergreen State. Celebrating its centennial this year, Washington looks to its rich agricultural and industrial base to carry it into its second century, says Mike Edwards. Photos by Sandy Felsenthal.

NATIONAL GEOGRAPHY BEE WINNER

Our Year in Review 816

A Society-sponsored geography poll of Russians reveals that they share with U. S. citizens a poor awareness of the world around them. National Geographic President Gilbert M. Grosvenor details 1989 projects promoting geography education.

COVER: Restorer Pier Giorgio Bonetti wipes away dissolved dirt from Michelangelo's Libyan Sibyl, painted in fresco where the Sistine Chapel ceiling curves into a wall. Photograph by Adam Woolfitt.

MICHELANGELO

A RENAISSANCE

A restorer wipes centuries of dirt from a face in the Vatican's Sistine Chapel, as the gloomy masterwork is renewed to a glory of color and light.

WHO WOULD DARE change the arms of God on the first day of Creation? Michelangelo. First he scribed outlines for God's arms into wet plaster with quick strokes of a sharp tool. Then he abandoned those outlines in a flash of brushstrokes. He painted God's left arm so it swept directly overhead, made that arm plunge a divine hand into the turbulent light and wrench it from the darkness (page 697).

The Sistine Chapel quivers still with the aftershocks of Michelangelo's daring—now even more as nine years of careful cleaning and restoration by Vatican experts come to an end. They have been separating darkness—the accumulated grime of nearly five centuries—from Michelangelo's light. It is a light to amaze the eye and blind the soul.

Yet what a reluctant light it was, for the artist was cajoled and harassed, forced really, into completing one of the crowning masterpieces of Western civilization.

(Continued on page 696)

By DAVID JEFFERY ASSISTANT EDITOR

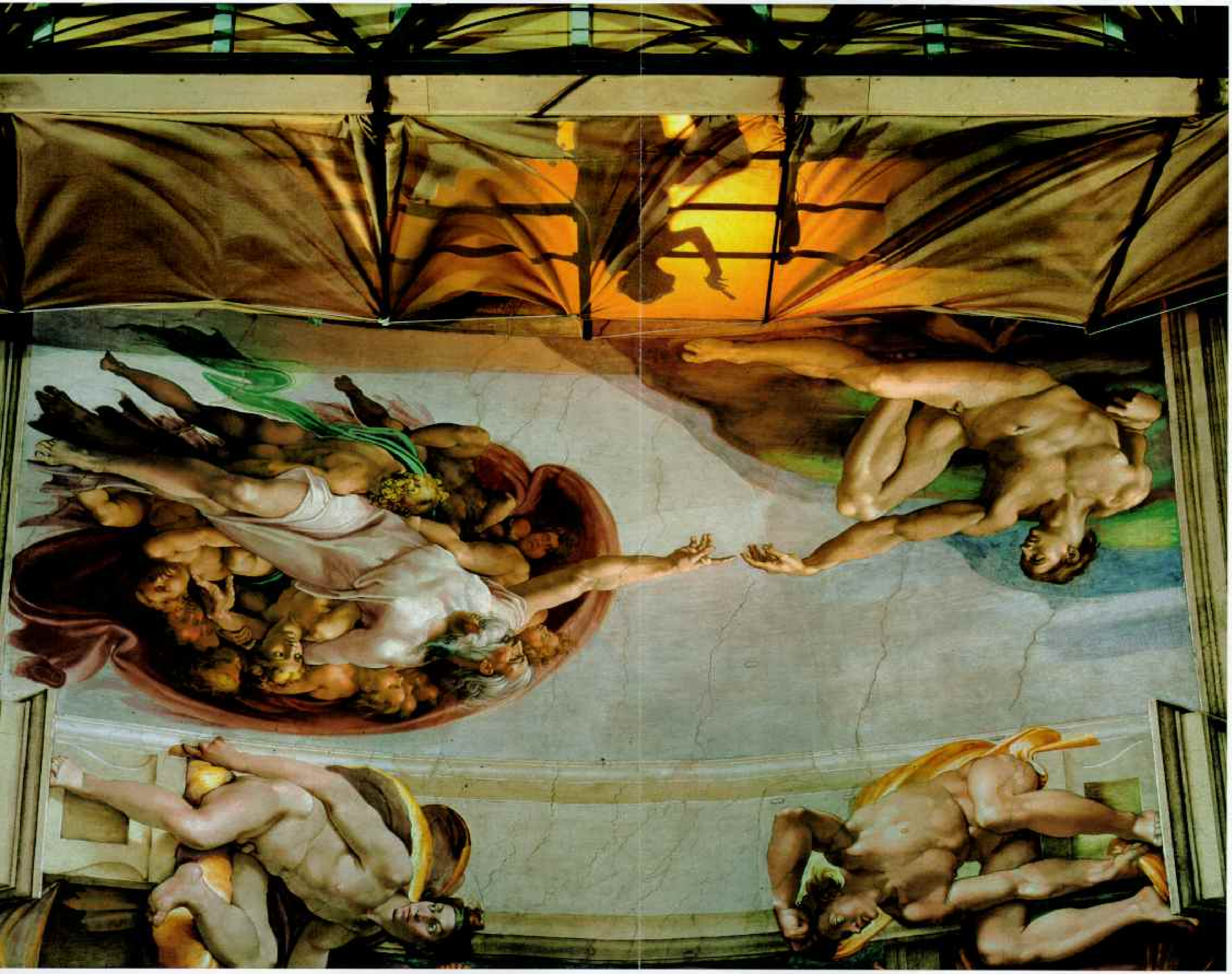
Photographs by ADAM WOOLFITT and VICTOR R. BOSWELL, JR.
NATIONAL GEOGRAPHIC PHOTOGRAPHER

COURTESY THE VATICAN MUSEUMS,
WITH SPECIAL CONSENT OF
NIPPON TELEVISION NETWORK CORPORATION

SANCE FOR

ANGELO

ADAM WOOLFITT



VICTOR R. BOSWELL, JR. (ABOVE AND FOLDOUTS)

Curtained scaffolding and elevator (above) divide dark uncleaned scenes, at top, from restored sections. The shadow of a restorer (left) falls on canvas beneath the newly cleaned creation of Adam. Though still partly obscured by scaffolding (previous pages), the chapters of Genesis from the Creation through the temptation of Eve to the Flood unfold from right to left along the chapel ceiling. Flanking those are portraits of prophets and sibyls, and below, under arches where walls begin, the ancestors of Christ.

(Continued from page 688)

By age 33 Michelangelo had already made his reputation as a sculptor equal to any ancient Greek or Roman. His marble "Pietà," the crucified Christ lifeless across the knees of a Mary forever young and innocent, transcended grief. His giant "David" glowered fiercer than any Goliath.

Now he had a commission from Pope Julius II to make for him a tomb of sculptures so elaborate and so huge as to confound the imagination. Julius, however, first insisted that Michelangelo paint the ceiling of the Pope's own Sistine Chapel.

Michelangelo did not want the Sistine job he began in 1508. Though trained to the brush, he had painted infrequently. Julius, whose fame came from enlarging the papal domain by the sword, bullied him like a drill sergeant, once hitting him with a cane, once threatening to throw him off the scaffold. The artist grumbled constantly, asked for release, signed his letters: "Michelangelo, sculptor."

Yet in little more than four years he filled the ceiling and upper walls with dozens of compositions: the ancestors of Christ, Old Testament prophets, and sibyls of the ancient pagan world. On 132 by 44 feet of ceiling, he painted scenes from Genesis, backward from the Flood to the Creation.

ADAM WOOLFITT (FACING PAGE); VATICAN MUSEUMS

As if garbed in a harlequin's motley, a half-cleaned figure shows just how heavily centuries of dirt, soot, varnishes, and other foreign matter had darkened frescoes of the Sistine Chapel. Cleaning the surface is done at a pace far slower than Michelangelo kept to paint it.

"All Rome admired it and crowded to see it," recounted one contemporary of the completed ceiling, unveiled in 1512. Another wrote: "It was such as to make everyone speechless with astonishment."

Astonished too were those who 469 years later crowded to see the first cleaned section opened to public view. Yet some academics, critics, and painters complained that the images now looked *too* bright, too flat. A few asserted that some, and maybe a good deal, of Michelangelo's own handiwork must have been erased in the cleaning process.

To see for myself, I visited the restorers at work. A clanking ascent in a narrow elevator brought me up to a scaffold similar to the one sketched by Michelangelo. The attachment points along the walls are even the same ones, and the central platform also has a few oversize wide steps at either side to facilitate working along the arc where the ceiling curves toward the walls.

Scaffolding had borne chief restorer Gianluigi Colalucci and his colleagues Maurizio Rossi, Pier Giorgio Bonetti, and Bruno Baratti for years. All worked under the direction of art historian Fabrizio Mancinelli of the Vatican Museums. Baratti was preparing to inject vinyl resin to secure a small section of ceiling weakened by a void behind the plaster, while others worked on figures out on the curve and Filippo Petrignani recorded every detail on a computer.

Years of restoration had passed, and with them daily strain, stress, and interruptions. Michelangelo described similar effects on himself: "I live here in great toil and great weariness of body, and have no friends of any kind and don't want any,

and haven't the time to eat what I need."

He then, as the restorers do now, stood day by day, head bent back, arms stretched up. He complained of paint splattering his beard, of pain, of problems with his eyes. The restorers keep on steadily, professional and serious but not solemn. Colalucci has a button pinned to his smock that reads: "Even the Pope had trouble with Michaelangelo."

Trouble ran both ways. The artist was desperate to quit the commission; the Pope was adamant that he continue. The work did not go well at first, partly from inexperience. The fresco of the Flood was soon hazed over by "mildew," the result perhaps of mixing too much water in the surface plaster, or *intonaco*. Michelangelo complained to the Pope:

"Indeed I told Your Holiness that this is not my art; what I have done is spoiled." Julius did not relent; Michelangelo must *make* it his art.

THE RESTORER'S CREDO is like the physician's: First, do no harm. The treatment is to lift layers of Rome's dust, sooty grease from burning candle tallow, and other substances—even the residue of Greek wine used as a cleaning solvent some 275 years ago. All have obscured Michelangelo's Promethean work.

Worst of all were varnishes made of animal glues. Applied in various centuries to brighten the darkening surface, they did so for a time. Then each deteriorated and turned the ceiling darker than before.

Despite its dingy appearance, most of the fresco remained in good condition. The technique of painting on fresh plaster was its own best protection. In the hours after Michelangelo painted, the day's application of fresco dried. As it did, the pigments were chemically bonded in a hardening layer of calcium carbonate. The various glues and gums of centuries did not penetrate that hard carbonate shell.

The glues have, however, shrunk and puckered, and in spots scabs of glue have fallen away, pulling pigment with them. This slow destruction by glue pox, rather than some large and immediate threat, has been the Vatican's principal motivation for cleaning the ceiling now. Water damage from roof leaks since plugged has also infiltrated dissolved salts to the surface, stains that cannot be removed as easily as ordinary grime.

Grooves outlining the features of God dividing the light from the darkness were incised by pressing a stylus along the lines of a paper design, or cartoon, affixed over damp plaster. Even as he painted, Michelangelo had second thoughts and changed the left arm's position.

The restoration plan calls for examination of each section of fresco with scientific instruments and assessment of the results with human judgment. Then, under exacting procedures, the gentlest effective solvent is applied to overlying grime and both are rinsed away. It seems a nearly magical process to watch.

On one side of the scaffold Bonetti is cleaning the figure of the Libyan Sibyl (pages 702-3). First he wets a natural sponge in distilled, deionized water and gently wipes a small section of fresco. With a natural-bristle brush he applies the cleaning solution. Used by restorers for

about 20 years and known as AB 57, it is made of bicarbonates of sodium and ammonium. An antibacterial, antifungal agent is added. All these are mixed in carboxymethylcellulose and water to become a gel that will cling without dripping.

The gel is applied and remains for about three minutes. Then the gel—together with the dissolved grime—is removed with sponge and water. Where grime is especially heavy, the process may be twice repeated at 24-hour intervals.

A RESTORER comes to feel on intimate terms with the creator of the work on which he labors. Bonetti works with a musician's rapt concentration. Here—and here!—he finds bristles from Michelangelo's brush embedded in the surface. The master must have been using an old brush. Bonetti smiles. Then—here!—he finds an arc of small indentations. Michelangelo was probably testing the set of the plaster, the intonaco—with his fingertips.

Bonetti works on, and the sibyl's glowing flesh appears from beneath a grayish brown hide. The back and left arm are smoothly modeled with color. Brushwork defining the face is ineffably delicate, yet the expression will be clear to someone standing on the floor some 60 feet below.

Details of brushwork along one fold of white drapery appear. Bonetti calls them "worms," tiny red curlicues that define the curve and give volume to the fold.

"The technique and results always surprise," Bonetti says. Even after all their years on the scaffold and the preliminary analyses, the photogrammetric mapping, the peering beneath surfaces with ultraviolet fluorescence and sodium monochromatic light and infrared spectrometry and liquid chromatography and atomic absorption spectrophotometry. . . . After all that, Michelangelo still surprises.

"We know what will be there, but to *see* it! . . . Just look at that green!"

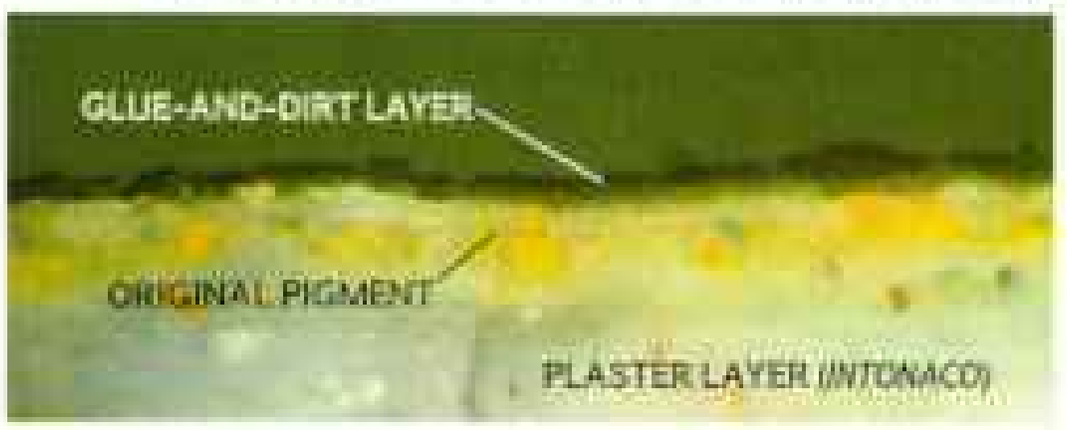
On the other side of the scaffold Maurizio Rossi confronts an image of Jeremiah as beset with cause for lamentation as was the prophet himself, who bemoans of his people in the Bible: "Their visage is blacker than a coal . . . their skin cleaveth to their bones; it is withered, it is become like a stick."

VATICAN MUSEUMS (ABOVE AND FACING PAGE)

Before cleaning, as on Ezekiel (above), many tests are made. Infrared light (top right) penetrates old varnish and overpainting to show original fine details as in the drapery. Ultraviolet light (bottom right) shows clumsy restoration of prior centuries as red on garments and dark shadows on small nudes.

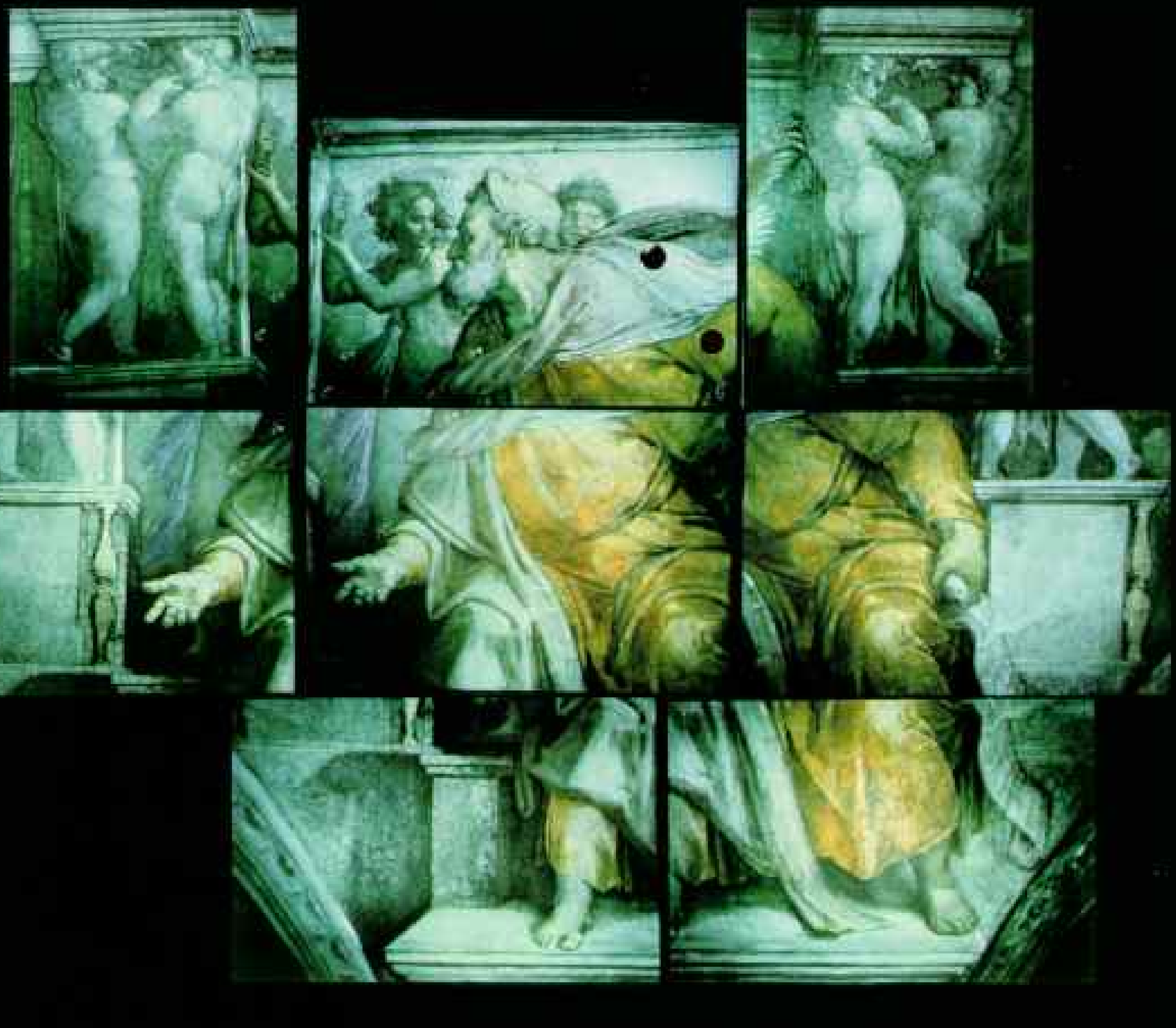
To determine the order of deposition of foreign matter, minute pigment samples are suspended in polyester resin (below). When it hardens, cross sections are cut and magnified (bottom sequence). Dirt beneath varnishes suggests that they were applied much later than the pigment and not by Michelangelo.

VICTOR R. BOSWELL, JR. (ABOVE); VATICAN MUSEUMS (BELOW, BOTH)



MAGNIFIED 137 TIMES

200X, SEEN UNDER ULTRAVIOLET LIGHT



Cleaning sequence by chief restorer Gianluigi Colalucci shows a typical procedure. First a solvent called AB 57, made of bicarbonates of sodium and ammonium with a fungicide and antibacterial agent in a gel, is applied by brush (top). The head represents an ancestor of Christ from one of the lunettes, or half-moon upper-wall sections. After three minutes solvent and residues of dirt and old varnish are wiped away (middle) with a sponge soaked in distilled, deionized water. The procedure is repeated 24 hours later to complete the cleaning (bottom). The process is documented in great detail by Nippon Television Network Corporation (right), which is funding the restoration in return for temporary reproduction rights and to help protect a world treasure.

Jeremiah's image was already damaged before Michelangelo's death in 1564. The Sistine Chapel, built in the 1470s by Pope Sixtus IV, racked slowly out of plumb as the massive structure settled unevenly into the soil beneath. Some of the ceiling's fresco, including part of Jeremiah, was sloughed onto the floor below.

Artist Domenico Carnevali's mid-16th-century restoration was the first of several in just a small region near Jeremiah's head. Rossi points to a detail where gray overpainting from the 19th century covers a layer of glue varnish that, in turn, had been applied atop an earlier repair.

Sorting through the complexity at Jeremiah amounts to micro-archaeology; all the layers and details are analyzed and recorded long before any cleaning begins.

MICHELANGELO passed from 33 to 37 years old during his Sistine ordeal but aged much more. Even his images of God seem to reflect the terrible weight. Painted first, the creator of Eve looks fairer and younger than the creator of sun and moon.

Gianluigi Colalucci feels that in a sense Michelangelo salvaged the design of the tomb he had wanted to build by turning it inside out, adapting the architectural and sculptural elements to the painting. He believes too that the artist underwent a personal transformation during the work.

"He is given a job he doesn't want, but at a certain point he starts to enjoy what

VATICAN MUSEUMS (FACING PAGE); NATIONAL GEOGRAPHIC PHOTOGRAPHER JAMES L. STANFIELD

he is doing. His designs become less constricted. It is hard to say exactly where, but the feeling begins to change.

"When we started cleaning the scene of the temptation, I realized that we were out of the everyday routine. I felt a new level of pleasure in the work.

"Then when I got to the head of Adam, I had another whole feeling. It was like a change in *stato d'animo*."

That literally translates as "state of mind." But Colalucci explains that he is describing not a flash of feeling, an emotion, but a deep and expansive change in his relationship to the work, both Michelangelo's and his own. Artist and restorer might now speak across nearly 500 years and say together: This is my art.

As for the lingering criticism, no one has produced tangible evidence that casts doubt on the validity of the restoration. By far the majority of interested art historians and conservators support the project.

"We made a mistake in the beginning," concedes Walter Persegati, then secretary and treasurer of the Vatican Museums. "After we uncovered the first cleaned part of the ceiling, we left the same strong lights there. The impression was left that the frescoes had been overcleaned. Instead, they had simply been overlighted."

The Vatican has now replaced the old, bright lights with dimmer ones, and the painted colors have retreated back into the design and rhythms of the compositions.

In the spring a gathering of experts from around the world will assess the cleaning of the ceiling. Analysis will already have begun in preparation for cleaning Michelangelo's fresco of the "Last Judgment," a work that rises 60 feet like painted thunder on the wall behind the Sistine Chapel's altar.

The wall, Colalucci says, has likely suffered even more damage than the ceiling: more handling, more deposition of dirt, and more sooty grease from the tallow of altar candles. He does not know what the laboratory analyses will show.

But does he expect that Michelangelo, painting that anthology of salvation and damnation 24 years after he finished the ceiling, used identical fresco techniques—techniques Colalucci now knows with the greatest intimacy?

"Perhaps," he says.

"*Speriamo*—we hope."

Between 1989 and 1994, **New Light on Michelangelo,** *a four-volume work chronicling the restoration, will be published by R.C.S. Rizzoli Libri S.p.A., Milan; Editions Mazenod, Paris; Mercatorfonds, Antwerp; Helen Goodkin, Chicago; Random House, Inc. (Crown Publishers), New York; Faksimile-Verlag Luzern, Lucerne; Ediciones Encuentro, Madrid; and Nippon Television Network Corporation, Tokyo.*

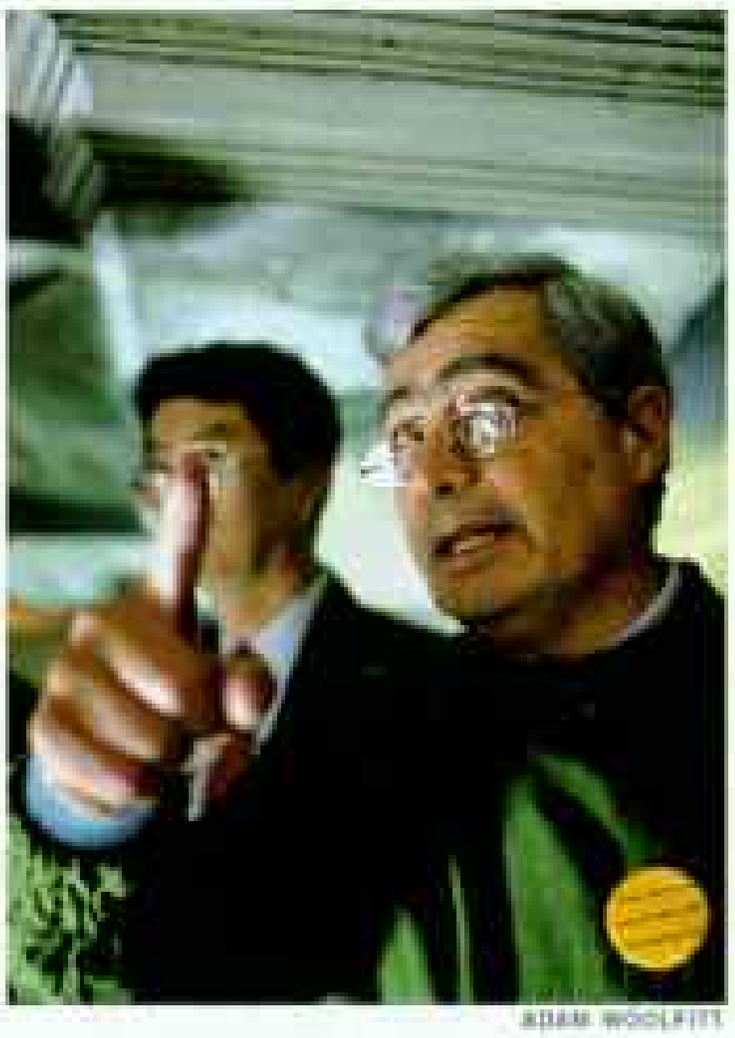
ANNIE WOOLFITT

ARCHIVIO BUONARROTI, BIBLIOTECA LAURENZIANA, FLORENCE (RIGHT); METROPOLITAN MUSEUM OF ART, NEW YORK (ABOVE)

THE COMPLEX POSE of a pagan female seer, the Libyan Sibyl, being cleaned by Pier Giorgio Bonetti (left) was first sketched by Michelangelo using a male model (above). Musculature in the sketch, emphasized to show detail, was softened and feminized in the fresco.

A more difficult problem was compensating for visual distortion induced by the curving surface on which the sibyl is painted. Called inexperienced by rivals, Michelangelo proved to be a master of foreshortening figures so that little distortion is evident to a viewer on the floor some 60 feet below. In this view the camera lens acts in a similar way: The wall curves much more than is apparent.

Contrary to a popular view, Michelangelo almost certainly did not lie down while painting. He drew a comic sketch of himself at work (above right) to accompany a satiric sonnet he sent to a friend. Translated from Italian, it reads in part: "I have already developed a goiter . . . that pushes my belly under my chin. My beard points to heaven . . . and my brush, continuously dripping onto my face turns it into a rich mosaic. My loins have penetrated my belly, my rump's a counterweight, and I walk around in vain, without seeing where I am going. . . . Behind, my skin is shriveled for too much bending, and I am stretched like a Syrian bow."



ADAM WOOLFITT

Today's restorers have similar problems, although their pace is slower and the lighting is much better. Where Michelangelo had a demanding and impatient patron in Pope Julius II, chief restorer Colalucci (left) has an endless parade of visiting scholars and dignitaries to enlighten.

VATICAN MUSEUMS (ABOVE AND BELOW)

THE CRAFT OF FRESCO, as used by Michelangelo, is shown in a series (right) at ICCROM, an institute for restoration training in Rome.

A smooth layer of thin, wet plaster, the *intonaco* (1), is troweled atop a rougher layer of dry plaster, the *arriccio*.

To make a guide for the image of a head to be painted, artist and Vatican restorer Maurizio Rossi has pricked holes along lines of a drawing on a sheet of paper. He tacks the paper lightly over the plaster and then taps along the holes with a porous bag of charcoal dust (2).

He removes the paper (3), revealing outlines defined by charcoal dust on the plaster. Called pouncing, this technique of transferring cartoons is still visible as dots in details of Michelangelo's own work (5).

With outlines established, Rossi paints while the plaster is wet (4). As it dries and sets, pigments of the water-based paint are bound in the outer layer, and colors lighten.

Michelangelo's original of the head as seen before (6) and after (7) restoration shows that the curl under the chin had been hidden by overpainting, and the transparent clarity of the fresco had been muddied.

Enormous contrast appears in the cleaned lunettes (left) that depict the ancestors of Christ. One of their main themes, motherhood and the passing of generations, was obscured in this panel when the child in the cradle was all but buried under grime. Michelangelo painted each lunette without benefit of cartoons. Except for one, each was completed in only three working days.

1

2

3

4

5

ADAM WOOLFITT (ABOVE, ALL); VATICAN MUSEUMS (BELOW, BOTH)

6

7

VATICAN MUSEUMS (ABOVE AND LEFT)

VICTOR R. BOSWELL, JR. (ABOVE AND BELOW)

Attempts at restoration in previous centuries varied from the good (considering techniques then available) to the dreadful. Modern restorers must evaluate each prior attempt and decide how much of it, if any, to keep.

In the 18th century T-shaped bronze clamps were inserted to anchor weakened plaster

ADAM WOOLFITT

(above). Where these cause no problem, they are left as part of the ceiling's history.

A section of plaster with the left hand of God (in the Genesis scene of the gathering of the waters) had fallen and smashed in the mid-16th century. Domenico Carnevali, an artist of the time, soon replastered the surface and repainted the hand, though crudely. A decision was made to keep the repainted hand but replace the surrounding background. Having protected the hand, restorer Bruno Baratti (above left) slowly removes the background. When new plaster is added and painted (left), the restoration is restored.

There was no question about removing bad overpainting on a scene of a woman and infant (far left). Not only was Michelangelo's original work beneath, but his depiction of the woman's breast evoked the familial loving bond of mother and nursing child.

"Here it is pitiful to see the human race perish so miserably in the waves," wrote Ascanio Condivi, the artist's own designated biographer, of the Flood in Genesis.

As people battle for a place on the ark and in a boat, others seek refuge on the final bits of land. Some are terrified, while others (detail, right) trudge on, as if putting up with an unseasonable stretch of bad weather.

Nor was Michelangelo, as Condivi put it, "without anxieties" about this early fresco, because when completed, "it began to mildew so that the figures could barely be distinguished." The condition may have been caused by Michelangelo having mixed too much water in the plaster.

He had never wanted the commission to paint the Sistine Chapel in the first place and, blaming the fiasco on his inexperience, he petitioned Pope Julius II for release. The Pope, however, would not agree.

Dismissing assistants, he took almost all the burden of the painting upon himself. As he progressed beyond the story of Noah, his designs became simpler and bolder, the color schemes more muted and elegant.

Prophets and sibyls burst beyond the confines of their niches. The powers of God at Creation, even the very look of divinity, were struck as indelible models for the mind's eye, and for the ages.

VATICAN MUSEUMS (ABOVE AND BELOW)

VATICAN MUSEUMS (ABOVE AND LEFT)

TRAPPED DIRT and old varnish that blemished a wild-eyed face (above left) were removed without loss of pigment. Elsewhere in the chapel contracting varnish has pulled original pigment from the frescoes, spurring the decision to do this complete restoration.

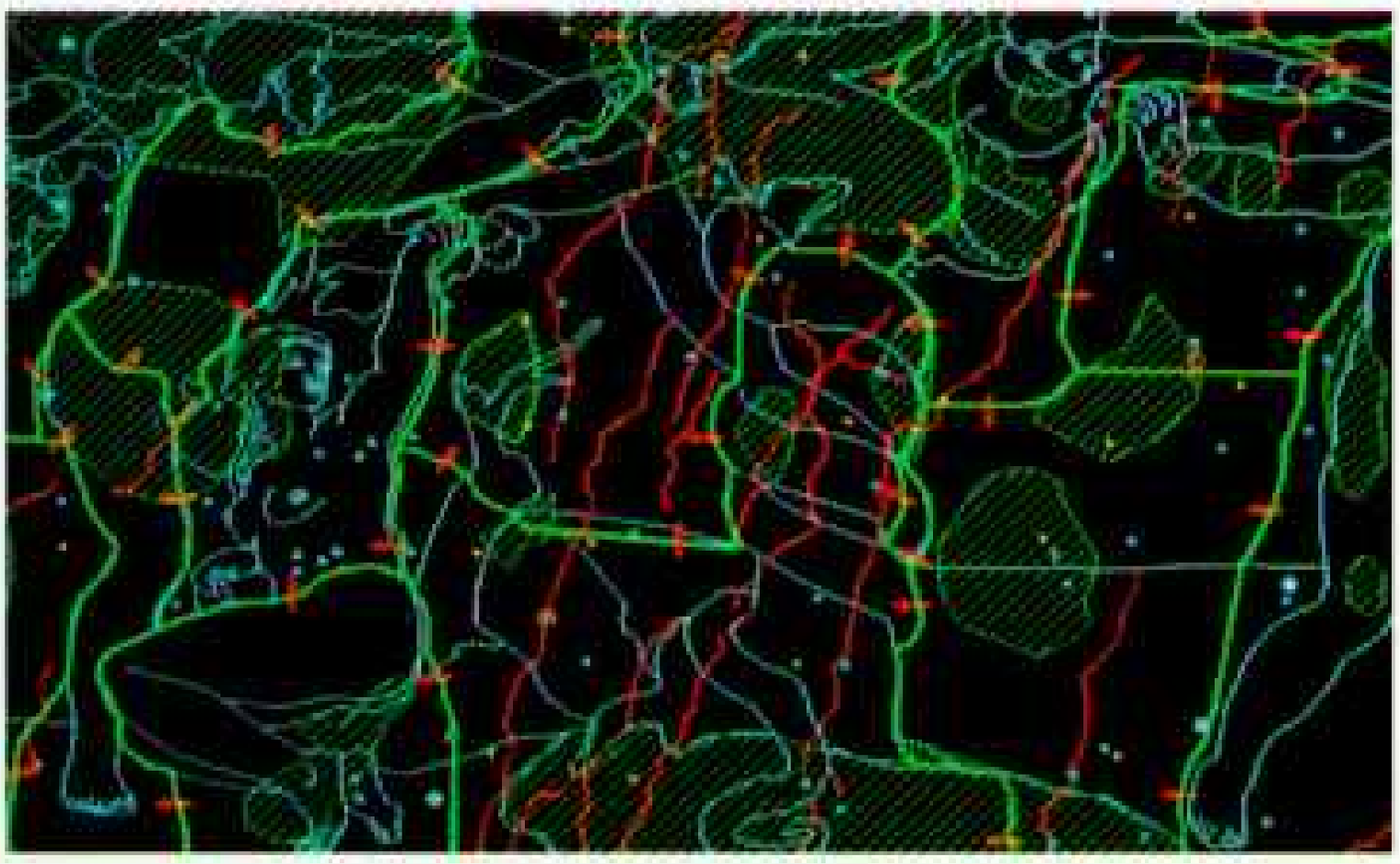
Varnishes made of animal glues were applied through the centuries to brighten the frescoes. A temporary remedy, varnish would soon deteriorate, making them darker yet.

An especially sloppy job was done on one of the nudes (right) positioned at each corner of the ceiling's central scenes. The lighter swath across the right thigh and abdomen was missed by a careless worker perhaps wielding a long brush from below.

Giant acorns associated with many of the nudes, or *ignudi* (facing page), referred to a heraldic device on the Pope's coat of arms.

The figures themselves echo Michelangelo's changing moods, his love of ancient statuary, and his abiding desire to be, above all, a sculptor.

VICTOR R. BOSWELL, JR. (ABOVE); ADAM WOOLFITT (RIGHT)



TEMPTATION in Eden and expulsion from its lush garden were composed around a serpent once more iridescent in evil.

The kaleidoscope of colors displayed on a computer's screen (left) records significant information about the frescoes and the restoration's progress. This constellation of Eden shows diagonal green lines, loose plaster; heavy green lines, one day's work for Michelangelo; red lines,

cracks; yellow crosses, metal clamps; and blue circles, weak areas from past restorations.

The computer mapping is based on a photogrammetric survey that details even small surface variations, of which there are many since the ceiling undulates like an inverted washboard road.

Logged on to God making the sun and moon, Filippo Petrignani enters data for Creation's fourth day. The software took a year to create. □

VATICAN MUSEUMS (ABOVE); ADAM WOOLFITT

BAJA CALIFORNIA

Mexico's Land Apart

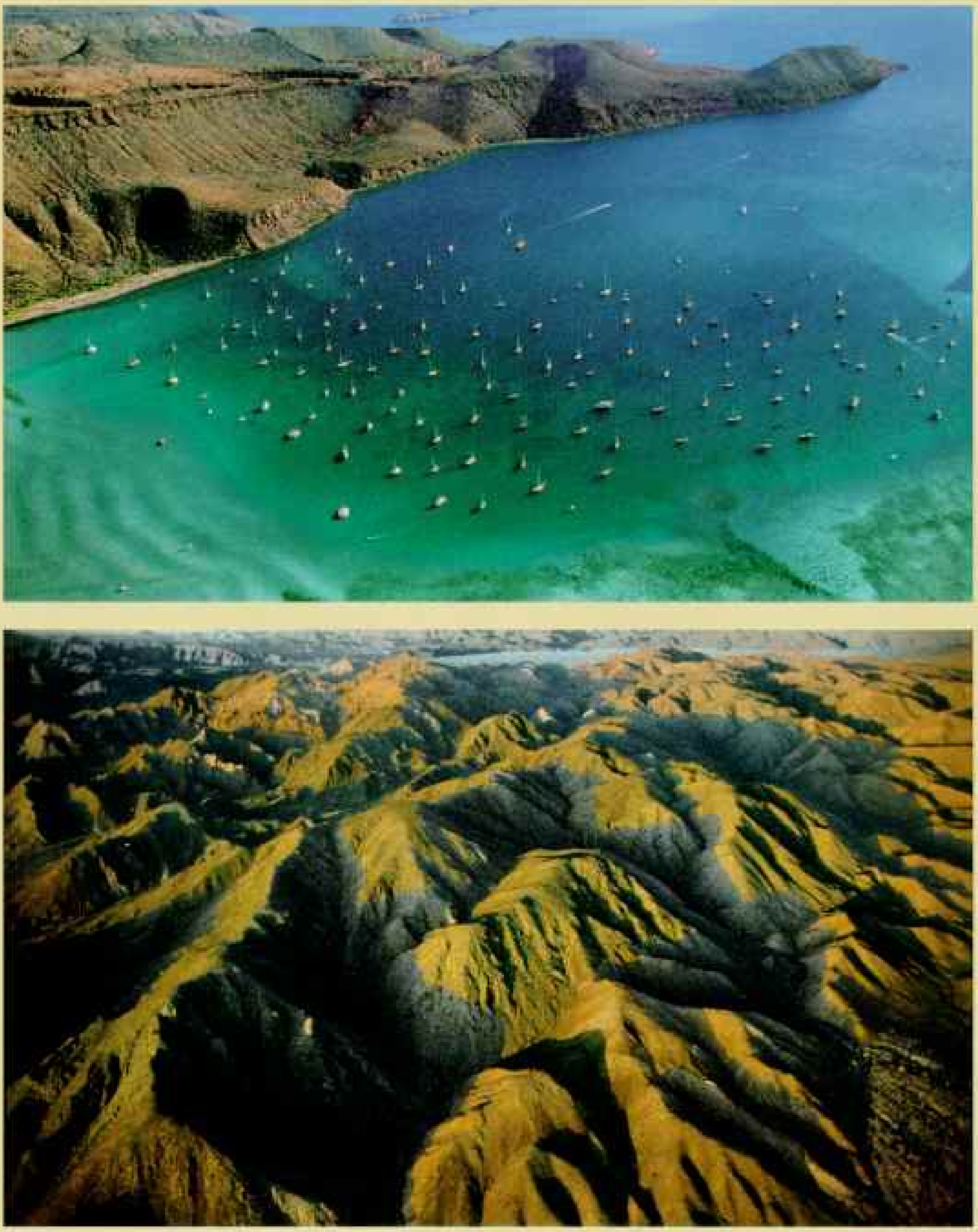
By DON BELT
NATIONAL GEOGRAPHIC STAFF

Photographs by
ANNIE GRIFFITHS BELT

"A pathless, waterless, thornful rock, sticking up between two oceans." Thus wrote a Jesuit missionary in the 18th century, describing the scene of his ordeals—the peninsula called Baja, or Lower, California. Isolated by the incredibly rich Sea of Cortés (gatefold), where dive-bombing brown pelicans feed on schools of fish, Baja California has been steadily gaining ground since 1973, when its dusty back roads were buttressed by a paved peninsula-long highway.

FULVIO ECCARDI

Tapped out by irrigation before it reaches the Sea of Cortés, or Gulf of California, the Colorado River no longer flows through its own delta (left). What appear as rivers are actually runoff from tidal surges, among the world's highest. Gray whales migrate from Alaska waters to breed in sheltered bays and lagoons along Baja's lonely Pacific coast (top), while humans inhabit rare oases such as Mulegé (above), blessed with one of the peninsula's few perennial streams.



High and dry, the mountains forming the peninsula's backbone are practically uninhabited. The same is true of islands in the Sea of Cortés (top), despite their growing popularity as anchorages. Science finds them even more irresistible as natural laboratories for the study of evolution. "They're like a poor man's Galápagos," says George Lindsay, a pioneer of scientific exploration here. "Many of them have plants and animals found nowhere else on earth."

"If it were lush and rich, one could understand the pull, but it is fierce and hostile and sullen."

—JOHN STEINBECK *The Log from the Sea of Cortez*

THE WORLD WAS AT WAR in December 1944, when a young Mexican pilot named Luis Coppola Bonillas, ferrying an American B-17 bomber from Canada to England, landed in Greenland and fell in love with Baja California.

Somewhere over the Atlantic his plane hit hurricane-force winds. Coppola and his crew made an emergency landing at a weather station in Greenland, which in those days was one of the few places in North America more remote than the Mexican desert peninsula this story is about.

"There we were with the biggest war in history, and all we could do was hunt ducks in the snow and read," he recalled. "Luckily I'd picked up a little novel somewhere called *Journey of the Flame*, all about a young man's adventures on the frontiers of Baja California. To me it sounded like the most exciting place in the world. By the time we got our plane off the ground, I knew my destiny was in Baja California. I can't explain it, except to say that one has rocks in his head when he's young."

Five years later Coppola was manager of the peninsula's largest airline. He was also its only full-time pilot. Flying back and forth across the Sea of Cortés, he hauled chickens from La Paz to Guaymas, people from Loreto to Ensenada, and fighting bulls from Jalisco state to the bullrings of Tijuana. He flew a military surplus DC-3 his partner had picked up at an auction for $11,000. "It had seen action in Europe during the war," Coppola said. "But the flak holes were good for ventilation."

ONE HUNDRED MILES of water, more or less, divide the peninsula called Baja, or Lower, California from the rest of Mexico, and flying into La Paz on a clear day, you can see mountains along the west coast of Sinaloa, rising dreamlike through the haze above the Sea of Cortés.

This body of water is also known as the Gulf of California, although most native *peninsulares* prefer the more evocative Mar de Cortés, for Hernán Cortés, the conqueror of Mexico, who came here hunting pearls in 1535 and claimed the peninsula for Spain. Judging by maps from this period, Cortés may have called the gulf the Vermilion Sea, perhaps after watching its surface turn blood red, as it often does in the hour between sunset and dark.

By whatever name, the gulf has isolated Baja California and many of its islands since they tore free of the mainland some five million years ago along the San Andreas Fault system, which zigzags up the gulf before rising from the mud flats of the Colorado River Delta to menace citizens of the other California.

In a thousand small ways this isolation has shaped the natural and human history of the Baja peninsula and made it as distinct from mainland Mexico as twins raised on opposite sides of a mountain range. Both were born poor and have spent their days looking to the desert sky for miracles. But Baja California grew up harder and lonelier and generally worse off than other parts of Mexico—mainly because here the sky so rarely cooperates.

Baja's central desert, which covers a third of the peninsula, gets between one and three inches of rain a year—about the same as Death Valley. Except for hurricane years and a few regions that get unpredictable downpours, all Baja California is a desert full of thorns and sharp rocks and wide-eyed children who have never seen an umbrella.

As you might expect, people are spread thin over this land. Of the estimated 2.5 million persons living in the states of Baja California and Baja California Sur, some 80 percent are crowded into the big northern cities of Tijuana, Ensenada, and Mexicali near the United States border, with 160,000 living in the southern capital of La Paz. Most of the others live in fishing camps or small villages scattered along a wraparound coastline that if unraveled would stretch from downtown Tijuana to somewhere just north of Juneau, Alaska.

Because it is barren and mountainous and exceedingly lean in the things that make men rich, Baja California has repeatedly foiled man's attempts to make something out of it.

In 1949, when Luis Coppola began flying the peninsula's first mail route, Cabo San Lucas was a ramshackle fishing village strewn around a tuna cannery at Baja's southern tip. "A couple of hundred people lived here then," he told me. "There were a few goat ranches, but most people worked at the cannery and fished in their spare time. The whole town smelled like tuna fish."

He wasn't the only pilot landing his plane on the dirt strip down by Cabo's waterfront. It was used also by a handful of gringos who loved the anonymity and funky charm of the place—men like John Wayne and Bing Crosby, who flew down in private planes and spent their days hauling trophy-size marlin from the waters around the cape.

These men would sometimes invite friends down to join them, and soon Coppola was shuttling passengers along with the mail between Cabo and La Paz, which was then in its heyday as a duty-free port. "That was a crazy time," he recalled. "Baja was a last frontier, like Alaska. You thought big in those days."

One morning in 1952 Coppola woke up thinking really big. Backed by his father-in-law, he made a "ridiculously low offer" for Los Arcos Hotel in La Paz. He fully expected the owner to laugh in his face. Instead the man pulled a ring of keys from his pocket and handed them over. "Congratulations, Mr. Coppola," he said. "You're now a hotelier."

One thing led to another, and soon Coppola was opening a 24-room hotel in Cabo to accommodate the growing celebrity fishing crowd. Then came the Finisterra, a luxury hotel he opened in 1971—about the time Cabo San Lucas began popping up in the travel sections of major U. S. newspapers. Coppola was a decade ahead of FONATUR, Mexico's bureau of tourist development. Around 1982 they started talking about Baja as another Cancún and followed up by expanding the international airport serving Cabo.

"In the beginning we all wanted to keep this place a big secret," Coppola recalled. "Guys would go home and lie about how crummy the fishing was."

He looked out at the buildings transforming the quaint fishing village of his memories into one of Mexico's premier tourist destinations. "There are a thousand new hotel rooms being built on the cape right now," he said with a sigh. "I guess it's safe to say the secret's out."

At last count the secret was being shared by

about half a million tourists a year in Baja California Sur. Their free-spending ways accounted for a third of all income and helped give Mexico's least populated state one of the country's highest standards of living.

For every ten vacationers strolling the dust-filled streets of Cabo, it seems, there is also a businessman in white shoes striding about with a portfolio full of architectural sketches under his arm. From those drawings spring forth projects of every description, designed to cash in on the success of FONATUR's development at "Los Cabos"—the name coined to promote both Cabo San Lucas and the neighboring pueblo of San José del Cabo.

At Pedregal, a hilltop development overlooking Cabo San Lucas, owner Manuel Díaz Rivera watched as workers put the finishing

To turn parched land into farms, Baja Californians use underground water. On his ranch near Ciudad Insurgentes, where annual rainfall is four inches, Arnulfo Reyes irrigates cotton, wheat, and other crops with well water.

touches on a mansion of mortar and stone. Commissioned by a Los Angeles couple, the house covers 8,500 square feet and took 70 men three years to complete. Yet it was built for only $390,000, a fraction of what the buyers would pay for the same home in California.

"We live in a state of continuous gossip about who's building and where," said Díaz, who speaks in the glib, rapid-fire tones of a Mexico City native. "Yesterday I watched a cabdriver point to my house and tell a tourist, 'That's where Sylvester Stallone lives.' "

Word of all this has spread to distant states in the Mexican interior, where unemployment soars. Perhaps one out of three people living in Cabo San Lucas today is a construction worker, and hundreds more arrive each week looking for work. These newcomers live in a sprawling shantytown on Cabo's north end, far beyond the village's ability to provide them with basic services like sewerage and water.

"This town reminds me of Puerto Vallarta a few years ago," Luis Coppola told me. "Tremendous growth with absolutely no planning. Private enterprise can work miracles for the Mexican economy. But we need government to give us infrastructure. Otherwise it doesn't take a genius to see the problems ahead."

On the other hand, some see Baja California's chronic inefficiency as not all bad,

Baja California

Discovered in 1533, this new land was dubbed "California" for its resemblance to a fictional island described by a Spanish author of the day. After attempts to colonize it failed, Spain turned California over to missionaries, who watched helplessly as European diseases claimed virtually all their Indian converts. Supplied from Loreto and other peninsular missions, the padres pushed north into the greener pastures of Alta, or Upper, California and eventually abandoned their Baja missions. The 1848 treaty ending the Mexican-American War divided California between nations.

National Geographic, December 1989

functioning as a kind of unofficial conservation program. "One of the saving graces of Mexico is that it's not perfect," said American Tim Means, a soulful expatriate whose company, Baja Expeditions, trains local guides to lead environmentally conscious tourists into the backcountry. "If gringos ran this place, it'd look like Miami Beach."

THE GRINGO MULTITUDES shuttling down to Los Cabos today were just a politician's dream on December 1, 1973—the day the long-awaited peninsular highway, Mexico 1, paved from Tijuana to La Paz, opened for business. At the border between the peninsula's two states, Mexican President Luis Echeverría led dedication ceremonies, which climaxed with the unveiling of a 135-foot steel-beam sculpture of an eagle, Mexico's national emblem. In a symbolic gesture the eagle was placed facing north, toward the United States.

Today the colossal symbol of hope is a little worse for wear, its wings rusting in the heavy, salt-tinged air drifting

from nearby Guerrero Negro, where the world's largest solar-evaporative salt mine is located. But no matter. The highway has paved the way for development and watered Baja's dry-gulch economy with a steady stream of American cash.

Mexico Highway 1 officially begins some 450 miles to the north, at the Tijuana border crossing, where each year some 13 million vehicles cross from one California into another, heading south. Beyond Tijuana the highway rambles along the scenic Pacific coast, its reverie interrupted by billboards and banners plugging, in fractured English, the condominiums, restaurants, and hotels built along the road for U. S. consumption.

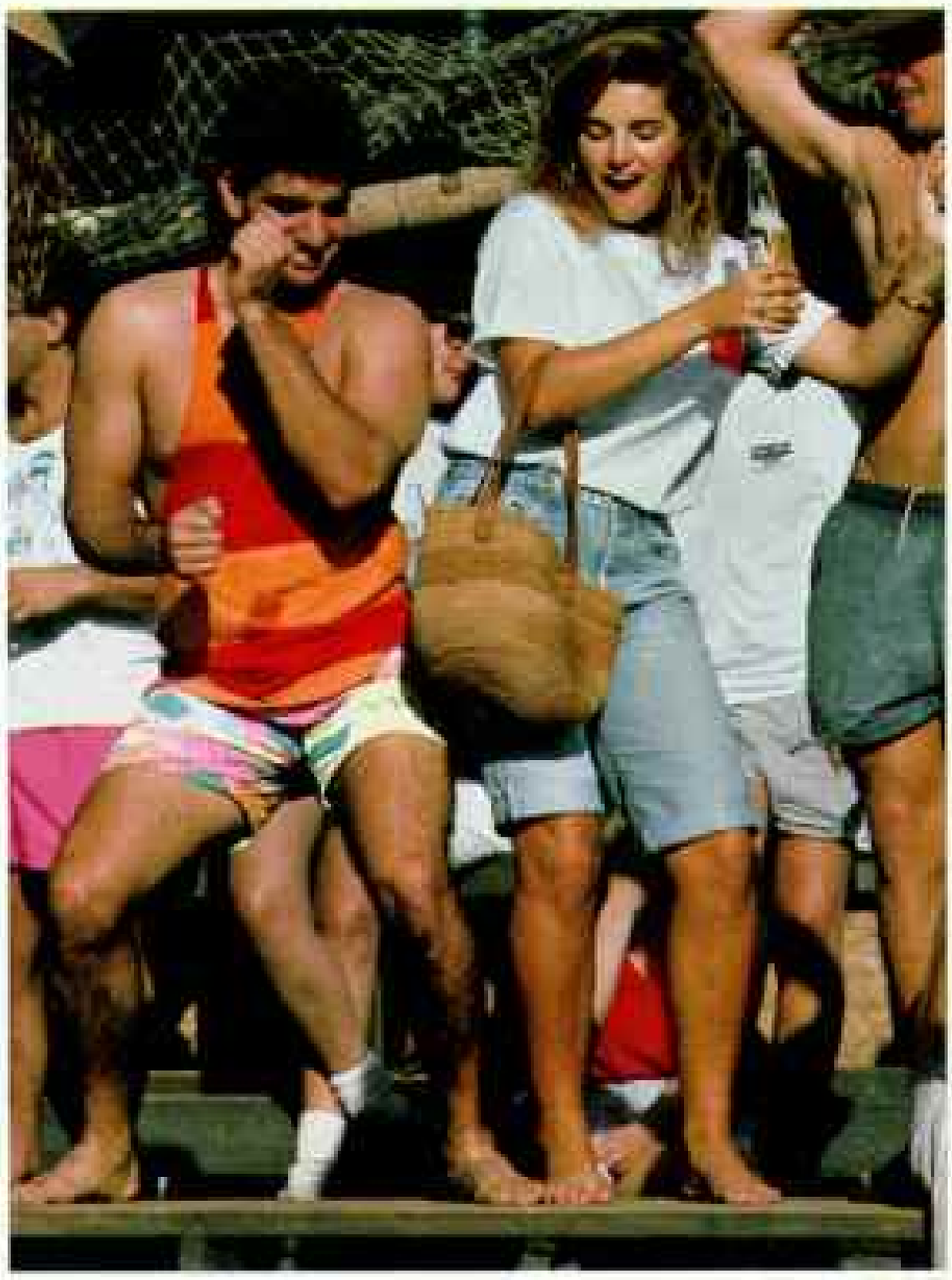
Wherever this highway goes, it captures towns—pulling commerce away from their centers to a strip alongside the pavement. This is the contact zone between cultures, where the guy at the PEMEX gas station comes face-to-face with the man behind the wheel of the $50,000 Winnebago with dirt bikes and surfboards strapped on top. The language of Baja Californians is laced with words that have passed from English into Spanish around a gas pump. You may not find the words *autopartes*, *parkiar*, *carro*, *trocke*, or *lonche* in your Spanish dictionary. But you'll hear them sure enough when a Baja Californian fixes your water pump, tells you to park your car behind his truck, or invites you to lunch.

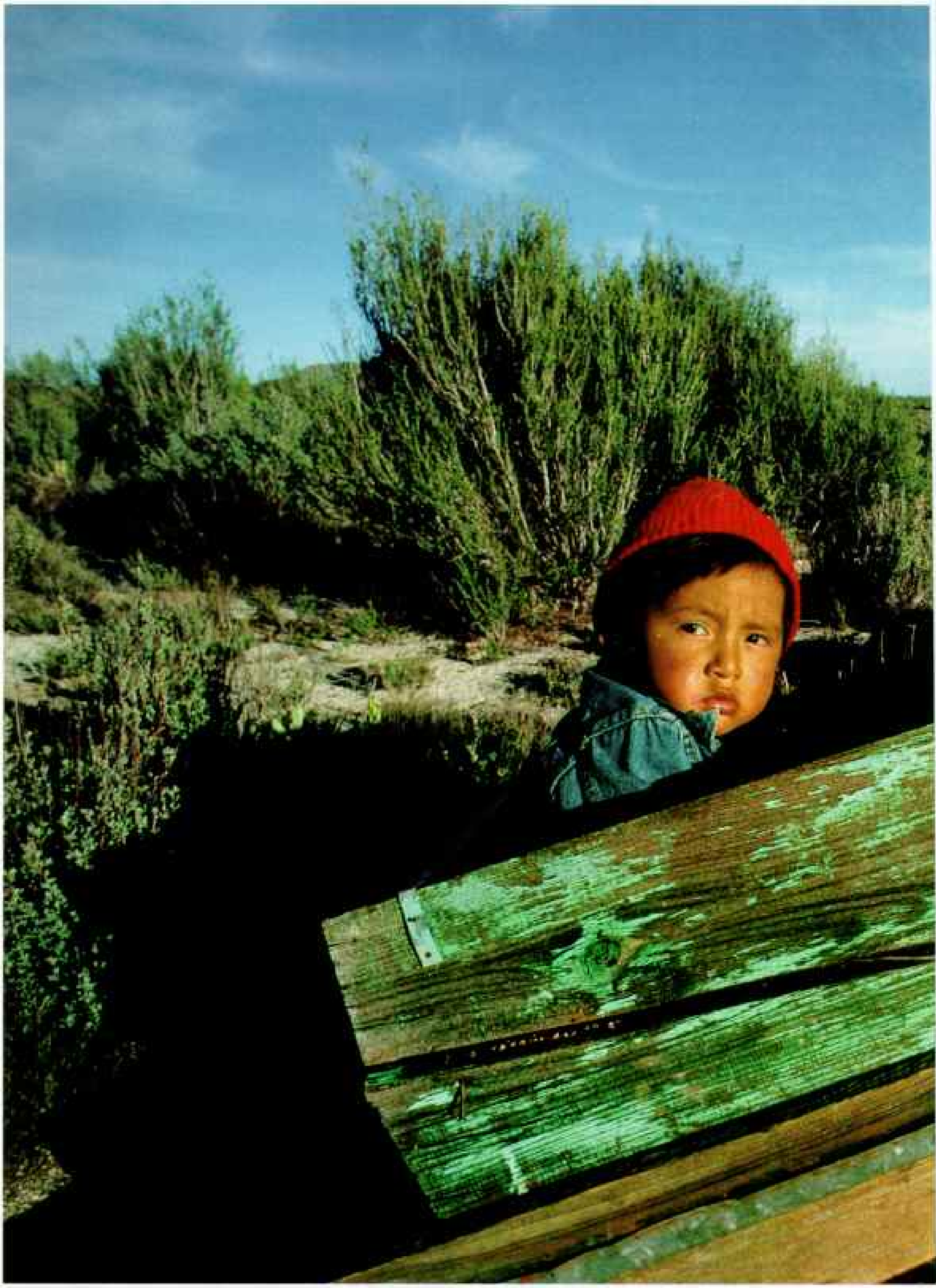
Tourists become fewer the farther south you drive along Mexico 1. Many never make it past the curio shops and cantinas of Ensenada, home to both the Baja 1000 off-road race and the Mexican tuna fleet, where an "attorney for tourist protection" is on call to put visitors at ease. Others turn east on a new paved highway to San Felipe, a quiet fishing town on the Sea of Cortés where residents more often need protection from the tourists.

Recently San Felipe has been overrun by the party animals of southern California, and the scene on Easter weekend has turned especially ugly. Said one American visitor: "If Mexicans went to San Diego and acted the way some Americans act down here, we wouldn't just throw them in jail—we'd close the border."

Doña Anita Espinoza, the gray-haired matriarch of El Rosario, has a saying about this: "Bad roads, good people. Good roads, all kinds of people." In her coastal town 150 miles south of Ensenada, she has watched, with a twinge of regret, as good roads replaced old

A gringo invasion is launched every weekend, as thousands of California students head for Baja (an abbreviation that quietly rankles many native peninsulares), favoring hot spots like Rosarito Beach (below). Ensenada hosts the Baja 1000 (above), the legendary off-road race run by SCORE, a U. S. racing organization. "The peninsula is like a crazy mixture of Mexico and the U. S.," observes a Mexico City native. "It's a different kind of culture."





Living off a barren land, Paipai Indian Teresa Castro and her grandson Miguel comb the desert for firewood near Santa Catarina. The Paipai were so isolated that they escaped deadly epidemics of smallpox, measles, and other diseases that

spread from mission to mission. Like her ancestors, Teresa uses a fire pit to bake agave, a staple of the Indian diet. "It's not easy to get food from cactus," she observes. "But if we work hard, God gives us just enough to live."

Spirits soar on Sunday in Todos Santos, where Padre Hipólito Zacarías conducts a children's Mass in his church. Affectionately known as "little father," the young priest also takes his ministry on the road, driving his pickup truck to remote ranches and fishing camps.

values with gringo ways and dependencies, even as they earned her little restaurant a reputation for the best lobster tacos in Mexico.

Just beyond her door the highway turns inland, away from the cool Pacific, and sets out alone into a torrid landscape of cactus and dust and the bones of a thousand dead automobiles, picked clean by backyard mechanics.

This is back-lot Baja California, a destination you'll never see advertised in FONATUR's slick brochures. Its symbol is a tumbledown mission, say, or a heap of rusty mining equipment, or a clutch of abandoned ranch houses reeling in the wind. These monuments to the failed dreams of Baja Californians bristle with the sound of sand carried on the hot wind, and they invariably gather other things cast away, blocking the litter that blows incessantly across the landscape, fluttering around forever, immune to the disintegrating effects of rain because there is none.

For years the pavement ended just south of Anita Espinoza's restaurant, and few dared to drive the rough-and-tumble dirt road between here and La Paz, 700 miles to the south. Anita fondly remembers the odd collection of American biologists, Baja 1000 drivers, and assorted wild men who passed her door in those days. "Those were the ones I called heavy-duty Americans," she said. "They'd stay out in the desert, make camp, eat their Wheaties. They loved this land with a passion."

NORMAN ROBERTS is a heavy-duty American. He's 69, moves like he's 30, and has been scrambling around Baja California since he was seven. He wears wire-rimmed glasses and an old chewed-up straw cowboy hat, even when cooling off in the Sea of Cortés. He was a high school sophomore in 1936 when he first bounced through El Rosario in a '29 Model A. And he recollects a trip north out of La Paz in 1948 when he and

a few buddies had so much trouble that after they reached El Rosario ten days later, they jumped out and kissed the pavement.

Norman told me this story in the gruff, wry, deliberate style that served him well during his veterinarian days, back when he doctored racehorses in Tijuana. That was after his snake-collecting days and before his days as a consultant at the U. S. Department of the Interior. These days he manages investments from his San Diego home, serves on the International Whaling Commission, and writes scientific literature about the natural history of Baja California in his spare time.

Norman, his bride Gelín, and I drove south one August in his Baja truck, a four-wheel-drive camper fortified for off-road travel. Norman's truck is the only thing I've ever heard him brag about. "It'll drive forever and climb a wall," he likes to say. He was working on a new edition of his field guide to the plants of Baja California. Gelín, a former schoolteacher from Mexico City, had never traveled south of Tijuana and wanted to see the land that won her new husband's heart so long ago.

As we drove south from El Rosario, we passed the canteen back and forth in a kind of trance, lulled by heat waves rising off the pavement. I wiped dust from the little plastic thermometer I'd clipped to my bag; it read 110 degrees. The scene out our window was a no-man's-land of reddish volcanic mountains and scorched vegetation. Mars with cactus.

"It's a thin line between life and death this time of year," Norman said. "A lot of desert plants—cholla, creosote, mesquite—go into a dormant phase during drought, like deciduous trees in winter. They die by degrees—first the tips of branches, then the branches, then the stem. The roots are the last to go, and all it takes is a little rain to reverse the process."

Indians roamed this desert during pre-Columbian times, he said. They hunted snakes to supplement their diet of beetles, mice, lizards, cactus pulp, and roasted agaves. "In other words," he said, " you and I would have gone hungry most of the time."

Red meat was a delicacy so prized that they customarily tied a string around each morsel, chewed and swallowed it, then pulled it back up for the next fellow. During summer they gorged themselves on cactus fruit, then dried their feces in the sun, picked out the seeds, ground them up, and ate them again. They were nomads, probably driven south into the peninsula by enemies, and spent most of their lives on the move from one water hole to another—"not unlike the old Baja travelers," Norman observed.

AS THE HEAT began to lose its edge one afternoon near Cataviña, we turned off onto the peninsula's original road, which bumps along in the dust next to the paved highway. "That's the old road right there," Norman would sing out as we traveled along, pointing with pride to some hair-raising stretch of switchbacks winding up a russet cliff. "They ought to make that road a national monument," he declared once. "Of course, you're talking to a guy who thinks the whole peninsula should be a national park."

Cataviña sits among remnants of an ancient mountain range, reduced now to huge granite boulders strewn across the land. Winds and a thousand changes in climate have sculptured these rocks into monuments to the sublime hand of erosion, and in the white sands grow plants that match them in size and majesty.

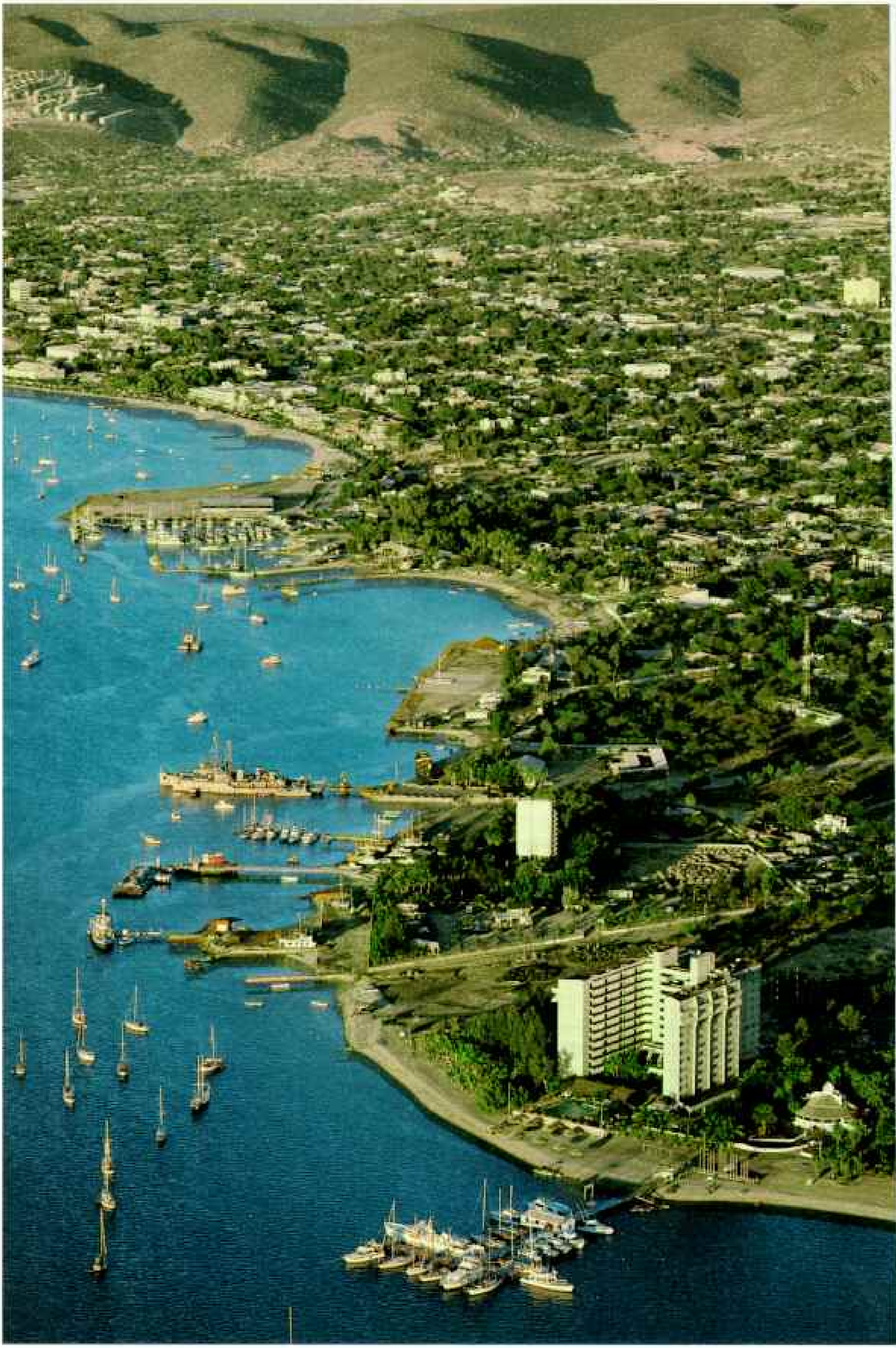
This is the realm of the *cirio*, or boojum—a tall, outlandish tree whose slender branches curl skyward like tentacles (page 739)—and the stately green cardon, its thorny trunk squat and gnarled as an ancient oak. Norman explained that both species occur mainly in Baja California and in a few small colonies in Sonora—suggesting that they may have evolved as the peninsula split apart from the mainland and started moving toward Alaska at the rate of some two and a half inches a year.

He told me this while poking around for rattlesnakes before dinner, an old habit of his. "This is prime red habitat," he explained, referring to the red rattlesnake common in Baja. He stopped and turned over a fallen cardon with his foot. He learned to hunt rattlers as a boy, he said, working on commission for the San Diego Zoo. His hero was the zoo's herpetologist—a man so comfortable with snakes that he once got bit while waving a rattler around during an animated conversation.

"Never been bit myself," he mused. "Ordinarily herpetologists don't get bit because they're always looking down."

"Ornithologists get bit," he continued, "because they're always looking up."

The three of us made camp in a clearing and climbed a boulder, the loose grains of granite crunching beneath our boots, to watch the sun



set. Later, cloaked in the light of our dying fire, we listened to the creak of cactuses swaying in the wind and warmed our bellies with tequila from a tin cup. Somewhere out in the boulders, a coyote wailed beneath a spray of cold stars. Norman and Gelín conversed for a moment in Spanish, the language they were married in. Gelín is a merciful soul, and she gave me a brief translation. "The most perfect night in the world," she said, her dark eyes shining.

"This is the stuff that keeps you coming back to Baja," Norman said quietly. "The primitiveness, the aloneness of it. My problem is I never get tired of it. It seems like my compass always points south."

MOST OF THE YEAR you can drive the length of Baja California from Tijuana to Cabo San Lucas—a journey of some 1,050 miles on the peninsular highway—and cross running water exactly once, at the little town of Mulegé.

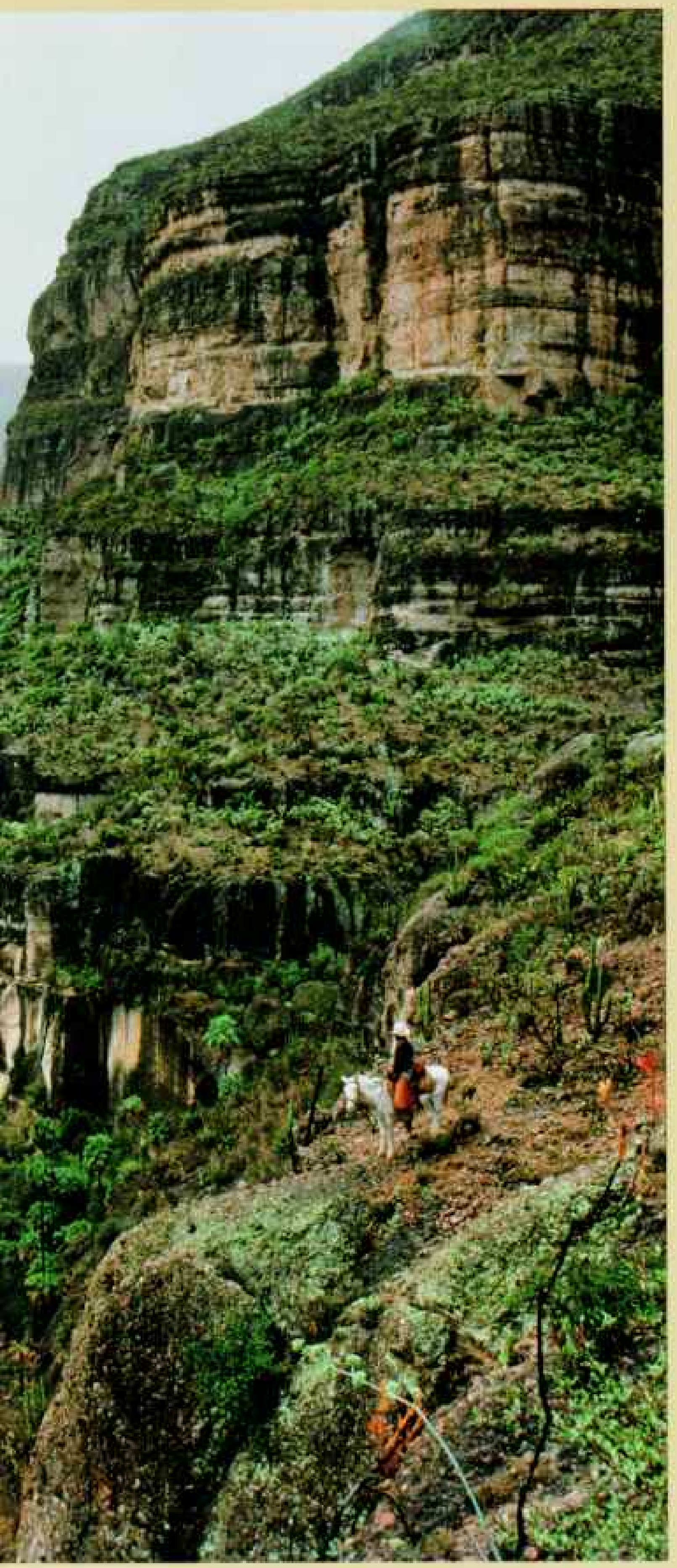
There a trickle of underground water rises to daylight two miles from the gulf and finds itself the centerpiece of a palm-lined oasis. Its sudden appearance in a land where 90 percent of all rain evaporates practically on impact seems so improbable, even bizarre, that many here believe the water must originate somewhere else. Alaska, they whisper. The water comes all the way down from Alaska.

To my mind there is no more dramatic sight than coming upon one of these rare green oases in Baja's desert, and no regional figure of speech more pleasing to the ear than *agua dulce*, meaning water that is sweet, or potable. Baja Californians speak the word *agua* with love and reverence and a sense of ultimate consequence, much as they say *Dios*, the word for God. "*No hay agua*," a rancher will say solemnly, explaining why an entire mountain range is uninhabited. There is no water. Or, "Without *agua* we have nothing," a remark I heard a hundred times from the lips of farmers and fishermen and waiters and politicians all over Baja California—a land where only fools waste water, and then not for long.

"Once there was nothing here but cactuses," said Marco Antonio Nuñez, a farmer from Ciudad Constitución, a prosperous farm town northwest of La Paz that gets only about four inches of rain a year—barely enough to keep a cactus happy. For the past few decades farmers have *(Continued on page 738)*

Fast times are nothing new to La Paz (facing page), capital of Baja California Sur. This is where a ship full of Spanish mutineers first blundered upon California, and where rumors of stunning pearls brought Hernán Cortés in 1535 to see for himself. La Paz earned her nickname "La Perla" exporting pearls to the crowned heads of Europe, even as the rest of Baja California languished. When oyster beds died mysteriously in the 1940s, La Paz's status as a duty-free port and fisherman's paradise drew Mexican tourists to soften the blow.

Tourism has changed Cabo San Lucas at spine-tingling speed from a sleepy fishing village to a booming resort. Visited mainly by tourists from the U. S., resorts along land's end earned some 70 million dollars in 1988 and brought nearly full employment. This news spread throughout Mexico, and thousands of mainlanders have immigrated to Cabo by ferry (top). Many find construction jobs, and a few entrepreneurs survive by selling their wares to beached visitors from the north.



Californios flourish in sierra oasis

Francisco Arce and his family live a hard day's ride from the nearest dirt road. The trail to their ranch, San Gregorio, picks its way over high windswept plateaus and down loosely cobbled drop-offs where even mules study their steps. Each twist of this trail, it seems, leaves the 20th century further behind and brings you closer to the late 18th, when this area was settled by families who stayed on after the missions failed. They became known as Californios, and precious few of them remain here in the Sierra San Francisco.

One morning Francisco Arce led the author to a tiny spring gurgling from a crack in the dry riverbed above his ranch. "*Aquí nació el rancho,*" he said: "Here the ranch was born." He explained that the spring gushes forth even during years of drought. This, he said, is what sparked the imagination of his late father, Loreto Arce, who came upon this place while herding goats as a young man. He devised a way to use this water—piping it in hollowed-out palm logs half a mile down the arroyo. There, in a few acres of soil that he and his family had scraped and toted down from the hills, he planted an orchard.

"Very sweet," the author said one day, savoring the orange Francisco had plucked from a tree planted by his father. "Of course," the rancher replied, his eyes filled with pride. "It's an Arce."

Besides his reputation as a skilled fruit grower, Francisco Arce (below, at left) is known throughout the sierra as an expert saddlemaker. He recently taught his sons, Francisco Jr. and Luis, foreground, to make *teguas*, the hand-stitched shoes worn here by *vaqueros*, from pieces of cowhide so thick that cactus thorns won't penetrate them. For twin brothers Pepe and Martín Ojeda, who spend their week herding goats, workaday teguas are also dressy enough to wear with their Sunday best (right).

At a neighboring ranch (left), Francisco's 87-year-old uncle, Fernando Arce, and his wife, María, pose with their son and son-in-law beside houses thatched with palm fronds from the oasis below.

Ingenuity is everything in the sierra, which is why most ranches raise goats—an ingenious animal if ever there was one. As one rancher explained, goats eat anything, rarely stray, and—most important—can survive droughts that would kill cows, pigs, even chickens.

One of these goat ranches is a day's ride up the mountain from San Gregorio. Its name is Rancho San Pedro, and, in contrast to the cool, peaceful, orchard air

of San Gregorio, here the author and photographer found the air filled with dust and goat stink and a dull throb of excitement—the men had sunk a well and it was filling with water.

In one of the ranch houses, they came upon a young woman, Sofía Altamirano (above), holding her infant niece while cooking tortillas on a stove made from a car's gas tank. Life is good in San Pedro, she said. There is water in the well.

(Continued from page 731) drawn water from an aquifer to grow wheat, sorghum, and other crops for sale to Conasupo, Mexico's national grocery store, or for export.

Then several years ago water from wells west of the highway—closest to the Pacific—turned salty. Seawater had invaded the freshwater aquifer, seeping in as fresh water was pumped out. Now, with wells growing saltier by the day, how long before the water will be too salty to use?

"Twenty years if we're lucky," said Alberto Jaime, a government expert on water resources. "The water table is dropping a meter a year beneath those fields. We must use this limited resource more wisely." The average farm in Ciudad Constitución, he said, uses 300,000 cubic meters of water a year and provides two or three jobs. A hotel room, on the other hand, creates two jobs and uses just 550 cubic meters. "My friends in Mexico City ask, 'Why don't you seed the clouds?' " he said. "I say, 'Great, that's a fine idea, but where are we going to buy the clouds?' "

Farmers in the San Quintín Valley south of Ensenada have dealt with this equation differently. "Most wells in this valley yield water so salty it's deemed unsuitable for agriculture," said José Santos, supervisor of seed production for Rancho El Milagro. His company pioneered the use of drip irrigation systems, developed in Israel in the early 1960s, that deliver precise quantities of water along plastic tubes to the plants—including salt-resistant strains of cantaloupes, tomatoes, and cut flowers for export to the United States.

"When we started, everyone looked at us like we were crazy," said Santos. "Now everyone's doing it. We're producing the tomatoes that used to be grown in San Diego for a fraction of the cost—thanks to cheap land, cheap labor, and those little plastic tubes."

THE MISSION TOWN of San Ignacio sits squarely in the center of the peninsula, within striking distance of the highway and flanked by the alkaline wastes of the Vizcaíno Desert on one side and a devilish wilderland of rust-colored lava on the other.

Like Mulegé, this town is blessed with water that rises from a spring. For decades the

Using a hands-on approach, biologist Enriqueta Velarde (left) of the Universidad Nacional Autónoma de México studies birds nesting on Isla Rasa in the Sea of Cortés. Alarmed by rapid tourist and fisheries development in the gulf, Dr. Velarde leads a movement to preserve the region's unique habitats.

Evolved in isolation, the boojum tree (right) grows only in Baja California and across the gulf in Sonora.

people of San Ignacio have collected this water in a man-made lake and tapped it, via canals, to wash clothes, sprinkle dusty streets, and irrigate oranges and date palms.

The Pacific is near enough that many San Ignacians earn their living on the water, fishing during the week, then returning to their families on weekends. They come home to one Baja town whose soul hasn't been paved over by the highway, and many here pass their leisure hours in the cool of the plaza, chatting peacefully in the shade as workmen whisk the sidewalks clean with palm fronds and the girls of San Ignacio, whose praises are sung from Cabo to Mexicali, pass sweetly by.

In 1716 when Jesuit missionaries first explored this area, they found hundreds of Indians in the oasis. As they had begun doing two decades earlier at Loreto, the Jesuits established a mission colony and built a church.

The padres ran a tight ship, carefully screening the soldiers and tradesmen brought in from Sonora missions to support the colony. They strictly forbade sexual intercourse between their Indian flock and these workers. But they couldn't shield the Indians from the white man's diseases, and during the 18th century one epidemic after another—typhoid fever, measles, malaria, typhus, and smallpox—devastated the Indians. Between 1743 and 1808 the native population at San Ignacio plunged from 2,000 to a hundred. And by 1850 the Indian population of Baja California—perhaps 35,000 when the missionaries landed—was all but extinguished.

As the missions deteriorated, the laymen dependent on them looked for alternatives. A fortunate few acquired land near an oasis or pushed north with the missions into present-day California. Others fanned out to claim ranches in the dry surrounding mountains.

Perhaps 20 of these ranches remain in the Sierra San Francisco (page 733), which lies north of San Ignacio. It is there, in the remote mountainous interior, that an older—some would say truer—Baja California lives on, little changed by the tourist caravans, the highway, or the events of the past 200 years.

BEYOND THE SIERRA to the east lies the Sea of Cortés. There, in the cool air that lingers in the hours before dawn like a truce between the desert and the fierce yellow sky, barefoot fishermen nudge their *pangas* out into the still waters of the gulf.

Depending on the season, the fishermen may motor out to check lines they set the night before—thick cables baited with hunks of dorado to attract hammerhead and thresher sharks—or to tend 300-foot nets unfurled to catch manta rays. These days they might instead be taking tourists out to troll for marlin, roosterfish, snapper, or yellowfin tuna—species present in such abundance that the Sea of Cortés has acquired a reputation among sportfishermen as the "world's greatest fish trap"—implying that fish somehow take a wrong turn into the gulf and get stuck there.

The "world's greatest fish hatchery" is

A sea of plastic ripples across the San Quintín Valley, where farmers grow tomatoes using drip irrigation systems and mini-greenhouses to conserve underground water supplies. Baja California farms are consuming water much faster than it's being replenished.

more like it. For these fish are mostly the homegrown products of an incredibly bountiful food chain, set in motion by the upwelling of nutrient-rich cold water from the gulf's deep basins and submarine canyons.

Marine scientists have counted more than 800 species of fish and 2,000 species of invertebrates in the gulf and found a cetacean population as varied as any in the world. It includes fin, blue, gray, humpback, and sperm whales, as well as the *vaquita*, or Gulf of California harbor porpoise—an endangered species endemic to the northern Sea of Cortés.

Such variety and abundance have historically led Baja Californians to see these waters as a cornucopia, delivering blessings that the sky so often withholds from them.

"In Baja California nobody starves," Anita Espinoza of El Rosario had told me, pointing out what she regards as a key difference between the peninsula and the interior of Mexico. "No matter how poor you are, here you can always catch a fish to eat."

THOSE DAYS may be numbered. Mexico's economic crisis has put new pressure on fishing exports to earn foreign exchange. Mexico has nearly doubled its catch in the past decade, and the gulf now accounts for 40 percent of Mexico's total fish production.

Many small independent operators like Cristóbal Vizcaíno, a 65-year-old fisherman from La Paz, are concerned about *cooperativas*—the government-sponsored fishing cooperatives licensed to take prize species such as shrimp, lobster, and abalone from Mexican waters. Vizcaíno blames the growing Mexican shrimp fleet—some thousand boats in the Sea of Cortés alone—for killing the *escama*, or trash fish, and other creatures caught in their nets along with shrimp.

"They kill everything," he told me angrily. "They pick out the shrimp, then shovel the dead fish off the deck—ten tons for every ton of shrimp. Why waste fish when people are starving in Mexico?"

"What may be more critical is what the shrimp industry does to the bottom environment," said Greg Hammann, a fisheries biologist with CICESE, a government scientific agency in Ensenada. "Their nets drag along the bottom, plowing up habitat, and nobody knows how long it takes to regenerate."

Nobody knows, either, how the loss of some 200,000 metric tons of trash fish each year affects the great web of life in the Sea of Cortés. But this much is certain—shrimpers aren't the only ones taking biomass from this sea. Every fisherman I talked to has seen foreign boats fishing inside the gulf or lurking nearby, violating the various limits Mexico has declared to protect her coastal waters.

LUIS COPPOLA's eldest son, Luis Jr., manages the Finisterra, the family's hotel in Cabo San Lucas. Also the author of a scathing book on government corruption, the 41-year-old Coppola shows plenty of his father's vigor. Lately he has channeled it into a bold crusade against illegal fishing in the waters near Cabo.

It all started with the *Fukuju 17*, a Japanese boat flying the Mexican flag that put into Cabo in May 1982. A surprise navy inspection revealed that its hold was filled with frozen marlin, swordfish, and dorado—all species then reserved by Mexican law for sportfishermen.

There have been at least five other incidents in recent years, said Coppola, pulling a stack of documents from his files. "We have names,

"Catch and release" is a motto in Cabo San Lucas, where roughly half the marlin caught by tourists are set free. The rest are often cut into steaks (below) and given away. Anglers claim Cabo's legendary catches are being depleted by commercial fleets—a complaint echoed by fishermen on the gulf (right).

crew lists, and registration papers, along with taped interviews of people who work on these boats." All support his belief that Japanese and Korean boats have been issued permits illegally to fish the waters of Baja California.

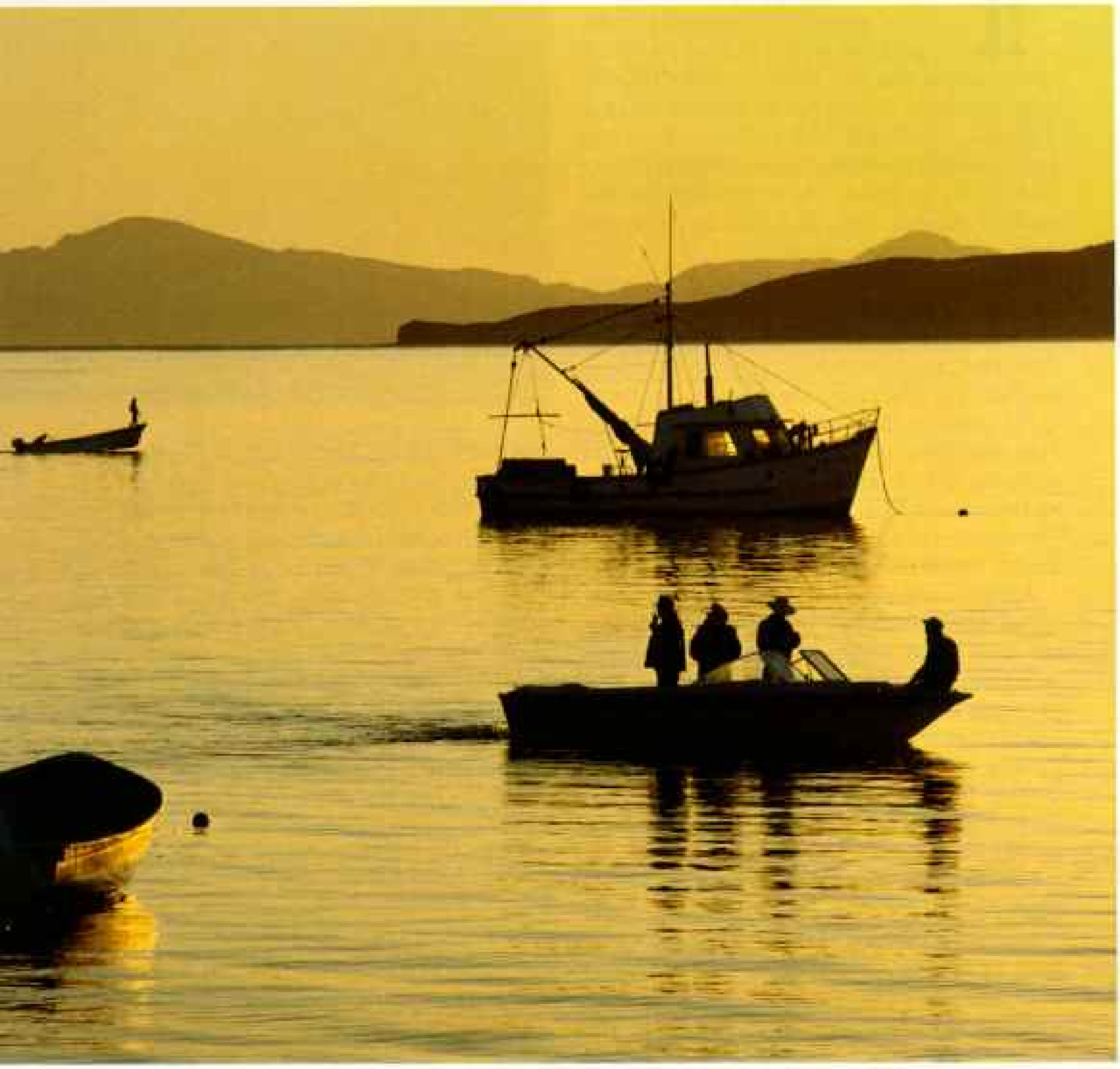
Even more threatening, he said, are the foreign long-liners—huge vessels equipped with processing plants—that steal in at night to plunder the billfish populations near Cabo, reeling in 50 miles of baited hooks at a time.

After years of battling to stop these long-liners, Coppola and his allies may be getting some results. Three Japanese boats have been seized for fishing illegally off Baja's coast during the past year—reflecting, many believe, the attitude of Mexico's new reform-minded president, Carlos Salinas de Gortari.

"It's a new breed of leader we're seeing these days—and not a moment too soon," says Coppola. "Many people in Baja California depend 100 percent on their sportfishing clientele. You kill those marlin and you're writing 'out of business' on their doors."

Marlin may be the lifeblood of tourism, but no type of fish has caused biologists so much concern as the sardine, a choice item on nature's menu that serves as a barometer for the gulf's ecosystem. Brown pelicans, gulls, terns, boobies, dolphins, and many fish depend on sardines for food.

Within the past two decades most of the Mexican sardine industry, once in Ensenada on the Pacific coast, has moved to Guaymas, and boats are pulling record numbers of



Once disdained, stingrays are now sought after by fishermen on Isla Espíritu Santo, whose declining catches may reflect overfishing in the gulf. Despite economic benefits, recent development threatens the self-reliant life-style of the born peninsular.

sardines from the Sea of Cortés. Recently fishermen began to notice that schools were getting smaller, and so were the fish. Fearing a population crash like the one that wiped out California's sardines in the late 1940s, the government in 1987 began declaring a brief, annual moratorium on sardine fishing in the gulf.

THAT WAS A STEP in the right direction, says Enriqueta Velarde, whose work on Isla Rasa, a tiny, guano-covered island in the gulf, serves as a beacon for Mexican conservation. Dr. Velarde, of the Universidad Nacional Autónoma de México, and her colleague, biologist Fulvio Eccardi, along with a team of students, man a research station each spring on Rasa, where 95 percent of the world's elegant tern and Heermann's gull populations gather to breed.

"Our studies had shown that the birds rely on sardines for food," said Velarde. "But until three years ago we had no idea how much." That year, mysteriously, the roving schools of sardines vanished from the waters near Rasa.

"It was a disaster," recalled Eccardi. "Usually about 15,000 tern chicks survive to leave the island. That year we counted 200—and witnessed what happens when the sardine population suddenly drops. It was a scary year for the world's elegant terns."

Armed with data, Velarde and her team spend much of the year in Mexico City, working with other conservationists to convince government leaders that further study and planning are urgently needed to manage the Sea of Cortés ecosystem.

"It's essential," she says. "Not just for wildlife but for those guys out there with the nets—Mexican fishermen—who are having a harder and harder time making a living."

One of the guys out there with the nets is Marcelo Lucero. Born in the tiny seaside village of San Pedro México, southeast of La Paz, he learned to fish from his father and grandfather. "Now there was a fisherman," Lucero said. "He learned to fish from the missionaries."

A few years ago Lucero adapted to changing times. He became a fishing guide, taking tourists out to fish the waters he knew so well.

"With commercial fishing it's a big risk," he said. "Maybe you catch fish, maybe no fish. But with *turismo*, you know you will make money. Seventy dollars a day, maybe more, plus tips." Not long ago he pooled his resources and bought a taxi—an '83 Dodge van painted school-bus yellow, with a big black stripe around it. I asked him why.

"Because I want to be prepared," he said cheerfully, "when all the fish are gone."

"What do you mean?" I asked.

He shook his head slowly. "Every year the fish are down, down, down. The commercial boats, shrimpers, Japanese, us, gringos—everybody. We all fish, fish like crazy, and there won't be enough to go around. I think in ten years you come back and I'll be driving a taxi all the time. No more fishing. My wife says I'll probably die from lack of salt water."

I WENT FOR A WALK one afternoon in the desert northwest of La Paz, on the day I understood Baja California best. On this particular afternoon a cool wind from the west suddenly came up. Then dark clouds rolling in off the Pacific gathered over the Magdalena Plain, and it looked as if it might actually rain. My wife, Annie, and I had parked on a dirt access road behind the farms of Ciudad Constitución. On our right were fields of wheat, ripe and ready for harvest, watered from an aquifer that each year grows more salty. On our left the desert stretched uninterrupted, west to Magdalena Bay.

Annie and I—along with the farmers, no doubt—were thrilled by the prospect of a good soak. Together we walked out into the desert to welcome the first rain we'd seen in more than two months of traveling. Surely it would rain any second: We could smell rain, and it seemed that somehow the desert could smell it too. On that afternoon, in that place, I could hear those sun-tortured old cactuses, cloaked in thorns and withered hide, sigh with sweet anticipation. The desert was poised for rain.

Then the clouds went away, as they always seem to, and the land became very still and quiet. The sun shone, and again the heat was clear and sharp. But for one overcast moment I had seen something as profound in its way as the Virgin of Guadalupe, the miraculous vision in the desert that gives Mexicans hope.

"We have many obstacles to overcome," Luis Coppola had told me. "There is little water and even less planning. But Baja Californians always find a way. We are experts at adapting to our surroundings."

With a motion of his arm he sent my imagination wandering up the long, twisting highway of hope toward Tijuana, more than a thousand miles away.

"Take a good look around you as you go," Luis Coppola said.

"This crazy desert is full of life." □

RESHAPING OUR LIVES

ADVANCED MATERIALS

Technological progress can be gauged by how humans have used the materials provided by nature. Now, equipped with greater understanding of the structure of matter, modern-day alchemists in laboratories around the world create new materials that are revolutionizing our times.

By THOMAS Y. CANBY SENIOR ASSISTANT EDITOR

Photographs by CHARLES O'REAR WEST LIGHT

WE HAD JOGGED a hundred feet, and already the man beside me was straining. But his face showed triumph—triumph over the impossible.

Sixteen years ago in Fremont, Nebraska, a seed truck crushed Roger Charter's legs. Both were amputated above the knee. For more than a decade the onetime star athlete fought for a normal life with traditional wooden legs. But the hopelessness of it ate away at his spirit.

Now, thanks to that resilient spirit and new limbs made possible by the miracles of advanced materials, Roger Charter (opposite) is the first such amputee ever to run.

"My old wooden legs weighed 15 pounds apiece and hurt my stumps—I'd clomp two blocks and have to sit and rest," said Mr. Charter, today a dispatcher for the Union Pacific Railroad in Omaha. "My new legs weigh half as much and flex like real."

Those high-tech legs comprise a tidy little inventory of advanced materials: knees and ankles of light titanium alloys born of the space age, shins of a powerful composite of carbon fibers pressed into a matrix of resin, sockets of a flexible but strong new polyethylene to fit comfortably on the residual limbs.

And the feet? "The most difficult part," acknowledged John Sabolich, president of a prosthetics firm in Oklahoma City and a pioneering designer in advanced materials. "The human arch is like a complex leaf spring, almost impossible to duplicate. Fortunately a new plastic provided the springiness."

Like Roger Charter, all of us will find our future shaped in part by profound changes taking place in the stuff things are made of.

Plastics, so versatile that the same substance that makes your garbage bags also armors U. S. Army tanks, have surpassed metals in volume sold. For tomorrow manufacturers are talking about synthetic fibers—cousins of the plastics—bringing us sweaters that change color with the turn of a dial and suits that change their cut at fashion's whim.

Composites, pound for pound the strongest of all materials, have moved beyond pricey tennis rackets and golf clubs into the sinews of aircraft and missiles and now enter mass production. Ceramics, everyone's dream material but a nightmare to work with, soon will bring cleaner-running auto engines in the fight against air pollution and global warming.

What about steel and other alloys, shouldered aside by the flashy synthetics? They are countering with new blends to recapture old markets. Even staid concrete is blossoming. There's a materials scientist out there who is casting cement coil springs, and another who built a concrete *(Continued on page 752)*

New products to solve old problems

A breakthrough occurs in a Swiss lab, and Japan's magnetically levitated train (left) comes closer to commercial reality. The aluminum-alloy skin falls on an aged airliner, and the aviation industry awakens to the threat of metal fatigue. Thus materials shape our lives.

A 1986 discovery in Zurich made a household term of superconductivity—the flow of electricity without resistance. Superconductors have been harnessed for three decades, but only at temperatures near absolute zero. The Zurich team identified materials that superconduct at higher temperatures, promising faster computers, more efficient power transmission, and inexpensive electromagnets that will help get Japan's 300-mile-an-hour Super Maglev off the ground.

JAMES A. SUGAR, BLACK STAR, AND GEORGE F. MOBLEY, NGS STAFF

Putting its faith in innovation, the Beech Aircraft Corporation of Wichita, Kansas, brought a new look to aviation with its Starship (left). Carbon fibers in an epoxy matrix form the body of this corporate passenger plane made entirely of composite materials.

The plane is powered by twin jetprops behind wings that feature vertical-tip sails. The result is a craft that, although

STEVE BRONSTEIN; BACKGROUND PHOTOGRAPH BY ROBERT RICHKIS, BLACK STAR

slower than a jet, has better fuel economy and more headroom than most small planes.

Composites appeal to the aircraft industry because of their strength and lightness, qualities that earned them a market in sports equipment such as tennis rackets, golf clubs, and surfboards. But composites can be laborious and costly to make—drawbacks that are now yielding to automation.

Age caught up with an Aloha Airlines jetliner on April 28, 1988, when the roof of the forward cabin tore off at 24,000 feet, killing a flight attendant and injuring 65 passengers. Heading from Hilo, Hawaii, to Honolulu, the 19-year-old plane was making its 89,681st flight.

Passengers are seen evacuating in a photograph taken after an emergency landing on Maui. In the foreground, metallurgist James Wildey of the National Transportation Safety Board holds pieces of the Boeing 737 that tell the tale: The repeated stress of thousands of takeoffs and landings caused the growth of tiny cracks at rivet holes—cracks that, though small enough to escape visual inspection, led to disaster. The NTSB findings prompted fresh awareness of the vulnerability of metals to fatigue.

The track is never muddy at Remington Park in Oklahoma City, where the "dirt" is composed of polymer-coated sand particles. The surface is also fast and soft, report pleased jockeys.

Man-made polymers, known familiarly as plastics and synthetic fibers and rubbers, have profoundly changed our material world. Most are built on carbon molecules found in petroleum and other hydrocarbons, with hundreds of new varieties entering consumer products annually. Their potential is almost limitless, say chemists like Richard Fleming of Du Pont: "Compared with metals, plastics are in their infancy, yet they are already more complex. Over the years manufacturers have enhanced them with one property after another—stiffness, toughness, flame retardation, lubrication, color—and we're only beginning."

A lightning bolt or a nuclear blast would never blind a pilot wearing these goggles, developed by Sandia National Laboratories in New Mexico. Made of polarized glass and a ceramic called PLZT, the lenses are clear when linked to an electric current. A flash breaks the circuit, instantaneously blocking all light.

Light in weight and resistant to heat and corrosion, ceramics hold promise for widespread use. Materials scientists focus on overcoming brittleness, a limiting weakness.

More reflective than a bathroom mirror, a giant heliostat focuses sunlight for generating energy at Sandia National Laboratories. A silvered polymer film coats a thin metal membrane stretched over a steel hoop 26 feet in diameter, producing a mirror far lighter than conventional glass for easy mounting and aiming.

Versatile plastics today surpass metals in volume sold, exacerbating the waste problem at landfills as well as creating unsightly refuse along highways. State governments and plastics manufacturers pursue a variety of solutions. One approach is to make plastics that degrade, either in sunlight, bacterially, or chemically. Another answer is recycling. A growing number of jurisdictions require curbside pickup or impose deposits to encourage return of empty containers.

ANDERSON CLINIC, ALEXANDRIA, VIRGINIA

Determined to continue her ballet career despite degenerative arthritis, Zina Bethune stretches in her Los Angeles studio. To ensure maximum flexibility, Bethune helped design her hip replacements, shown in an X ray. A porous cobalt-chrome coating on the implants permits strong bonding with bone.

Seen with his son Jeremiah in Duncan, Oklahoma, Ken Whitten uses artificial limbs that replace forearms lost in a power-line accident. The prostheses, of carbon composites, use computer chips to send impulses from upper-arm muscles to his new fingers.

(Continued from page 746)

hang glider.

The people concocting these materials will tell you they are working a revolution.

"For the first time in history," observed Merton Flemings of the Massachusetts Institute of Technology, "we can design materials precisely to fit our needs, molecule by molecule, atom by atom."

They get help from incredibly sophisticated tools. New microscopes reveal atoms nestled in their lattices almost as clearly as we see eggs in a carton. Lasers lay down atoms on surfaces so artfully as to endow them with entirely new properties: Insulators become conductors, metals become glasses. Magnetic cannons firing ion beams harden metals and ceramics against corrosives. Fulfilling an age-old dream, computer graphics enable materials scientists to study a complex molecule on a screen, rotate its shining galaxy of atoms, and select where to place an additional atom for a desired effect.

Yesterday materials makers were mainly metallurgists. Today they must also be chemists, ceramists, engineers, and physicists. In their labs you often see them staring at the wall; follow their gaze and you see a copy of the periodic table, that cryptic tabulation of the elements they so cleverly manipulate.

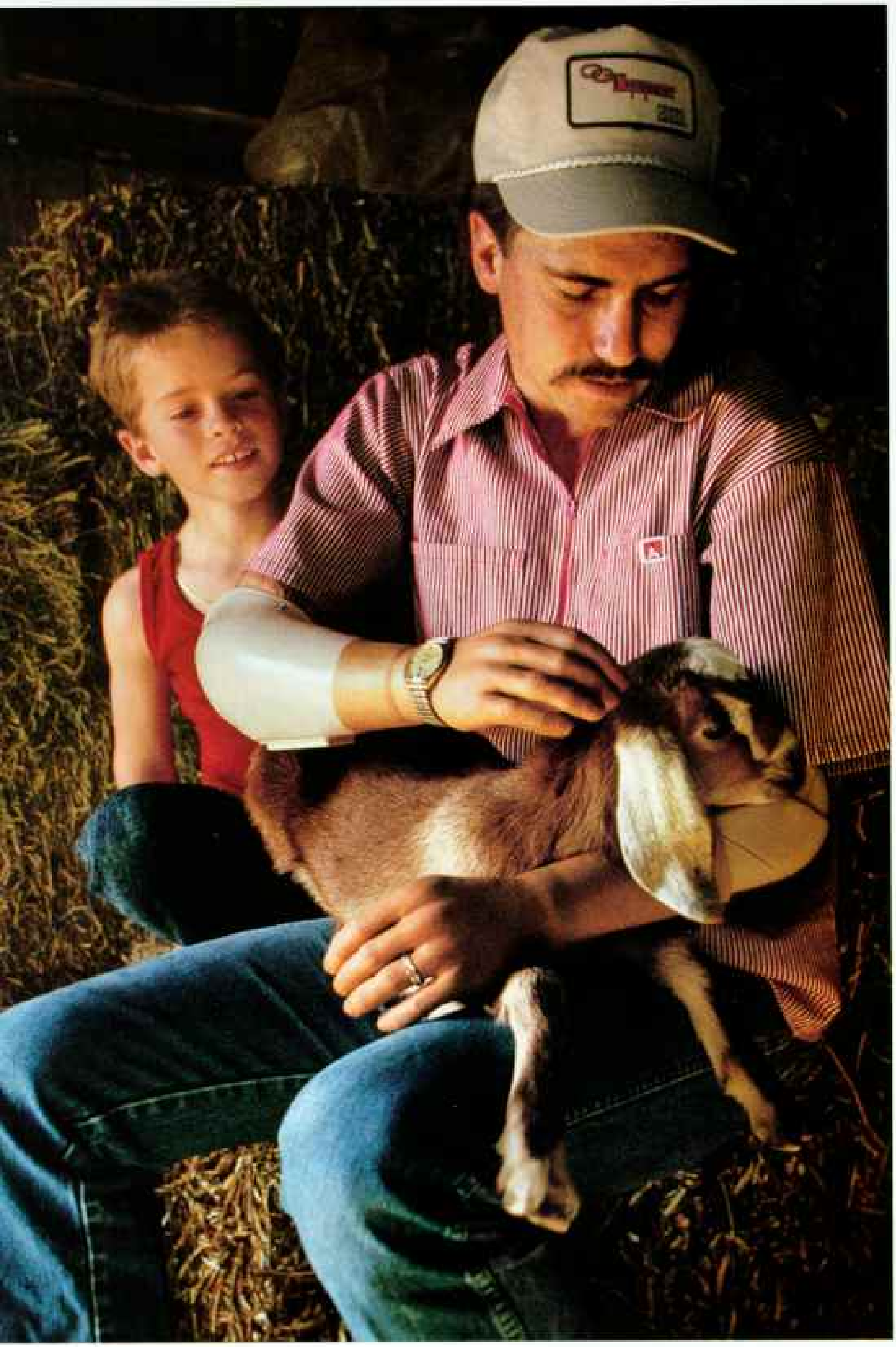
Little to their liking, these scientists find themselves caught up in global competition. Japan, the Soviet Union, the major European countries, China—all are locked in the crucial struggle to develop new materials and processes. At present the United States leads in research but often lags in commercialization. And the stakes are high.

"Materials are the building blocks of the future," observed Rudy Pariser, former research director for the Du Pont Company. "Today's advanced material is tomorrow's commodity."

"Tomorrow" can be a long time. On average, a decade elapses between test tube and marketplace for a new material, with exhaustive testing in between. Many deplore this slowness. But haste can be costly. I heard some of the horror stories:

How Britain's Rolls-Royce Ltd., switching from metal jet-engine blades to light composites, went bust because the blades had not received a rigorous "goose test" to determine the effect of bird impacts—and they shattered.

How U. S. Liberty ships, welded together by the hundreds *(Continued on page 760)*



Rebuilding the body from nose to toes

Each year Americans replace 135,000 hips; 110,000 knees, and tens of thousands of other body parts—at an estimated cost of two billion dollars. These implants face a hostile environment: The human body is wet, hot, salty, and ever in motion, and its immune system is triggered to reject any intruder. Exhaustive testing, monitored by the Food and Drug Administration, often requires ten years. Prosthetic costs run high: A simple heart valve can cost $2,000 for the part alone.

Hydrocephalus shunt carries "water on the brain" via a catheter to the abdomen to be reabsorbed. SILICONE ELASTOMER, VARIES IN DESIGN, BY DOW CORNING WRIGHT

Multifocal intraocular lens restores near and distant vision after cataract removal. POLYMETHYLMETHACRYLATE, BY IOLAB

Orbital floors replace damaged bone for the support of eyeballs. SILICONE ELASTOMER, BY SURGITEK

Cochlear implant, undergoing clinical testing, sends electric signals to auditory nerves of the inner ear. Requires small external power source. TEFLON INSULATION OVER PLATINUM WIRE AND ELECTRODES, BY RICHARDS

Artificial ear, covered by a skin graft, replaces a natural ear destroyed by trauma. SILICONE ELASTOMER, BY SURGITEK

Nose implant for cosmetic reshaping. SILICONE ELASTOMER, BY DOW CORNING WRIGHT

Mandibular mesh of titanium, a biocompatible metal, provides a foundation for jaw reconstruction after loss of bone through disease or accident. BY TECHMEDICA

Titanium dental implant allows permanent attachment of bridge to jawbone. BY IMPLEPHARMA

Artificial chin can be solid or gel-filled silicone elastomer. BY DOW CORNING WRIGHT

Heart pacemaker provides cardiac pacing for hearts with rhythm malfunctions. TITANIUM AND EPOXY OVER LITHIUM BATTERY MICROELECTRONICS, BY CARDIAC CONTROL SYSTEMS

Shoulder prosthesis mimics bone structure. The stem fits into the humerus, the socket onto the scapula. TITANIUM STEM, SOCKET OF PLASTIC-LINED TITANIUM, BY ORTHOMEDICS

Artificial heart, a UTAH-100 awaiting FDA approval, is designed for temporary use pending a heart transplant. Air pulses from an external power supply drive diaphragms that pump the blood. MOSTLY POLYURETHANE, BY UNIVERSITY OF UTAH

Prostheses enlarge the breast or rebuild breast and nipple after surgery. SILICONE ELASTOMER, BY SURGITEK

Pectus implant expands the chest for persons born with a depressed sternum. SILICONE ELASTOMER, BY DOW CORNING WRIGHT

Hinged elbow implant with titanium extension into humerus and ulna; plastic bushings prevent metal-to-metal contact at the hinge. HUMERAL AND ULNAR DESIGN, BY ZIMMER

Artificial arm for an above-the-elbow amputee utilizes muscle contractions in the remnant arm to activate electric signals that flex the elbow and wrist and open and close the hand.
COMPOSITE EXPANSION OVER ELECTRONICS, BY MOTOR CONTROL DIVISION

Soft-tissue patch replaces tissue of the chest or abdominal walls when the patient's has become inadequate because of disease. GORE-TEX, BY W. L. GORE

Hip implant uses a composite femoral stem of thermoplastic reinforced with carbon fiber. Still undergoing tests, the composite is believed to rival bone's flexibility.
COMPOSITE STEM, CERAMIC BALL, AND TITANIUM SOCKET, BY ZIMMER

Vascular prosthesis connects the abdominal aorta to the left and right iliac arteries when damaged by atherosclerosis.
DACRON, BY MEDTRONIC

Adjustable femoral implant replaces cancerous bone removed from growing children. Every six months the surgeon makes a small incision and inserts a turn key to extend the tubular prosthesis like a car jack.
COBALT-CHROMIUM-MOLYBDENUM ALLOY AND ADVANCED POLYURETHANE, LEWIS DESIGN, BY DOW CORNING WRIGHT

Artificial ligament provides a replacement for ligament in a damaged knee.
GORE-TEX, BY W. L. GORE

Ankle implant replaces the talus and lower portion of the tibia.
PLASTIC, COBALT-CHROMIUM ALLOY, AND MOLYBDENUM, BY ZIMMER

Great toe joint is often implanted during bunion operations.
SILICONE ELASTOMER WITH TITANIUM GROMMETS, SWANSON DESIGN, BY DOW CORNING WRIGHT

Penile prosthesis is inserted into the corpora cavernosum.
SILICONE ELASTOMER AND DACRON, BY SURGITEK

Testicular implant replaces one or both testicles after surgical removal or when missing at birth.
SILICONE ELASTOMER, BY SURGITEK

Spinal fixation device, still being tested, fastens vertebrae together for stabilization after fracture or removal of a tumor.
STAINLESS STEEL, BY UNIVERSITY OF VERMONT

Dialysis-access graft links a major artery and vein in kidney-failure patients to permit withdrawal of blood for cleansing and return to the body.
GORE-TEX, BY W. L. GORE

Absorbable pins fix in place bony or cartilaginous fragments, eliminating surgery to remove metal pins.
POLYMER, BY JOHNSON AND JOHNSON

Hip implant employs a zirconia ceramic ball on a titanium-alloy stem. Titanium beads on the upper stem and acetabular shell encourage ingrowth of bone for improved fixation.
BY RICHARDS

Wrist implant replaces bone damaged by arthritis, aseptic necrosis, or injury.
SILICONE ELASTOMER, SWANSON DESIGN, BY DOW CORNING WRIGHT

Finger-joint replacements, shown here for the metacarpal joints, also are made for the smaller joints.
SILICONE ELASTOMER, SWANSON DESIGN BY DOW CORNING WRIGHT

Temporary tendon, implanted during surgical reconstruction of a damaged hand, forms a tunnel through which a permanent tendon graft is threaded.
SILICONE ELASTOMER, HUNTER AND SWANSON DESIGN, BY DOW CORNING WRIGHT

Artificial leg flexes at the knee, ankle, and arch.
SOCKET AND FOOT, PLASTIC; KNEE AND ANKLE, TITANIUM AND ALLOYS; SHIN, COMPOSITE; BY SABOLICH

PHOTOGRAPHED BY TOSHI TAMBURO. PROSTHESES COLLECTED BY MARK L. BERNES, WSU STATE CONSULTANT; DONALD E. MARLOWE, FOOD AND DRUG ADMINISTRATION

Chemists' keyboard: the periodic table

Building blocks of all matter, 103 elements provide the raw components for forging tomorrow's materials. (There are at least five additional man-made elements, produced in minute quantities and existing then only briefly.) These basic substances differ as widely as buoyant hydrogen and heavy iridium—twice as dense as lead. But when arranged in ranks in the periodic table, here simplified, atoms of these disparate elements reveal family relationships that bring order to the physical world and provide an invaluable guide to chemists in their labs.

Each key bears an element's symbol; the full name appears on the key's right side. The front side lists the element's atomic number—the number of protons in its nucleus. Beginning with hydrogen, at upper left, these numbers increase sequentially along the horizontal rows, known as periods: helium, 2, upper right; lithium, 3, beneath hydrogen, and so forth.

Family similarities unite elements aligned in vertical columns. For instance, lithium and the five other metals beneath it share traits of softness, lightness, low melting point, high heat conductivity, and similar reactions in forming chemical compounds. Exceptions are the elements known as lanthanides and actinides, smaller dual keyboard, whose family ties run horizontally (see note at right).

Colored blocks on the keys, coded at right, identify some of the elements that play important roles in materials, both traditional and exotic.

Hydrogen compounds similar to those found in petroleum and living organisms are the foundation materials of many plastics.

Lithium, the lightest metal, finds growing use alloyed with aluminum for aircraft. Molten lithium reacts explosively with water, making processing dangerous.

Abundant calcium is the basic ingredient of cement.

Zirconium combined with oxygen forms a hard heat-resistant ceramic, zirconia.

The rare earth lanthanum was a constituent of the first high-temperature superconductor discovered.

Barium, a metallic component of some high-temperature superconductors, is highly reactive; it is never found in the pure state.

Beryllium, attractive for aircraft construction because of its lightness and stiffness, is toxic and costs as much as $1,600 a pound.

Magnesium offers the greatest strength for weight among metals but readily corrodes. Intensive research is overcoming this problem.

Yttrium, found in some garnets, is also a component of one of the high-temperature superconducting materials.

Wonder metal of rocketry and jet engines, titanium occurs also in ceramics and metal-matrix composites.

Hard and corrosion resistant, chromium protectively plates other metals and is alloyed with iron and nickel to form stainless steel.

Iron, principal ingredient of steel, is the workhorse metal of the industrial world.

Nickel is alloyed with steel to give impact resistance. When alloyed with cobalt, it forms heat-tolerant superalloys for jet engines.

Renowned for its conductivity of electricity and heat, copper also is a vital ingredient of most high-temperature superconductors.

Useful alloys of aluminum constantly multiply. Aluminum serves as a matrix for some composites, and aluminum oxide compounds form rugged ceramics.

SELECTED ELEMENTS AND THEIR USES

- SUPERCONDUCTOR
- CERAMIC
- POLYMER
- COMPOSITE
- ALLOY
- CEMENT

Color codes link elements to categories of advanced materials referred to in the text.

LANTHANIDES AND ACTINIDES

Two series of elements defy the table's normal order. The lanthanides, with properties similar to the element lanthanum, have two electrons in their outside shell and behave much the same chemically. Once thought scarce, they are called the rare earths.

The actinides, chemically similar to the lanthanides, are radioactive. All except uranium and thorium are rare in nature.

Thallium, a highly toxic element, occurs in the high-temperature record holder among the new superconductors.

An element in some new superconductors, bismuth has a low melting point that makes it useful in automatic fire sprinkling systems.

ilicon, the stuff of electronic chips, reacts with carbon to orm a hard ceramic and a ce- amic fiber used in compos- es. It is a component of springy silicone elastomer.

Carbon is one of the most versatile ingredients of structural materials: in plastics, in the fiber and matrix of composites, in heat-resistant ceramics, and in carbon steels.

Nitrogen atoms go into nylon and other polymers and can give hardness to ceramics and metallic surfaces.

Oxygen bolsters most plastics and composites, as well as cement and most ceramics. It is essential to high-temperature superconductors.

AN ELEMENT OF PREDICTABILITY

To the practiced eye the periodic table suggests how elements will react with one another. The key lies in their electrons, which can orbit the nucleus in as many as seven layers, called shells. Each shell can hold a limited number of electrons: the inner, two; the second, eight; and so forth (diagram below). The number in the outer shell dictates whether an atom will donate electrons to another, share electrons, or seize them, and how tightly the two will bond. If the outer shell is filled, the atom is inert, as with helium and the other noble gases.

LIGHT TO HEAVY

The weight of atoms generally increases in relation to their atomic number. At right, heavier elements receive darker shading.

SOLID, LIQUID, GAS

Each element assumes one of the three states of matter at room temperature, 77°F. Here solids appear white, liquids turquoise, gases magenta.

METAL VERSUS NONMETAL

Metals can usually be recognized by an ability to conduct electricity. Here metals are bright blue, nonmetals deep red.

THE NOBLE GASES

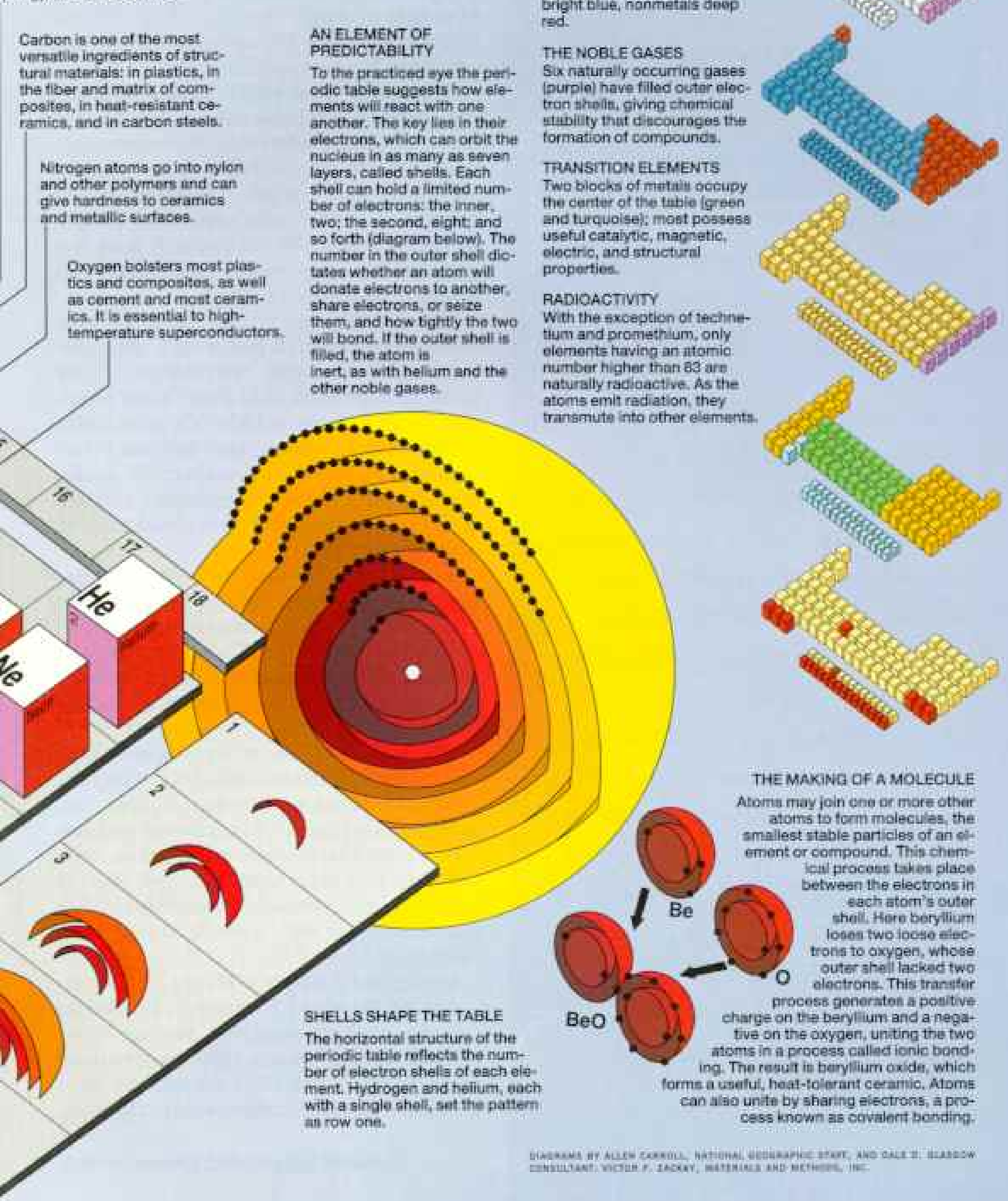
Six naturally occurring gases (purple) have filled outer electron shells, giving chemical stability that discourages the formation of compounds.

TRANSITION ELEMENTS

Two blocks of metals occupy the center of the table (green and turquoise); most possess useful catalytic, magnetic, electric, and structural properties.

RADIOACTIVITY

With the exception of technetium and promethium, only elements having an atomic number higher than 83 are naturally radioactive. As the atoms emit radiation, they transmute into other elements.



SHELLS SHAPE THE TABLE

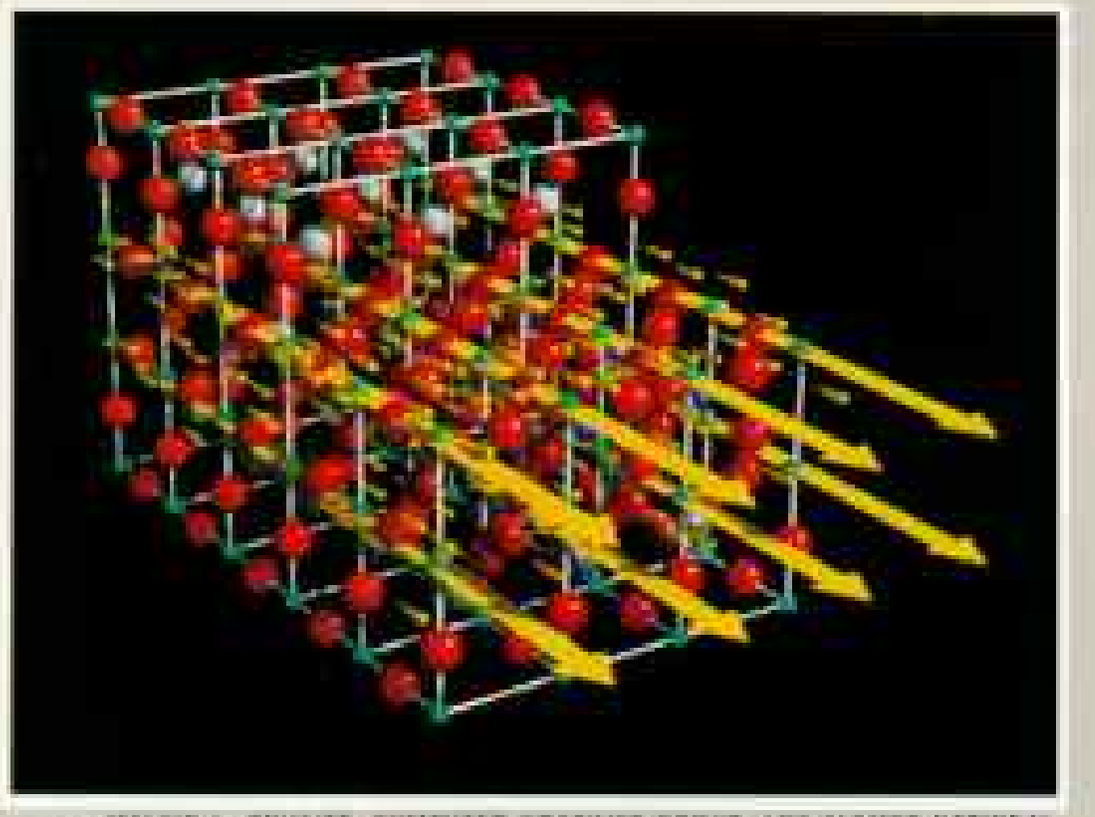
The horizontal structure of the periodic table reflects the number of electron shells of each element. Hydrogen and helium, each with a single shell, set the pattern as row one.

THE MAKING OF A MOLECULE

Atoms may join one or more other atoms to form molecules, the smallest stable particles of an element or compound. This chemical process takes place between the electrons in each atom's outer shell. Here beryllium loses two loose electrons to oxygen, whose outer shell lacked two electrons. This transfer process generates a positive charge on the beryllium and a negative on the oxygen, uniting the two atoms in a process called ionic bonding. The result is beryllium oxide, which forms a useful, heat-tolerant ceramic. Atoms can also unite by sharing electrons, a process known as covalent bonding.

DIAGRAMS BY ALLEN CARROLL, NATIONAL GEOGRAPHIC STAFF, AND DALE R. BRAMOW
CONSULTANT: VICTOR F. ZACKAY, MATERIALS AND METHODS, INC.

Superconductors



WILSON L. PRUETT, COMPUTER GRAPHICS GROUP, LOS ALAMOS NATIONAL LABORATORY; DATA FROM TRES MUELLER, LOS ALAMOS NATIONAL LABORATORY

A Tinkertoy maze to laymen, to scientists this computer graphic depicts the possible anatomy of a modern-day miracle: one of the high-temperature superconductors.

In an ordinary metallic conductor, such as house wiring, moving electrons that flow as electric current often collide with atomic nuclei in the wire, losing some momentum. In a superconductor the electrons travel pathways that avoid these collisions, permitting them to flow indefinitely.

The crystalline model above presents the theoretical structure of the famous "1-2-3" superconductor, the first to superconduct above the temperature of liquid nitrogen (77K, or −319°F). The few royal blue spheres, representing atoms of the rare earth yttrium, are virtually blocked out by abundant red oxygen atoms. For each yttrium atom there are two of barium (light gray) and three of copper (turquoise). This structure permits pairs of electrons (yellow with comet tails) to speed unobstructed along crystalline planes in the direction of the arrows.

(Continued from page 752) during World War II, often sank with tragic loss of life because defective steel lost its toughness in the icy North Atlantic, permitting small cracks to explode into catastrophic rents.

THE USUAL CAUTION flew out the window, though, with the recent uproar over superconductors.

Even in the arcane world of physics, superconductivity stands as a marvel: a state of matter in which electricity flows forever without resistance. No current is lost, no heat generated in superconductivity.

It does not come easily. Superconductors lose electrical resistance only when subjected to intense cold. Traditionally this has required immersion in liquid helium at 4 Kelvin (−452°F). This makes superconductivity cumbersome and vastly expensive, sharply limiting its uses. (We encounter it most frequently in the costly medical process known as magnetic resonance imaging.)

Since its discovery in 1911, scientists have searched for materials that would "go superconductive" at higher temperatures. They made little progress until 1986, when physicists Georg Bednorz and Alex Müller in Zurich cooled a black ceramic pellet and saw it lose resistance at 30K. Many compare the significance of their Nobel Prize-winning achievement to the development three decades earlier of the famed transistor.

Scientists rushed to their laboratories, spurred by the new discovery. Their goal was a material that would superconduct at a temperature above 77K—still cold, but the point at which nitrogen liquefies. Nitrogen is easier to handle than liquid helium and could reduce costs to one-tenth.

The Bednorz-Müller ceramic contained the rare earth lanthanum—not your everyday conductor—along with barium, copper, and oxygen. Experiments that followed successfully replaced lanthanum with yttrium, then bismuth, and then thallium, and steadily increased the critical temperature. The historic leap—to 90K—came with an yttrium compound.

It triggered a scientific Mount St. Helens.

Around the world TV cameras focused on coin-size magnets magically floating above superconducting ceramic disks amid mists of liquid nitrogen. Scientists regaled the press with visions of miniaturized superconducting

motors, massive underground magnets storing electricity to power entire cities, transmission lines carrying current without loss of an electron, and, most exciting of all, magnetically levitated trains whispering across the land at 300 miles an hour.

How far off are such dramatic applications? Impressive progress is being made, but the obstacles are daunting. The crumbly ceramics of high-temperature superconductors lack the flexibility of metallic wires. They balk at carrying heavy current loads: Exceed the critical current point, and they cease to superconduct. Solutions lag because scientists do not yet understand the basic physics involved—how high-temperature superconductors work.

The fact that they do work, however, has stimulated prodigious efforts to harness them.

One of the most intriguing artifacts to date is a small superconducting generator made in England. Its fist-size coil carries ceramic wire fabricated by Imperial Chemical Industries (ICI) in Runcorn. Though years from commercialization, it generates small amounts of power—and encouragement.

Simpler superconducting devices are also being developed, mainly for use in passive electronics systems such as communications receivers and amplifiers.

"We were already in the ceramics business when the new superconductors came on the scene," said Richard Cass of HiTc Superconco in New Hope, Pennsylvania. "Radar receivers with our superconducting components give a signal at least 50 times stronger than copper; half a dozen of them are already being tested by the Army."

IN WHAT GUISE will high-temperature superconductors first serve us consumers?

"Possibly in your TV antenna," said Mr. Cass. "A component the size of a golf ball gives vastly better reception than conventional metal. Companies are developing liquid-nitrogen coolers the size of a cigarette pack. The two could fit inside your TV. Allow three years for the superconducting element."

The advantages that superconductors offer in electronics are not lost on the U. S. military. The Army, Navy, Air Force, and Strategic Defense Initiative Office have strong programs for applications research. DARPA, the Defense Advanced Research Projects Agency, funds 37 separate projects at a total cost of 30 million dollars a year. The appeal is strongest

Wisps of vapor from frigid nitrogen envelop a thallium-based superconductor at the University of Arkansas. This superconductor has a rare characteristic: the ability to suspend magnets both above and below it. Possible applications include ball bearings that operate with no friction.

in space defense, where launch costs of $10,000 a pound inspire miniaturization.

"We're going to need tremendous computational power in space," said Harold Weinstock, who coordinates the Air Force program. "A Cray 2 computer is not large—no bigger than a few file cabinets. But there's the monstrous cooling system, with its huge power requirements. Superconductors could slash its size and reduce the power need drastically."

Computer circuitry itself offers an obvious market for superconductors. Here the current would be carried by thin films, just as films of gold and other conductors form the nerve systems of today's chips. Film experiments held high priority when I visited IBM's Thomas J. Watson Research Center in New York.

"We're working with all three of the ceramic superconductors," said IBM's Robert Laibowitz in his lab. "They can carry millions of amps per square centimeter—enough to operate many electronic devices.

"But it's hard to reproduce the films reliably. Further, the heat required to make superconducting films is too much for the silicon chips they attach to. It could take years to work things out, but we're making progress."

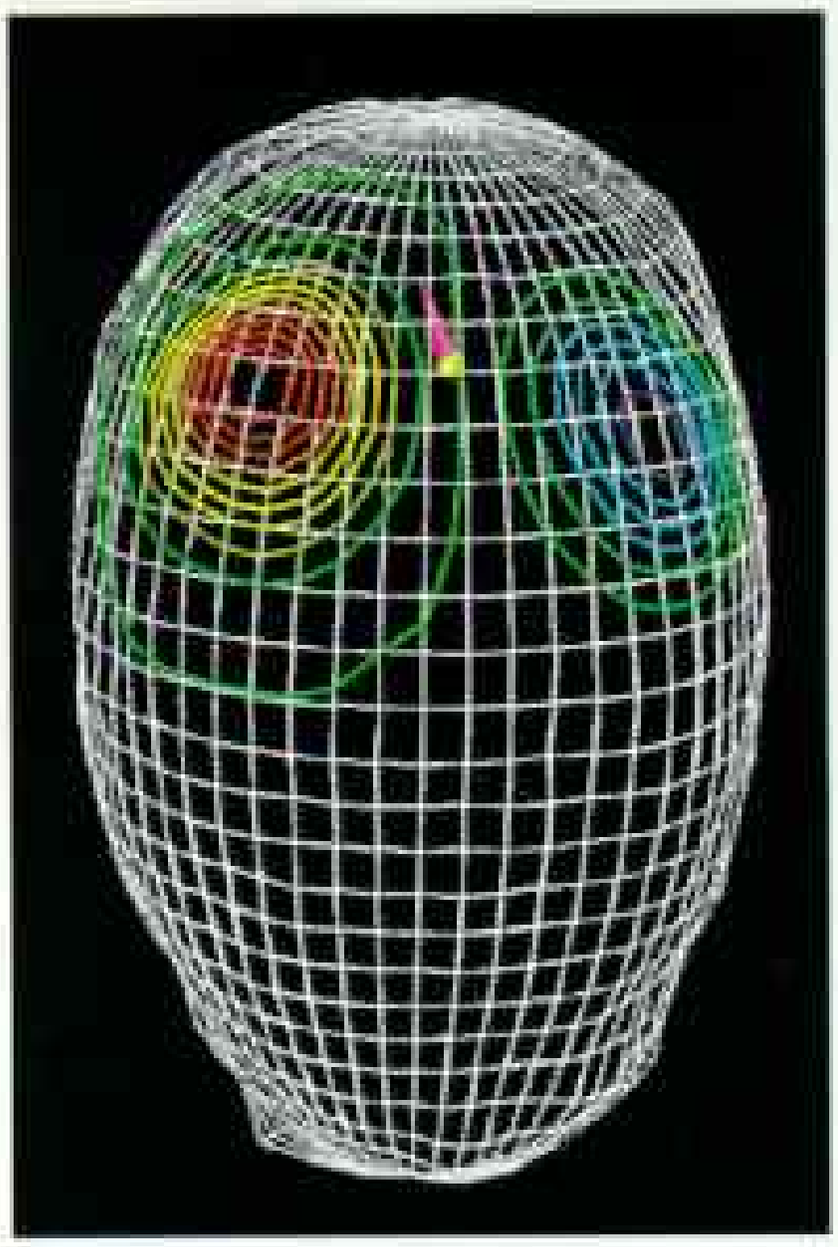
So important is this technology to national competitiveness that a presidential advisory committee has urged special collaboration between business, universities, and government. IBM has joined forces with two other research leviathans, AT&T Bell Laboratories and MIT. A similar consortium links Du Pont, Hewlett-Packard, and Los Alamos National Laboratory in New Mexico.

The effort to tame high-temperature superconductors ferments worldwide. I saw intensive programs in Britain, France, and West Germany. All three are dwarfed by Japan's.

Japanese scientists have filed more patent applications for superconductors than the rest of the world combined. More than 600 have flowed from Sumitomo Electric, Japan's leading manufacturer of electric wires and cables. While U. S. consortia are still organizing, a Japanese consortium headed by the renowned physicist Shoji Tanaka counts more than 90 scientists in elaborate new facilities.

What about the ultimate goal, a material that superconducts at room temperature? No need then for awkward liquid nitrogen. Many believe that if such a substance exists, its discovery awaits understanding of how high-temperature superconductivity works.

Expanding the frontiers of medicine in Japan, a powerful magnetometer called a SQUID uses superconductors to locate neural activity by detecting extremely weak magnetic fields in the brain (facing page). The fields are indicated by contours on a SQUID image made at New York University. Superconductors hold long-range potential for improved submarine detection by the military and the discovery of ore deposits from airplanes.



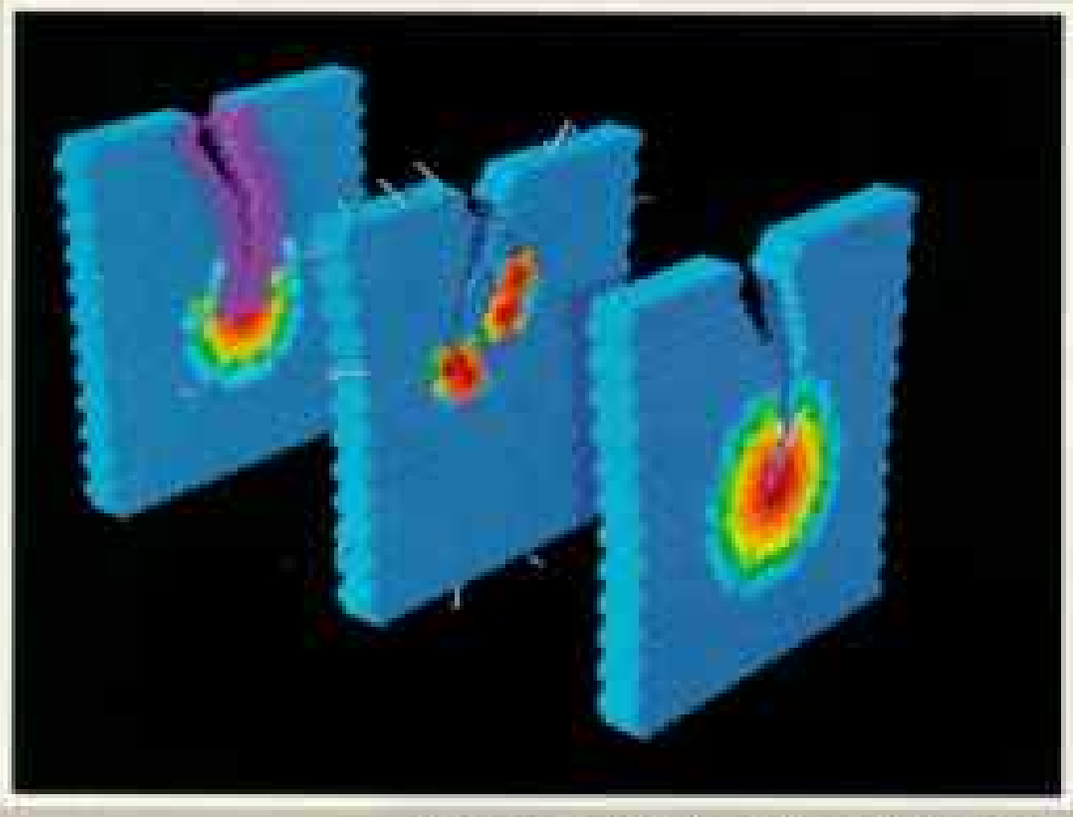
ODDLY it was ceramics, today's headline material, that gave birth to materials science some 13,000 years ago. Villagers in Japan discovered that if you cooked a clay vessel, it hardened into an entirely new substance—ceramic pottery—and retained its hardness ever after. Unknowingly these early ceramists caused atoms in the clay to lock tightly together, in what chemists call covalent and ionic bonding.

Today ceramics are riding a resurgence of interest that some call the New Stone Age. Partisans point out that compared with steel, ceramics can be harder, lighter, stiffer, and more resistant to heat and corrosion.

They can. But go back again to that ancient pottery: Drop it and it shatters. Today's ceramics behave somewhat the same.

"The problem is brittleness," explained Victor Zackay, a materials specialist with Teledyne Corporation. "Companies have spent

Ceramics



HELEN K. FRIETT; DATA FROM VICTOR F. HOKE

Attack a ceramic with heat or harsh chemicals, and it remains intact, held together by tightly bound atoms. But in that strength lies a fatal weakness: Unlike a metal, the ceramic cannot bend to absorb an impact and instead cracks, often catastrophically, as seen in the above graphic at right. Stress at the top of the ceramic has found a minute flaw, starting a crack. Because ceramic is unable to deform like metal, the crack tip rapidly wedges deeper, generating a stress pattern represented by the circular pattern around it.

The picture changes (center) when a crack begins in a ceramic toughened with fibers. As the crack hits successive fibers, its energy is partly absorbed, its course diverted, and its force spent.

In another defense, known as stress toughening, a ceramic containing two types of crystals halts the crack internally (left). As the tip penetrates, stresses cause one type of crystal to expand, squeezing the crack shut.

billions of dollars to develop useful ceramic devices, and in most cases they have failed because of brittleness. Metals, because of their crystalline structure, can deform under stress instead of fracturing, and still do their job. Stress ceramics, and their atomic bonding prevents the crystalline planes from sliding over each other—deforming. Instead a crack opens, and the object fails catastrophically.

"Before ceramics are accepted as reliable, they must be made so they can fail gracefully. This will not be easy. But ceramics offer far too many advantages to discourage trying."

The driving dream is the ceramic engine.

"Ceramic engine parts offer enormous advantages over metals," said Richard Alliegro of the Norton Company, a Massachusetts research and development firm that already markets ceramic ball bearings. "Engines would run more efficiently if they could run hotter. But metal would melt; instead we install costly radiators to get rid of that valuable heat. With ceramics we can harness the heat—and get rid of the bulky radiator."

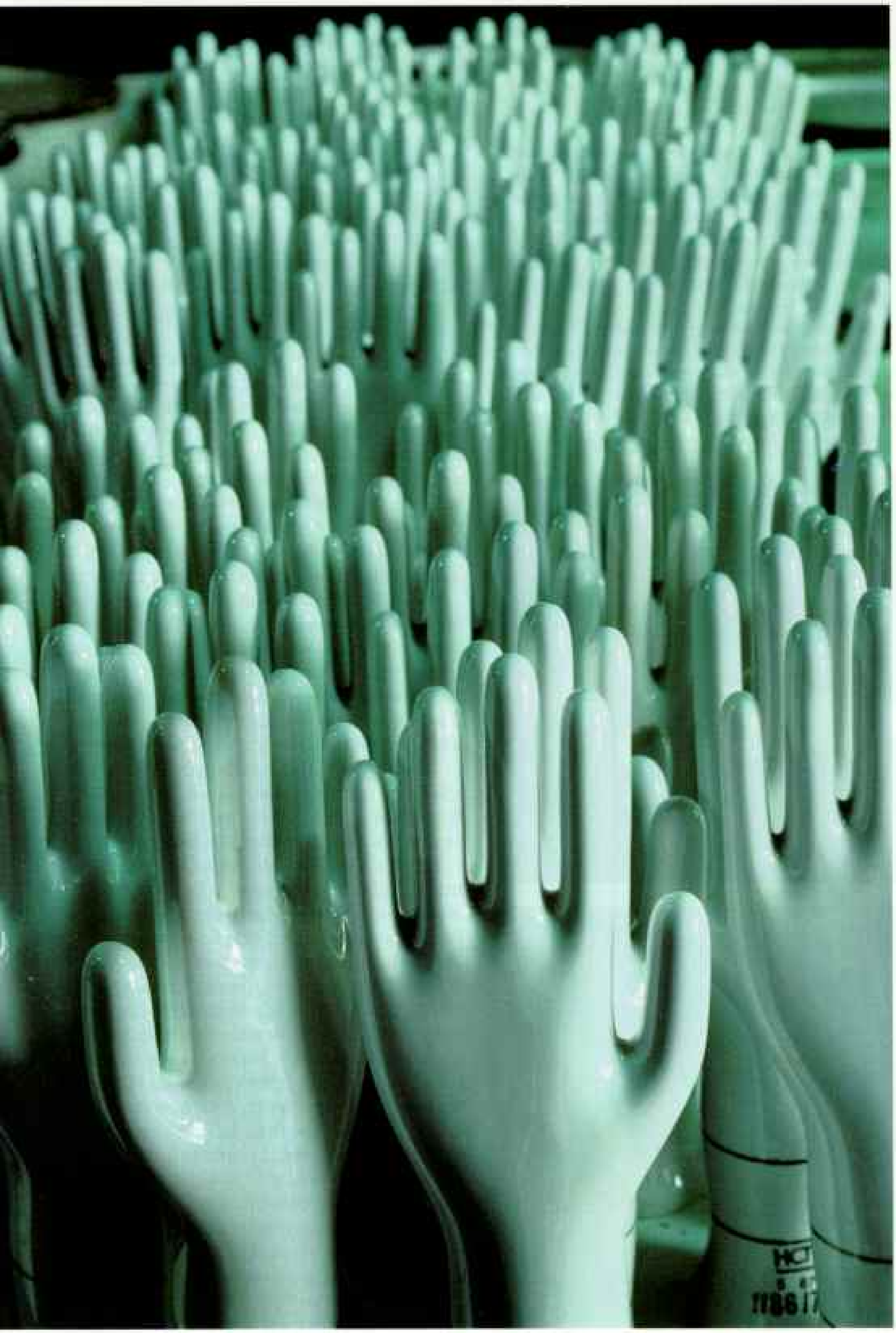
MOST EXPERTS AGREE that the greatest advances are being made in Japan. Here, where pottery began, government and industry have poured money into ceramics development.

The Japanese also have kindled intense grass-roots interest, known as ceramic fever. The fever traces in part to the relentless drive of the Kyocera Corporation, the leading maker of ceramic packages for computer chips.

"We saw a need to stimulate public acceptance of ceramics to help drive industry," said Ryusho Nagai, Kyocera's director of international affairs. "We began producing consumer items—ceramic scissors, ballpoint pens, sushi knives. Meanwhile MITI, the Ministry of International Trade and Industry, built the Fine Ceramics Center. The fever spread."

With Kyocera chairman Kazuo Inamori, I admired ceramic products gracing the lobby of his Kyoto headquarters: scissors made of

Helping hands in the fight against disease, forms made of porcelain are used in manufacturing medical gloves at a plant operated by Ansell Incorporated in Dothan, Alabama. The ceramic fingers' resistant surface and uniform heat transference permit high quality control as the forms travel on a chain through vats of latex and on to curing ovens.



The cutting edge of ceramic technology is found in Japan, where both business and government pour money into research. Light easily shines through the porous blade of a zirconium oxide knife made by the Japanese Kyocera Corporation.

A microscope photograph (bottom) shows that the Kyocera blade, at right, has a cutting edge smoother than that of a top-rated steel knife made in West Germany. Although it is keener than conventional knives and seldom needs sharpening, the Kyocera knife is brittle, a shortcoming that is the subject of continuing research.

Not all advances in ceramics are recent. Beginning 40 years ago aluminum oxide, or alumina (facing page), was used for improved spark plug insulators demanded by high-compression engines in cars and airplanes.

FRANK W. GAYLE AND ALEXANDER J. SHAPIRO, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (BOTTOM)

zirconium oxide, so hard as to rarely need sharpening; ceramic prostheses—skullcaps, elbows, hip joints, knees. We paused at turbocharger rotors being built for an experimental Isuzu diesel. They were made of silicon nitride, increasingly the ceramic of choice.

"We minimize brittleness by quality control," said Mr. Inamori. "By a precise mix of our ceramic powders, in clean rooms kept free of contamination."

Mr. Nagai and I toured a Kyocera plant just outside the sacred imperial city. Ball mills pulverized powders of aluminum oxide and silicon nitride to the fineness of particles in cigarette smoke. Products cooked inside squat furnaces, aglow like Shinto shrines. Technicians processed sheets of sapphire—aluminum oxide ceramic—that would become tooth implants and microchip wafers. I stroked a slab bigger than my notebook.

To see ceramic auto parts in action, photographer Chuck O'Rear and I followed the beacon of snow-sheathed Mount Fuji to Yokahama, to Isuzu's Ceramic Research Institute.

Institute director Hideo Kawamura gestured, and technicians raised the hood of a low sedan emblazoned with the name Ceramic (page 769). Nothing fancy, I thought on seeing the metallic-looking diesel engine. But wait! The radiator was missing, the engine tiny. This car was using its heat, not rejecting it.

"We've put 5,000 kilometers on it at high speed, up to 150 kilometers an hour," said Mr. Kawamura. "Our tests indicate a ceramic engine will last five times as long as metal."

I spun the Ceramic around Isuzu's test track, and it handled nicely. But it gave trouble starting. "Ceramic engineering is very difficult," acknowledged Mr. Kawamura.

Another Japanese partnership has staked a bold claim on the ceramic frontier. Each month NGK, the huge manufacturing company, casts 8,000 turbocharger rotors that give pep and power to new Nissan Cedrics and Fair Ladys—appealing inducements to buyers in the land of ceramic fever. But there is a downside: The rotors require costly individual spin testing for flaws, and the bulk price of ceramic powders hovers about $150 a pound.

The U. S. government effort, like Japan's, has focused on the ceramic auto engine. To me it seemed quite skimpily funded; R & D for ceramic car parts received only 11.3 million dollars for fiscal 1989. A similar program develops ceramics for diesel truck engines.

Both are run by the Department of Energy.

The auto engine that emerges from the DOE program will be different from the one in your car. Instead of being powered by pistons, it will use a ceramic gas turbine strikingly similar to a jet aircraft's propulsion system.

"Ceramic car engines will run at 2500°F," said Saunders Kramer, manager of the DOE program. "So far the rotors and other ceramic parts test well to 2200° and then fail rapidly. We need better ceramic powders to remove flaws and eliminate additives used in sintering—the baking process."

How long before ceramic engines hit U. S. highways? "We have millions of test miles to go before we prove them," said Arvid Pasto of GTE, the electronics giant. "We've reduced parts failures to one in a million. The goal is one in a billion. I see commercialization in the late 1990s." Asserts Saunders Kramer of DOE: "We'll have automotive gas turbines on the road by the year 2000—at worst."

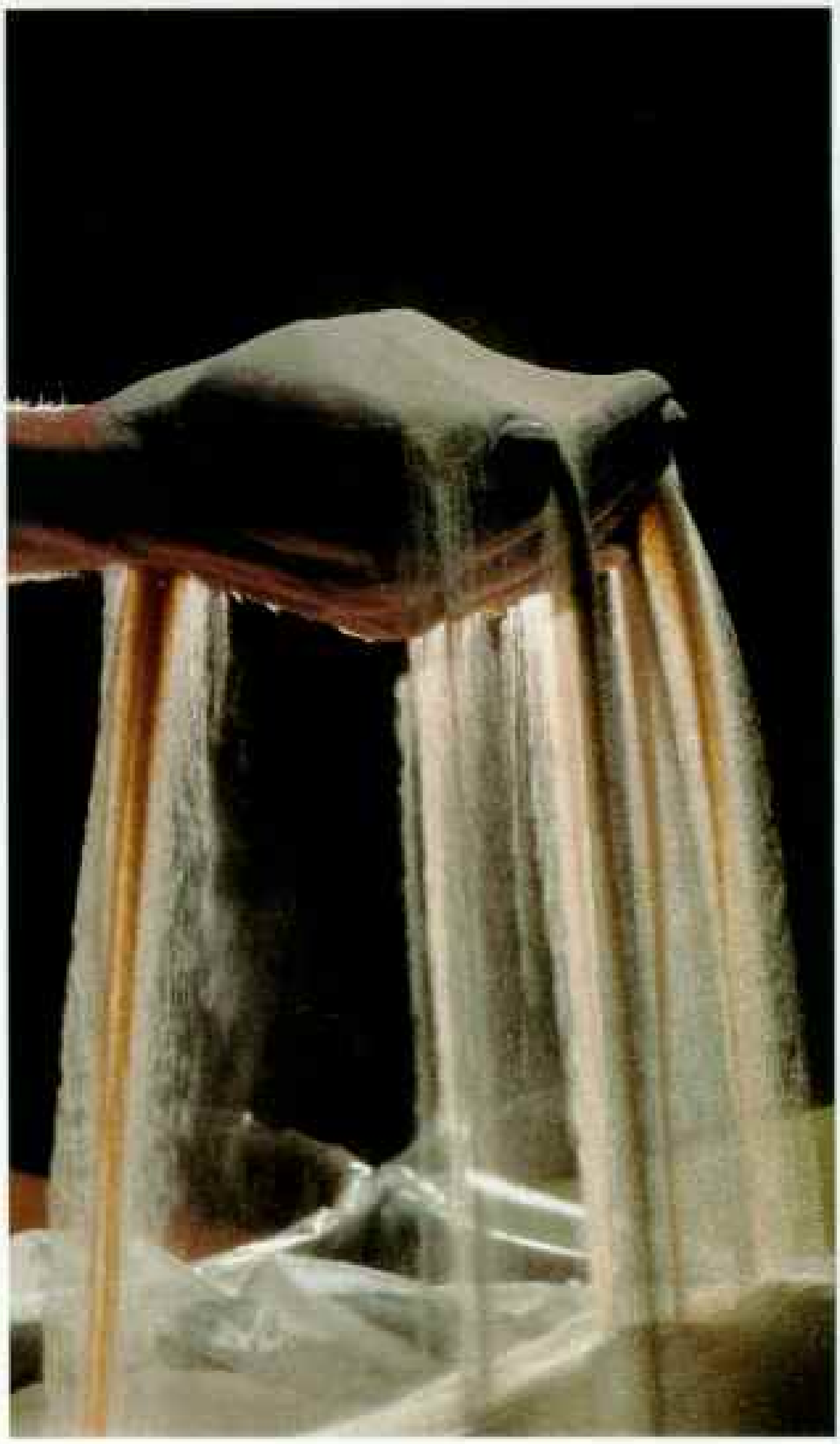
Some experts wonder if the Japanese will maintain their costly commitment. "They've invested 20 years and billions of yen," observed Sylvia Johnson, a ceramist at SRI International. "Some day they must decide how long they want to continue losing money. I've found them to be divided."

Two advanced ceramics, both developed by Corning Incorporated, already play roles in our daily lives. One is the catalytic converter in your car's exhaust system—a triumph of ceramic fabrication. The other is Corning Ware, a basic feature in 70 percent of U.S. kitchens.

Ceramics find increasing use as thin coatings on objects made of conventional materials. When next you visit your hardware store, look at the drill bits—the ones with the high price tags. These are coated with titanium nitride, a ceramic that extends the cutting life fivefold over steel. Many experts see in coatings a way to escape ceramics' vexing problems of brittleness and shaping.

The expertise of U. S. ceramics makers is growing. The Carborundum Company, a U. S. subsidiary of British Petroleum, is building a plant in West Germany to manufacture silicon carbide seal rings for European autos. GTE turns out tens of thousands of small ceramic cutting tools daily. At Norton, Jack Lucek conducted me through the process that converts silicon nitride powder into gleaming black ball bearings.

Could these intriguing spheres defy the



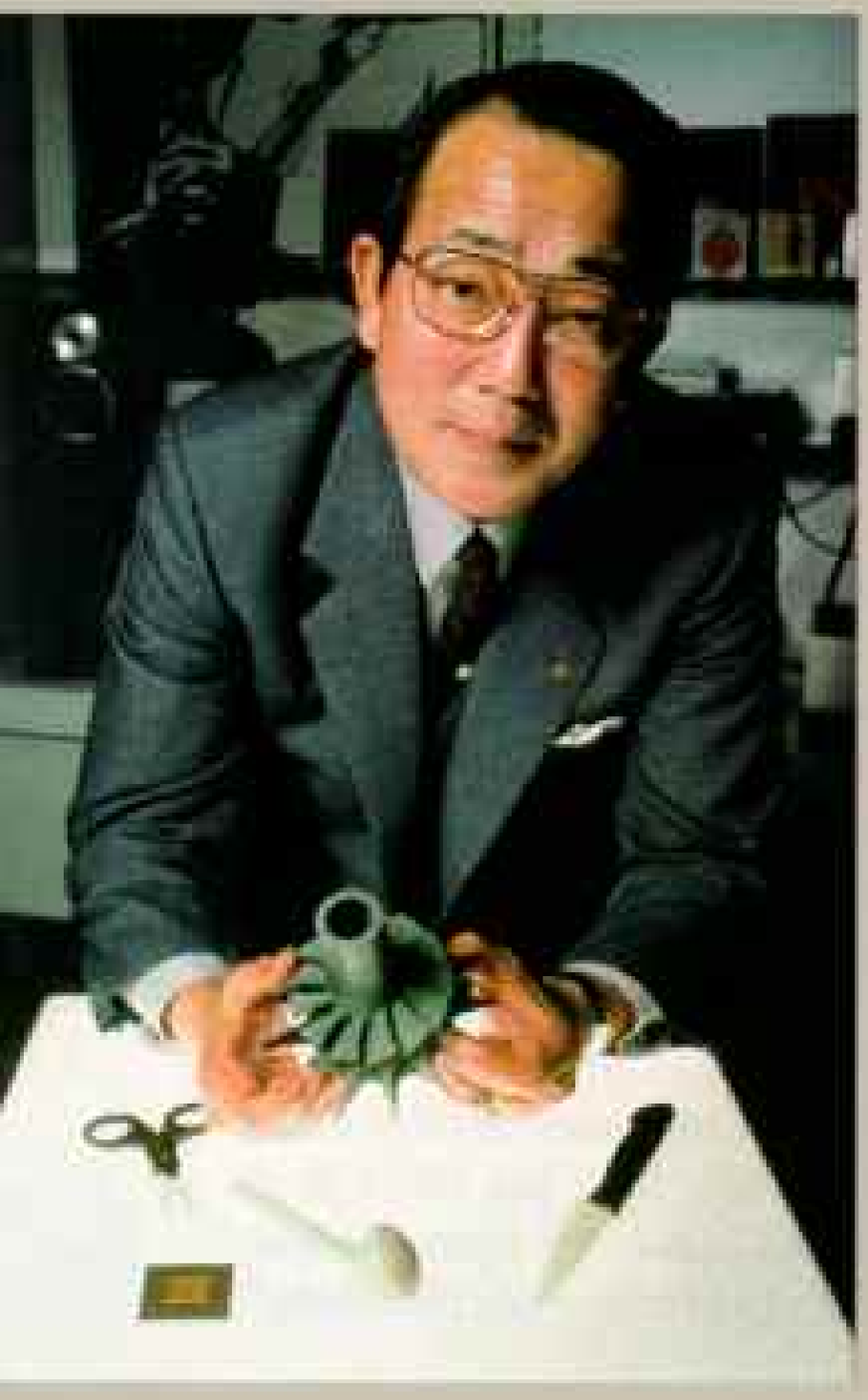
ceramics' age-old curse of brittleness? "Try and break them," suggested Mr. Lucek.

I took two the size of marbles to a blacksmith shop in Maryland. Smithies Peter Austin and Dana Dameron locked tongs around one, then bludgeoned it mercilessly with a sledgehammer. Not a nick marred the ball bearing. But the steel plate beneath wore deep dimples from the blows. The tingling wonder we felt—was it a touch of ceramic fever?

FOR A NEW MATERIAL to succeed, it usually must be able to muscle aside a metal or glass; after all, they got there first. The masters of this have been the synthetic plastics, a family of materials that didn't exist a century ago.

Ceramics help scrub the air

Antismog pioneer Rod Bagley of Corning Incorporated holds his invention, the ceramic honeycomb used in catalytic converters. The highly porous device, impregnated with chemicals, converts the harmful gases in engine exhaust to nonpollutants.



Giving metal a run for its money

Bold innovator of the Japanese ceramics industry, Kazuo Inamori (left) displays an automobile turbine rotor made by the company he heads, the Kyocera Corporation. The silicon nitride rotor can withstand the high temperatures produced by a new generation of gas-turbine engines. Leery of relying too heavily on semiconductors, the industry mainstay, Inamori has steered Kyocera into such fields as ceramic gemstones and biological implants.

Carrying a power plant is no problem for Matty Holtzberg, president of Polimotor Research (above). His four-cylinder car engine is made of resin-based composite plastic. Holtzberg hopes to interest Detroit with performance and economy, figuring that he can sell his engine blocks for half the cost of those made of iron.

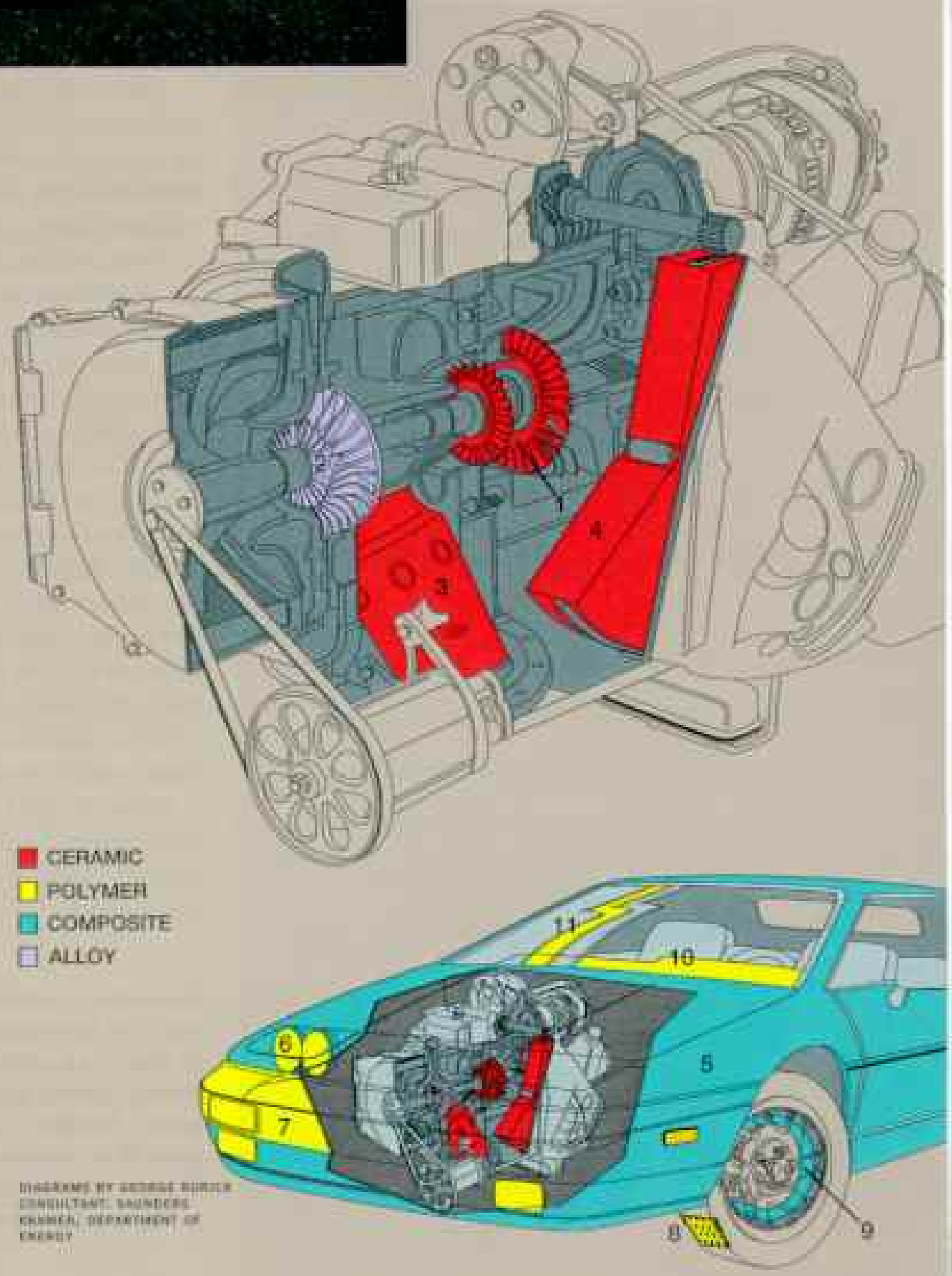
Japan tests a ceramic pioneer

An experimental Isuzu tests what may be the world's most advanced ceramic auto engine. Its dozen-plus ceramic parts include pistons, cylinder liners, valves, and turbocharger. Lighter and more heat tolerant than metals, ceramics permit the engine to run hotter—therefore more efficiently—and do away with the radiator. The car has logged more than 3,000 miles of high-speed test driving.

New engine can take the heat

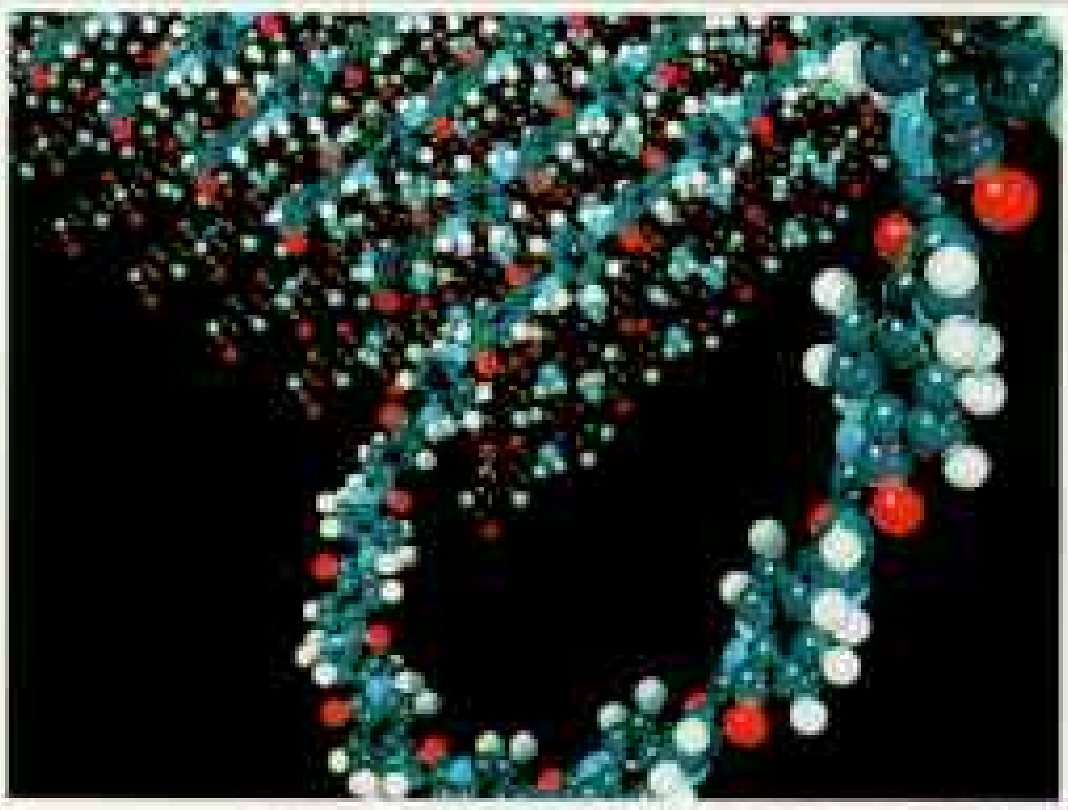
Unfamiliar technology will lie under the hood of America's ceramic automobile (right) when it takes to the road, perhaps in the year 2000. In place of pistons, two gas turbines of silicon nitride will provide power. With other ceramic parts sharing the high-temperature area, the car will run at a hot 2500°F, promising fuel efficiency and emission reductions. General Motors' Allison Gas Turbine Division has built three such test engines. The Garrett Auxiliary Power Corporation is testing an alternative ceramic gas turbine. Both programs are funded by the Department of Energy.

A range of advanced materials, color coded at right, are featured in the turbine engine and in a generic car body of today: (1) gasifier and power turbines, (2) air compressor, (3) combustor, (4) regenerator, (5) molded body panels, (6) sealed headlamps, (7) bumper, (8) reinforced tire belts, (9) brake pads, (10) dashboard, (11) safety glass.



DIAGRAMS BY GEORGE KIRIDA
CONSULTANT, SANDERS
ASSOCIATES, DEPARTMENT OF
ENERGY

Polymers



MELVIN L. PRUEITT; DATA FROM PAUL G. WIEWALD, DU PONT, AND FROM FLOYD DOWELL, LOS ALAMOS NATIONAL LABORATORY

Like gems in a necklace, molecules of Kevlar fiber form long straight chains, producing a substance five times as strong as steel by weight. In the model portrayed above, one such molecular chain loops into the foreground from a rank of identical molecules, aligned from upper right to lower left.

As revealed in the looping chain, each molecular cluster centers on a ring of six carbon atoms (black), which bind with tenacious strength. Around each carbon ring hover atoms of oxygen (red), hydrogen (white), and nitrogen (blue). In such chains thousands of molecules are linked to form a macromolecule of synthetic polymer.

Polymer-fiber technology, known to man for only half a century, has served the web-weaving spider for eons, with a basic difference: The spiderweb often is many times tougher than Kevlar. Many of nature's most common creations—bones, trees, seashells—possess a sophistication that defies duplication by materials scientists.

In 1907 Belgian immigrant Leo Baekeland invented Bakelite, a hard synthetic substance for making billiard balls and wire insulation. But Baekeland did not completely understand the complex chemistry he exploited.

That triumph fell to Du Pont chemist Wallace H. Carothers. In the 1930s he combined carbon, hydrogen, nitrogen, and oxygen—the basic ingredients of you and me—into long molecular chains. Neoprene and nylon were the results—the first wholly synthetic materials ever made by a knowing manipulation of molecular structure. They launched the materials revolution that now reshapes our world.

"Our building units," explained Du Pont's Dr. Pariser, "are simple carbon-based molecules known as monomers, derived from oil, natural gas, and coal. With the help of catalysts we connect monomers into long molecular chains known as polymers. The shape of a chain helps determine a polymer's properties.

"With Kevlar, an aramid fiber, the molecules lie straight, giving strength and stiffness. In synthetic rubber they're a tangle; stretch them straight and they try to curl up again like rubber bands, giving springiness."

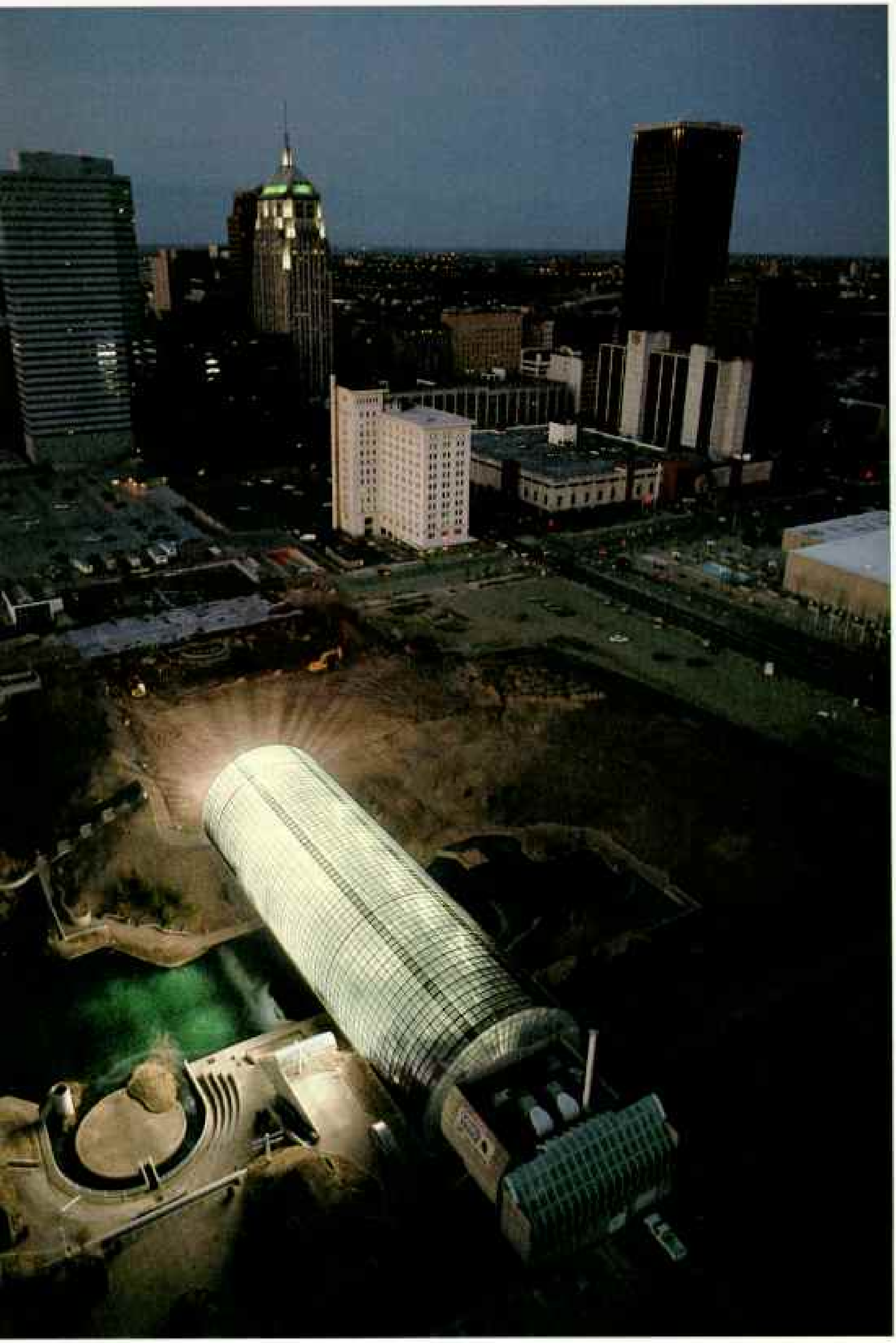
Competition is keen in every area of materials development. But nowhere is it as fierce as in the group of polymers called plastics.

Today 60,000 different plastics vie for a place in the market. Each week six or so new ones arrive at Underwriters Laboratories outside Chicago, where rigid testing for flammability and other properties qualifies plastics for components of UL-listed products.

Key targets, naturally, are Detroit's auto assembly lines, which feed so heavily on metals and glass. At GE's Application Development Center in suburban Southfield, a display of plastic car parts—fenders, bumpers, control panels—peered like safari trophies from a lobby wall.

"One of our best known successes is plastic headlamps," said Adgild Hop, the center's director. "Most Ford models use our integrated Lexan units." He referred to GE's renowned

Low-slung addition to the Oklahoma City skyline, the seven-story Myriad Gardens Crystal Bridge is sheathed in more than 3,000 double-paned sheets of a durable acrylic plastic called Exolite. The 224-foot-long conservatory, here lit by interior strobe lights, houses a collection of palm trees and other tropical plants, a 35-foot-high waterfall, and a skywalk.



A short but safe distance is maintained at the Houston Zoo, where a boy peers at a jaguar through a pane of a tough plastic called Lexan, the same material widely used as bulletproof "glass" in the vehicles of dignitaries.

A bulletproof vest made of Kevlar fiber saved the life of Nashville police officer Richard McKee, who holds his son, Weston, with an arm scarred by buckshot fired from a sawed-off shotgun 12 years ago.

A dummy studded with 122 heat sensors wears a fire-resistant military flight suit made of Kevlar during tests at a Du Pont Company laboratory (facing page).

see-through plastic that also gives bulletproof protection to the Pontiff in his Popemobile. More recent breakthroughs for the auto industry are thermoplastic bumpers and fenders.

But the plastics people admit to problems. Plastics can cost a dollar or two a pound, while metals cost pennies. And in the cutthroat auto business a difference of pennies makes decisions. Further, plastic parts don't always work as one-for-one replacements for metal.

EACH YEAR U. S. companies make 30 million tons of plastics—half the tonnage of the nation's wheat crop. Thirty percent goes into packaging—the myriad bags, bottles, and boxes that find niches in every environment from freezer to microwave. Far too many of these find a final niche in landfills or on the roadside.

Are the manufacturers responding?

They are, along with a score of concerned state legislatures. The major debate is not whether to act, but how: Should plastics be required to be degradable, like paper? Or should they be recyclable, like steel and aluminum?

Your average plastic container will linger on the roadside perhaps two centuries before those tight polymer molecules break down. How to hasten this? Research takes three approaches: biodegradability, in which a natural additive such as cornstarch gives bacteria a toehold; chemical degradation, in which additives cause the plastic to crumble away; and photodegradability, in which the sun's ultraviolet light attacks the molecules.

But degradability can weaken plastics. And environmentalists question the effects of decay residues. Degradability also could conflict with recycling, now gaining momentum.

To foster recycling, which now recaptures less than one percent of all plastics, nine states have laws requiring a deposit on plastic bottles. States are also weighing mandatory collection of plastics, now law in Rhode Island.

Recycling gets a boost with a joint venture by Du Pont and Waste Management, Inc. Next spring Du Pont will open the first two of five planned recycling plants, with trucks delivering an initial 30 million pounds a year.

GE is pushing both reusability and recycling. Harking back to the days of milk bottles, the company produces Lexan resin for milk containers that some dairies will buy back from the customer. GE's recycling effort is tied to the expectation that thermoplastics will

score as major new materials in autos and housing. Last October GE opened a prototype dwelling that is 30 percent plastic; the eventual goal is 75 percent. Still some years down the road are GE's recyclable plastic car bodies—sedan, convertible, pickup, van—that fit interchangeably on the owner's steel frame.

Polymers often are called the most versatile material. Part of the promise:

☐ BODY IMPLANTS. All too many of us will have a polymer part in us someday. Silicone elastomer, the soft springy polymer developed by Dow Corning, already replaces arthritic finger joints and forms a base for breast reconstruction. When little Jessica McClure was trapped for two and a half days in a Texas well and suffered severe head abrasions, silicone balloons stretched the adjoining skin until it was sufficient to cover her wounds.

☐ OPTOELECTRONICS. When electronic circuitry yields to faster, light-activated devices, polymers could provide the switches. "Light moves along the chain molecules," explained Ivan Goldfarb of Wright State University in Dayton, Ohio. "Polarizing polymers could switch the light on and off 100,000 times as fast as a chip."

☐ MAGIC MEMBRANES. The same polymer membrane used for concentrating frozen orange juice can remove salts from seawater. Du Pont has a joint venture with Saudi Arabia to build such a desalination facility. Allied-Signal Corporation uses membranes to separate out and recover industrial acids that would otherwise escape into the environment.

☐ CONDUCTORS. Plastic has long coated electric wiring as insulation. Can it also be conductive? "Its potential for carrying current approaches that of copper," said Alan Heeger at the University of California in Santa Barbara. Added colleague Paul Smith: "Conductive polymers could give us the ultralight batteries we need for the electric auto."

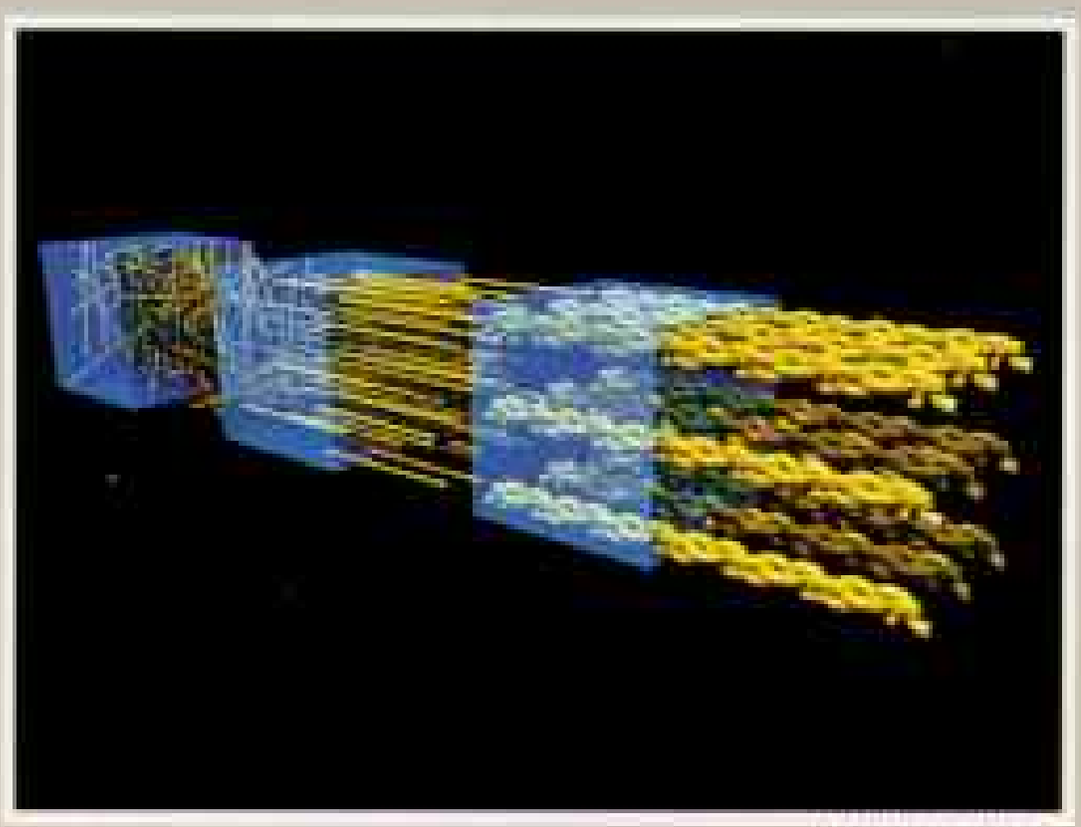
TAKE a polymer resin, add some tough fibers, and cook it awhile, and you have an example of another breed of material, the composites. Far stronger than steel by weight, composites are light. And their use is growing by leaps and bounds.

"In nature most useful things are made of fibrous composites," explained Frank Ko of Drexel University in Philadelphia. "A tree is a magnificent composite, with flexible fibers of cellulose in a matrix of rigid lignin."

Composites enjoy another priceless advantage: The fibers deter cracking in otherwise brittle materials. Israelite builders knew this in Old Testament times. Exodus 5 tells how they mixed straw with clay, doubtless to blunt the cracks that plague drying brick.

Many of us first met man-made composites in leisure equipment: the fiberglass boat, the fiber-reinforced tennis racket, golf club, or fishing rod. They capitalize on composites' extraordinary strength and lightness—and on sportsmen's willingness to pay: Composites can be costly.

Composites



MELVIN L. PRUETT

Strongest of materials pound for pound, composites draw most of their strength from their hidden fibers. These come in many types and can be arranged in various patterns. The cheapest and most used are short chopped fibers (above, at left). Often made of glass, they jumble randomly in a plastic matrix (blue shading). Such fibers strengthen fiberglass boats.

Far greater strength results when fibers are long and run in the same direction, at center. This is nature's way in a tree, whose long fibers of cellulose align in a rigid matrix of lignin. Thin layers of parallel fibers in a matrix often are laminated to form structural components of aircraft.

For additional stability, engineers intertwine fibers in three-dimensional shapes, simplified at right, by braiding or weaving. Such interlocked strands strengthen composite skis, golf clubs—and lightweight rocket launchers. More complex patterns produce shapes with enormous strength in all directions.

Lightness and strength endear composites to those who make things fly. The master artist in this medium is designer Burt Rutan, whose all-composite *Voyager* circled the globe without refueling in 1986. Rutan's composite kits for homebuilt planes have been assembled in thousands of U. S. garages. He also helped design Beech Aircraft's Starship, the first all-composite corporate plane.

Military aircraft and commercial airliners have clung longer to metals, but here too composites are gaining, especially with fighters and helicopters. "The F-14, F-15, and F-16 use composites for the empennage, or tail feathers," said Tobey Cordell of Wright-Patterson Air Force Base in Dayton. "The next generation of Air Force craft could be 50 percent composites."

At the vast McDonnell Douglas assembly plant in St. Louis, some 70 fledgling fighters were sprouting composite plumage. They included F-15s, F/A-18s, and Harrier IIs.

The stubby Harriers caught my eye. "The Marines wanted to double the range of the Harrier to give better support to ground troops," said Gerald Ennis, vice president of production operations at McDonnell Aircraft, or "McAir." Improved Rolls-Royce engines could increase the power, but still the vaunted fighter was too heavy for the needed range or payload. Only composites could peel off enough weight without sacrificing strength.

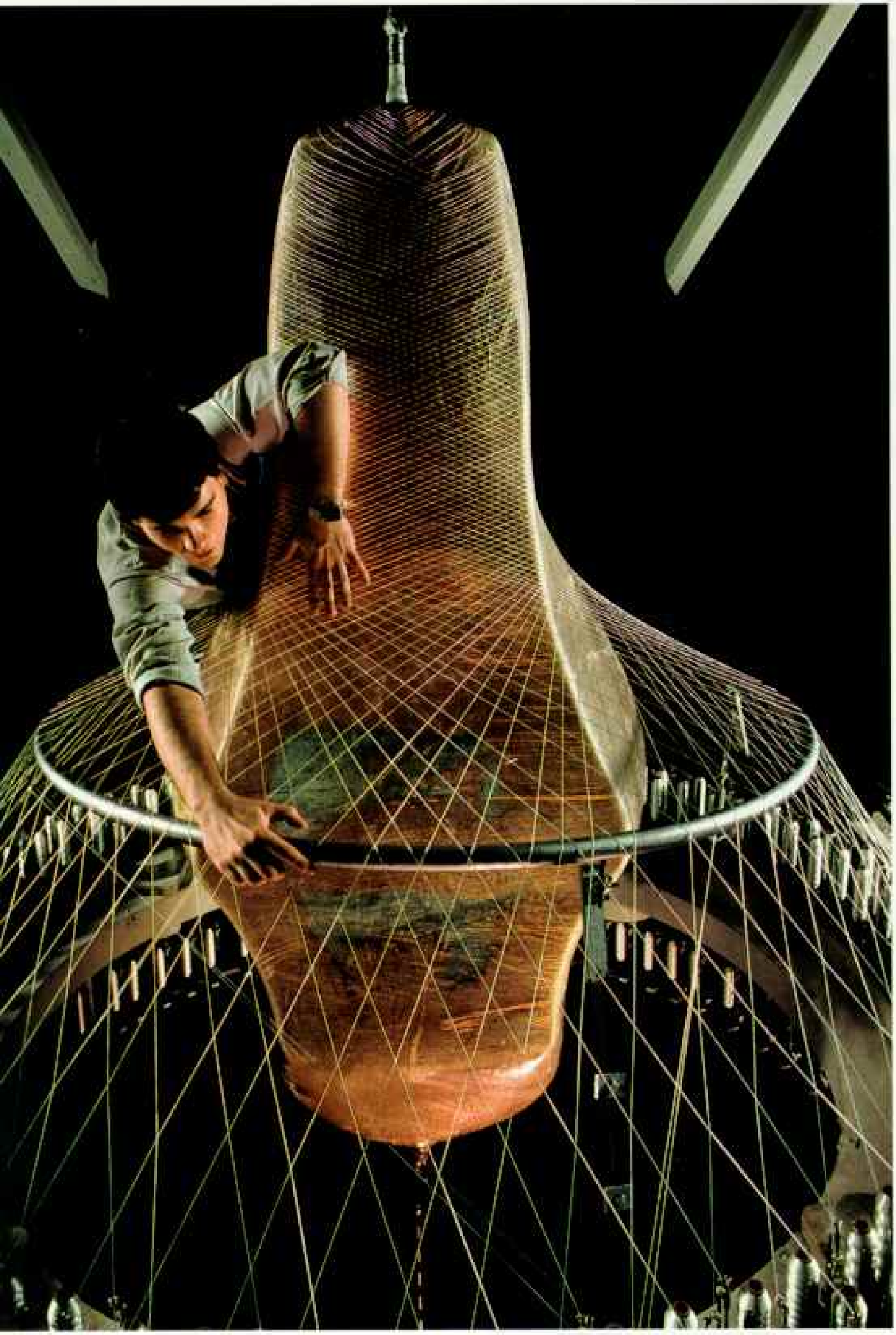
A VITAL AEROSPACE COMPOSITE is known as carbon-carbon—carbon fibers fused in a carbon matrix. It is unusual in that it thrives on heat. Where most other materials soften as temperatures rise, carbon-carbon tenaciously grows stronger. But it has a mortal enemy: oxygen. Heat it in air and it deteriorates. One cure is a protective coating, usually ceramic.

Not surprisingly, coated carbon-carbon is a favorite of spacecraft and missile makers, whose products endure torments of heat.

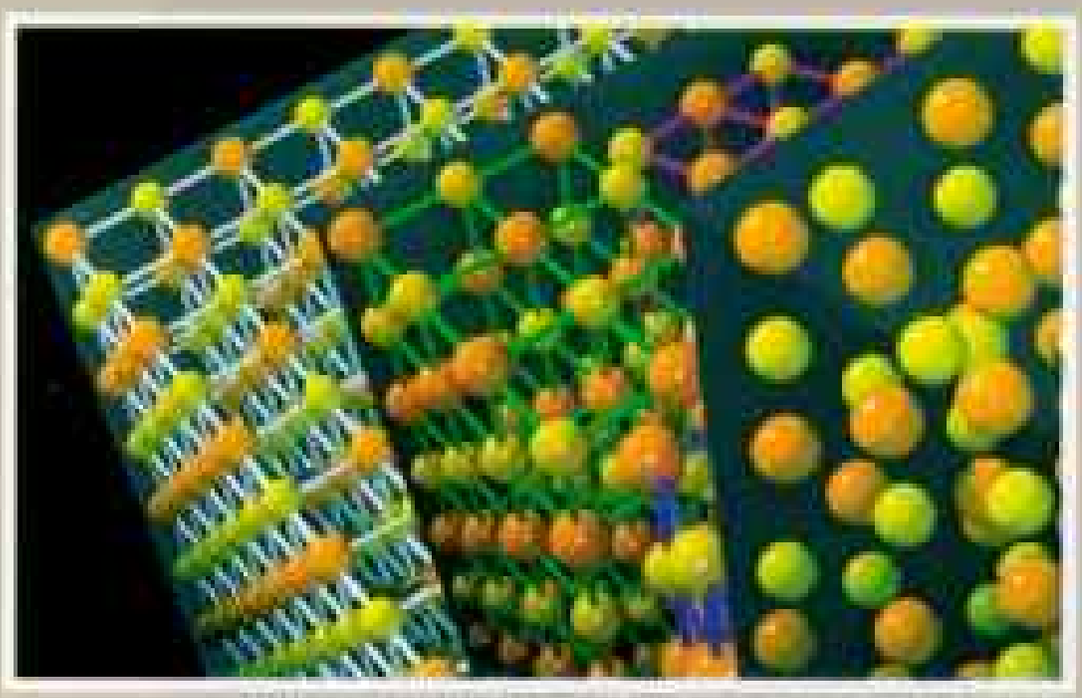
"We're making 101 different hot parts for

Sinews of a composite of Kevlar and glass fibers form the shell of a miniature racing car being woven with a braiding machine during a class project at Philadelphia's Drexel University. While being lowered to the ground from a laboratory window, the car got an unplanned test of its toughness when it accidentally fell two stories to the sidewalk. It was unharmed.

National Geographic, December 1989



Metals



Combining familiar nickel and aluminum creates nickel aluminide, a new metal that is extremely strong and heat resistant, albeit brittle.

The pattern at left illustrates the orderly alternation of nickel and aluminum atoms in a single crystal. When crystals combine, at center, irregularities form at the boundaries, providing sites for impurities that lead to corrosion and cracking.

To eliminate boundaries vulnerable to heat in jet engines, metallurgists make turbine blades by growing a single large crystal. For greatest strength at room temperature they strive for small crystals and a snug fit at clean boundaries.

The tendency of a metal to form crystals can be thwarted by heating, then rapidly cooling—a process known as rapid solidification. Here the metal solidifies before the atoms can sort themselves out in an orderly lattice, as happens with glass. In glassy form, at right, a metal can possess properties of strength, conductivity, and magnetism entirely different from its crystalline form.

the new space shuttle *Endeavor*," said Garland Whisenhunt, a production manager for the LTV Corporation near Dallas. "The leading edges of the wings reach 2600°F. During reentry the astronauts see them glow."

Here at the LTV factory technicians were cutting plies of woven fiber and stacking them for the shuttle's laminated leading wing edges. Slowly a stack grew, until a final fabric sandwich stood 38 plies thick in places. Then the stack disappeared into an ovenlike autoclave for curing. Afterward it would be soaked four times in alcohol and recooked four times, densifying the carbon matrix. Next would come a ceramic coating to protect against oxygen.

This laborious process helps explain composites' costliness. Automation has proved difficult; only human hands can reliably lay up those floppy plies. This shortcoming reportedly has been partly solved at the Northrop Company in making the composite B-2 "Stealth" bomber. The process still is classified.

WHAT IF you could braid your fibers in a three-dimensional pattern, like the strands of a rope? That would get rid of the tedious lamination process and the threat of delamination, which is always a worry.

The industry is moving fast in this direction. A guiding force is Drexel's Dr. Ko, whose ingenuity with fibers has spread its web worldwide. I followed a thread to the Atlantic Research Corporation in Virginia.

"Frank Ko helped us set up in 3-D braiding," said ARC's Jerry L. Fields. "Our initial output was small—primarily rocket nozzles for the Strategic Defense Initiative—but applications are doubling every year." Richard Brown showed me ARC's newest cost cutter: a high-speed braider developed at North Carolina State University that handles 9,000 fiber ends simultaneously, doing in one hour what takes a manual braider a week.

Such advances are leading the new composites into punishing arenas that are becoming

Sudden collapse of a hundred-foot-long section of the Mianus River bridge on the Connecticut Turnpike in June 1983 was attributed in part to rusted girder connections. With 135,000 of the nation's 576,000 bridges considered structurally deficient, highway engineers hope for progress in the development of noncorroding coatings and substitutes for metal.

National Geographic, December 1989

too hostile for most metals: jet engines and the National Aerospace Plane, or X-30.

If the remarkable X-30 ever flies—and that is not a certainty—it will launch America into the era of hypersonic travel (following pages). Attaining orbital speed of 17,000 miles an hour, it will subject materials to stresses of unprecedented ferocity.

Jet engines, properly called gas turbines, have demanded miracle materials since they first flew in World War II. They are extraordinary machines. Pratt & Whitney's powerful F-100 can propel an F-15 fighter straight up at a thousand feet per second. Yet military and commercial jets must perform flawlessly. "If something goes wrong," engineers like to say, "you can't go off and park on a cloud."

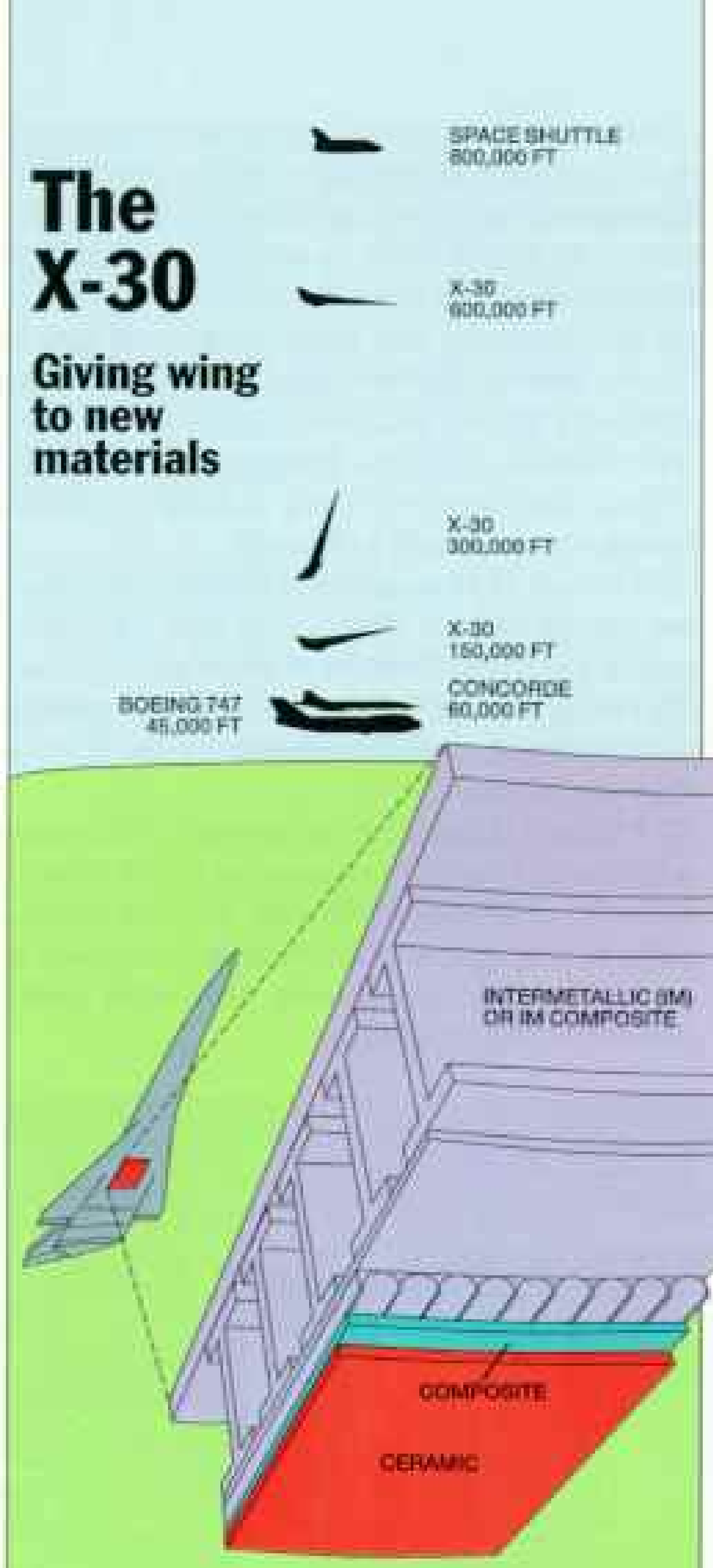
Jet engineers turned to titanium for lightness, then to superalloys of nickel and cobalt to handle fierce temperatures. Even so, turbine blades in an engine's "hot section" must be air-cooled or they will melt; this waste of heat and oxygen slashes combustion efficiency.

An ambitious government program aims to double engine performance by the year 2000. Composites dominate prospective materials, as they do for the X-30. In a handful of leading laboratories I saw newborn composite materials that someday will reign in sky and space:

☐ At United Technologies Corporation in Connecticut, a glass matrix grips silicon carbide fibers to form the composite Compglas. Strong and heat resistant, it holds promise both for engines and airframes.

☐ Textron of Massachusetts encases continuous silicon carbide fibers of its own manufacture in a powerful matrix of titanium—part of the family of materials known as metal-matrix composites. A strong candidate for the X-30's skin or skeleton.

☐ Martin Marietta Laboratories in Baltimore is perfecting the X-D process, in which microparticles of titanium diboride, formed chemically in a titanium-aluminum alloy, create a composite that withstands prolonged heat. Another X-30 possibility.



A new generation of materials will fly with the X-30, an experimental plane that will pioneer hypersonic travel, perhaps in the late 1990s. Engines gulping liquid hydrogen will carry the craft to cruising altitude above that of jumbo jets or the Concorde. A small rocket will then propel it to escape velocity of 17,000 mph (Mach 25) and into orbit near shuttle altitude.

To withstand searing temperatures reaching 3000°F, leading wing edges may be of a carbon-carbon composite, coated with ceramic to guard against corrosive oxygen, and the frame of titanium and aluminum in intermetallic form. Materials development has been accelerated by a consortium of aerospace companies collaborating in much of the research.

DIAGRAM BY GEORGE ROBICK
CONSULTANT: WILLIAM F. SMITH-G, DIRECTOR OF ENGINEERING, NASP JOINT PROJECT OFFICE

☐ Lanxide Corporation of Delaware holds patents on an ingenious process in which molten metal, penetrating a fiber preform, reacts with a gas to form a ceramic matrix, producing densified composites that require little or no shaping. For jet-engine parts.

☐ SEP, France's Société Européenne de Propulsion, boasts a ceramic-matrix process that is the recognized leader for making large, high-temperature engine parts. Du Pont has the license for the U. S. market.

To retain the advantages of composites but reduce problems of shaping and densification, companies often turn to short fibers that can be batch-mixed with the matrix.

A growing number of automobile flat parts—hoods, doors, roofs—are pressed from sheet-molding compound, a plastic reinforced with inch-long glass fibers. This technology began with Chevrolet's Corvettes and now is much improved.

Smaller fibers, grown as single crystals, are known as whiskers. Advanced Composite Materials of South Carolina mixes whiskers derived from rice hulls in a ceramic matrix. Because of the compatibility of whiskers and matrix, they form a composite that is strong and tough—a historic defeat for ceramic brittleness.

These silicon carbide whiskers are minute—shorter than the thickness of a human hair. "They pin ceramic crystals together just like nails join two boards," said Paul Becher of Oak Ridge National Laboratory, which developed the composite.

At Wright-Patterson I saw what may become the perfect composite—now merely an embryonic goo in a beaker. "The polymer molecules are tiny rods," explained Tobey Cordell. "Dissolved in a solution, they could potentially be processed into self-reinforced finished shapes—the ultimate composite."

A BAD TIME, one might say, to be in the metals business: plastics invading, composites on the march, ceramics poised to strike.

But in the tradition of challenge breeding response, steel and aluminum are fighting back.

Steel has reversed its retreat from the auto assembly line with alloys whose stiffness allows them to be stamped out with remarkable thinness, slashing weight.

National Geographic, December 1989

Fledgling eagle of the airways, a half-size model of the Department of Defense/NASA National Aerospace Plane, or X-30, rolls out at Virginia Polytechnic Institute in Blacksburg. Built by students, it was shipped to the 1989 Paris Air Show for display.

Military needs generate remarkable alloys. In Vietnam helicopters often crashed when lube lines were hit. Using a specialty steel made by the Carpenter Technology Corporation of Pennsylvania, the gears of the Marine Corps' new vertical take-off plane, the Osprey, can work as long as 30 minutes without lubrication.

Aluminum alloys find a welcome new ally in the metal lithium.

"You realize why," said Donald Lovell of Boeing, "when you look at the periodic table. Lithium is the third lightest element, after hydrogen and helium. Each percent of lithium you add reduces aluminum's weight by 3 percent."

Lithium is dangerous to handle, reacting explosively with water when molten. But several aluminum companies, led by Alcoa and Alcan, have revamped furnaces to make these alloys. "Lightness and stiffness make them ideal for satellites," said Jeffrey Wadsworth of Lockheed Missiles and Space Company, the biggest user.

Aluminum alloys came under scrutiny with the disaster that crippled an Aloha Airlines 737 in 1988. The plane, 19 years old, was making its 89,681st flight when a third of its roof ripped off. Miraculously the hulk landed with the loss of only one life.

Inspection by the National Transportation Safety Board identified the villain as metal fatigue—the opening of tiny cracks by the repeated stresses of takeoff and landing. In countless labs I saw experimental alloys being bent millions and billions of times—tests on the ground to avoid failure in the sky.

SINCE THE BRONZE AGE new metals have been made by alloying. Today they often are created by new methods of milling or processing. Some of the more promising new processes:

□ SUPERPLASTIC FORMING. Metals having small crystalline grains often can be stretched outlandishly—1,000 percent—and grow stronger in the process. Long a laboratory curiosity, superplasticity emerges as a bonanza, particularly in forming complex shapes with

minimal energy at low temperature. A superplastic ultrahigh-carbon steel invented by Oleg Sherby of Stanford University, for example, shrinks five costly operations into one.

☐ RAPID SOLIDIFICATION. Spray molten metal in a cold environment, and the tiny particles cool at a breathtaking rate—a million degrees a second. Known as rapid solidification, the process freezes the atoms in place before they can align in a crystalline lattice. "RS creates a new state of matter," said Nicholas DeCristofaro of Allied-Signal, "metals with new structures and new properties of magnetism, strength, stiffness, and heat and corrosion resistance."

RS appears poised for explosive application. Allied-Signal has invested heavily in a magnetic iron alloy now being installed in the nation's 40 million transformers; the annual energy savings may reach three billion dollars. Pratt & Whitney is introducing RS super alloys into jet engines and the power system for the X-30. The process could banish problems associated with using beryllium and magnesium—both much lighter than aluminum.

☐ MECHANICAL ALLOYING. In a conventional alloy two or more molten metals combine to form a third, different metal. Mix metals cold and pulverize them, however, and they combine, yet retain their individual properties. This is mechanical alloying. The novel process, pioneered by Inco Alloys, already produces some of the hottest parts for jet engines.

An irascible family of metals, so brittle they can shatter if you drop a wrench on them, is gaining favor with engineers who value lightness and heat tolerance. These are the intermetallics, chemical combinations of two metals, such as titanium and aluminum, that form a compound unlike either individual constituent. "They're moving up amazingly fast and could fly on the aerospace plane," said Donald Shockey of SRI International.

CAN A SUBSTANCE as weak as uncooked spaghetti be the world's number one structural material? Cement is that weak, and when mixed with sand and gravel it is indeed number one—the concrete of our buildings. Each year the world uses five billion tons.

"Concrete is 3,000 times more brittle than steel," said Derek Birchall of Imperial Chemical. "Yet nature, using calcium salts similar to those in cement, makes extremely tough objects—seashells, ivory, bone. We've learned the secret.

"In shells nature uses a polymer to unite the calcium carbonate particles so they pack tightly, without voids. We discovered that our cement was full of microscopic air holes left by water during curing. By adding a polymer lubricant, we came up with a doughlike cement you can mold in all kinds of shapes."

All kinds indeed. Dr. Birchall strummed a cement guitar, bounced cement coil springs on his desk, shone a light through a sheet of cement as thin as paper.

Supple canoes made of concrete already navigate lakes and streams. On gossamer wings of concrete reinforced with fiberglass mesh, a hang glider built by Robert Wheen of the University of Sydney in Australia has made its maiden manned flight.

The traditional concrete is a composite, often strengthened by fibers of steel reinforcing bars. This is the stuff of buildings and bridges. When bridges collapse, the cause often lies in corrosion attacking the rebars because of an electrical reaction with the concrete—a process greatly accelerated by use of de-icing salts.

Collapses occur in the United States all too frequently—and often with loss of life. Of the nation's 576,000 bridges, 135,000 are considered structurally deficient. "Bridge deterioration is one of the largest problems facing our transportation system," said Damian Kulash of the Strategic Highway Research Program.

Epoxy-coated rebars now help fight salt corrosion. Low-porosity concretes and glass-fiber reinforcement are under development. The state of Missouri has taken the lead in a promising technology known as cathodic protection, in which a weak electric current draws corroding ions away from the rebars.

WHAT ABOUT making materials in space? Would orbiting laboratories open new opportunities?

Unquestionably. But I found less enthusiasm than I had expected. A problem is launch costs. Call it the Rumpelstiltskin syndrome.

"If the legendary Rumpelstiltskin were to take up straw in the shuttle and fulfill his dream of turning it to gold," said Frank Lemkey of NASA, "he would lose money. Transportation is too costly. Only a few photonic devices and pharmaceutical materials could

A shower of strength rains down at Britain's Harwell Laboratory, where a beam toughens the surface of a racing-car crankshaft by implanting a thin layer of nitrogen ions. This vacuum chamber process eliminates the high heat of conventional hardening techniques, which can distort the metal being treated. As they begin to prove their value, such achievements further whet the appetite of researchers who see an ever broadening horizon of possibilities in the search for new materials.

come close to acquiring the needed added value if made in space.

"Space offers definite advantages," he continued. "A high-quality vacuum, cosmic radiation, micro-gravity. But gravity is a weak force that we're used to coping with. On the positive side, we can accomplish valuable science in space, studying principles that offer pathways to new materials on earth."

AS MATERIALS grow more complex, they become more difficult to make uniformly. An answer lies in intelligent processing, a program of automated quality control spearheaded by the National Institute of Standards and Technology (formerly the Bureau of Standards).

Explained Lyle Schwartz of NIST: "Sensors analyze a material as it is being processed, warning computers to correct errors. We're now doing this experimentally with aluminum products and metal powders, working with industry."

Today's materials serve us mutely, unable to warn of problems of overload or impending failure. How helpful if they could give warning: to an aircraft about ice forming on the wings, to an office building about the mounting stresses of a hurricane, to a window about sunlight overheating a room. And how helpful if those structures could respond with remedial action.

Such vocal materials (naturally they are called "smart") already are in the research labs. The secret is built-in sensors: in the wing to signal a microcomputer to change the configuration for more lift, in the building walls to activate braces against sway, in the window glass to suffuse it with reflective coloration. "The materials will respond like nature does," said Du Pont's Richard Hess, "like a tree leaf curling protectively in a drought."

Like nature. For materials scientists, the perfection of a tree, a bone, a spiderweb remains the distant goal. "We still can't begin to match them," acknowledged ICI's Birchall.

The quest will go on, for the soundest of reasons. "Ultimately," observed Mary Good of Allied-Signal, "materials development will determine our standard of living."

And then there's Frisch's Law, as expounded by Eldon Frisch, a longtime body-parts specialist with Dow Corning. "In the world of materials," he observes, "nothing is ever good enough." □

WASHINGTON STATE

Riding the Pacific

Chain saw in hand, independent logger Guy Hanson treks Mount Baker-Snoqualmie National Forest. Clear-cut patches marching toward Mount Rainier once held 400-year-old

Tide

By MIKE EDWARDS NATIONAL GEOGRAPHIC SENIOR WRITER

Photographs by SANDY FELSENTHAL

evergreens. As old-growth trees disappear, citizen groups and government officials debate how to preserve Washington's natural resources while feeding an expanding Pacific market.

Land of plenty, Washington's virtually treeless Palouse, east of the Cascade Range, rolls in waves of wheat. Its rich, deep topsoil produces some of the highest nonirrigated wheat yields per acre in the world. But there is a price to pay. Natural erosion combined with summer fallowing and poor plowing methods in the past caused rapid loss of critical amounts of topsoil. To combat the loss, farmers now divide a slope into two different crops and leave residues on the surface, reducing exposure to the forces of nature. Most of the state's soft wheat goes to Asian buyers, such as the Korean trade team (left) touring Merle and David Harlow's 3,000-acre Palouse wheat ranch. Washington actively courts Asian markets for many products, including apples, beef, and cherries.

AN ASSAULT ON JAPAN is being planned in the city of Wenatchee, in central Washington, down by the railroad tracks, where the warehouses are. In this war cherries are bullets and apples are bombs. As president of the Chief Wenatchee fruit growers' cooperative, Ted Zacher is one of the generals. His uniform of a Saturday was jeans, knit shirt, and a big silver buckle with an Indian visage—Chief Wenatchee, of course.

I was in his office when the phone rang. "Harada-san!" he said. "Where are you? . . . Seattle! Can we have dinner?"

Would Zacher-san drive 140 miles across the Cascade Range to entertain his caller, representative of a Japanese trading house that already buys Chief Wenatchee cherries and might someday buy apples and apricots? Is there a dam on the Columbia River? You betcha, as Washingtonians say (especially in eastern Washington, where the kinship with Idaho and Montana is strong).

In this, Washington's centennial year—it became the 42nd state on November 11, 1889—the gaze of many Washington business people is fastened upon the Pacific Rim. They court not only the Japanese. Regard, in the rich farming regions around Chelan and Yakima and Pullman, the delegations from Korea, Hong Kong, Taiwan, even Thailand and Singapore. Limousines whisk them to view orchard, field, and packinghouse. Washington sells the world not only fruit but also dry peas (India curries them), wheat (to Italy for pasta), and potatoes (everywhere for fries). This is a state of hucksters—you betcha! Products worth 55 billion dollars pass through its ports in a good year, and international trade pays one jobholder in five.

Chief Wenatchee has shipped cherries to Japan for a decade, though the fruit must be rigorously fumigated to satisfy Japanese agricultural officials. These stern gentlemen say that they are protecting Japanese orchards from insects and fungi; the American view is that Japanese growers constitute a formidable lobby indeed.

Even tougher restrictions protect the apple orchards from foreign contamination—and competition—one result being that the Japanese housewife pays five dollars for a single red globe. Yet Zacher-san, on one of his 15 trips to Japan, succeeded in selling a few apples there.

Washington State

Backbone of the state, the Cascades divide the verdant west from the rain-deficient east.

The Olympic Peninsula soaks under 200 inches of rain annually, which nourishes some of the oldest and fastest growing forests in North America. Nearby coastal waters are the realm of commercial fishermen, who in 1988 harvested 106,000 tons of salmon, halibut, shellfish, and other species.

The east averages only about 14 inches of annual rainfall. The Columbia and its tributaries irrigate plains and valleys that bring forth an agricultural bounty of fruits and grains.

In 1775 Bruno de Haceta claimed the region for Spain. British and American flags were planted soon after as other explorers moved into the territory.

American settlers arrived in the Protestant missionary era of 1834-1847, which ended with the massacre of Marcus and Narcissa Whitman and a dozen others by Cayuse Indians.

Statehood was granted in 1889, but this far-flung corner of the nation grew slowly. World War II sparked a still booming aircraft industry. Today the busy ports of Washington handle some 55 billion dollars in international trade, largely with Asia.

AREA: 68,138 sq mi (176,477 sq km). **POPULATION:** 4,660,700. **MAJOR CITIES:** Seattle, 497,200; Spokane, 170,700; Tacoma, 162,100; Olympia (capital), 31,070. **ECONOMY:** Aerospace, forestry products, tourism. **AGRICULTURE:** Wheat, beef, dairy, apples, hops, potatoes.

Not luscious, juicy apples graded Washington Extra Fancy; merely *frozen* fruit whose juice would be mixed with yogurt to make a tangy elixir. The buyer, a dairy company, advertised it as the "apple drink from the Rocky Mountains." Zacher did not think it necessary to challenge his customer's geography; after all, there are rocky outcrops of lava around the Wenatchee orchards.

Speaking of geography, the State of Washington holds an abundance. It seems like an up-coast California—without (fortunately, say I) the glitz. I remember a day when I exited a lush forest in the Cascade Range as the sky spat snow. I was soon in . . .

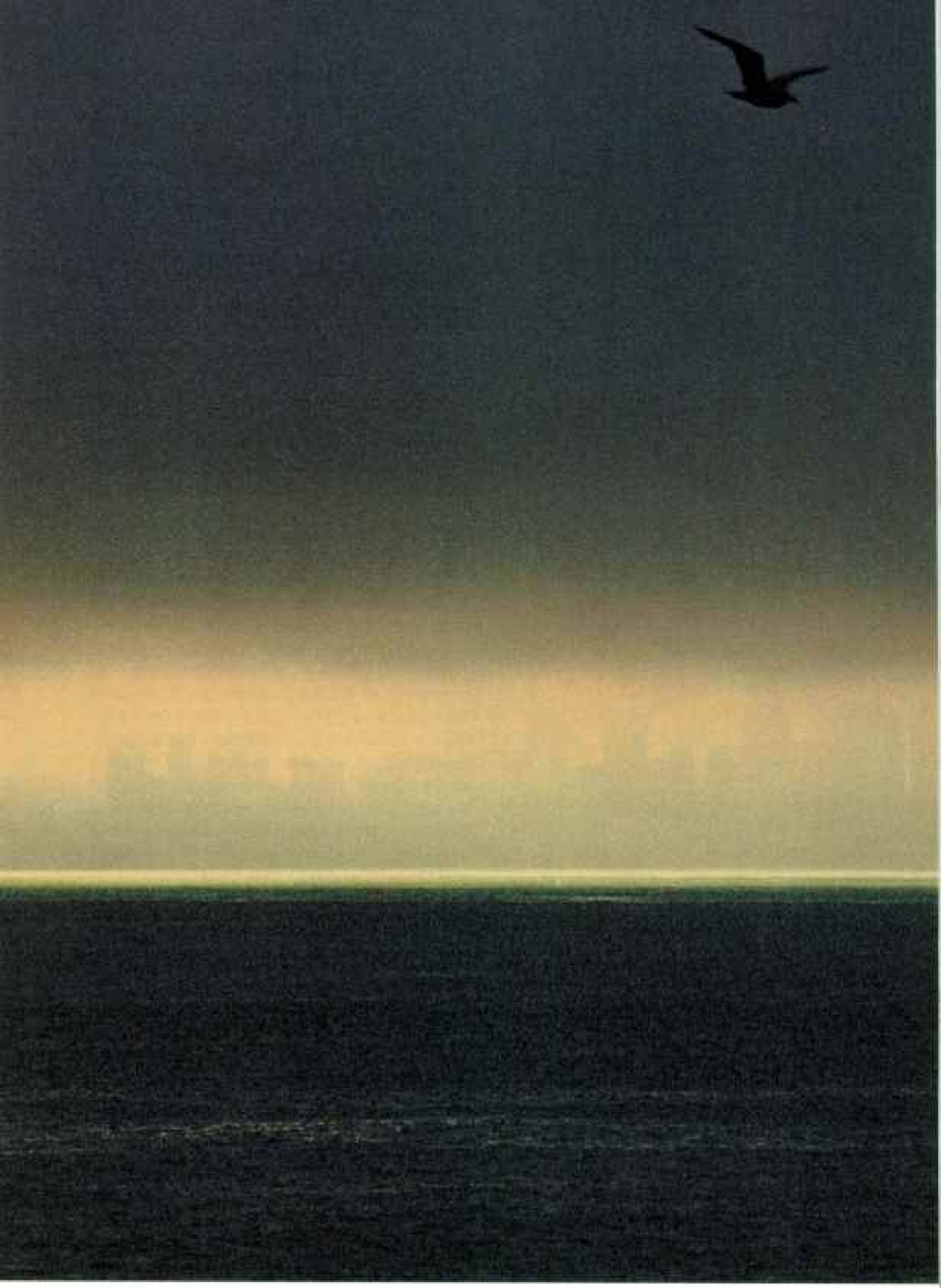
Afghanistan, or so it seemed among the treeless, sagey camelbacks around Yakima. Rain-shadowed by the mountains, the east is big-vista, small-town, large-farm country. Much commerce in this region inclines toward Spokane, a sturdy city of 170,700, whose banks and hospitals minister to an "inland empire" spilling into Idaho and Montana. Livability is enhanced by parks, especially Manito, noted for its well-tended gardens, and Riverfront, which has a dandy 1909 carousel. Riverfront, on the Spokane River, was skid row and railroad tracks until civic leaders (who had long wanted to clean up the place) mounted the Expo '74 world's fair, in itself an achievement for a small city. Eyesores became fairgrounds, then a hundred-acre greensward.

WESTERN WASHINGTON STATE, poised to receive wet kisses and balmy breezes from the Pacific, sprouts not sage but fern, not ponderosa but ponderous cedar. It lives by, and upon, water, washed by island-fleeted Puget Sound. The sound area is booming—60 percent of all Washingtonians live there—and booming not only because Boeing enjoys a 68-billion-dollar backlog of orders for airliners. Seattle is the handsome centerpiece, though its skyline (now soaring to 76 floors) does not please everyone. Concerned that their city's prized livability may vanish, citizens voted last May to restrict downtown development and to limit heights to about 40 stories.

Meanwhile, suburbs like Redmond and Bothell, semirural a decade ago, domicile the brainpower of new endeavors: programmers staffing 500 computer-software companies and scientists exploring the potentials of biotechnology in two dozen laboratories.

High tech applied to agriculture seems to have the opposite effect—big harvests but a lousy crop of jobs. I think of the little valley along the Methow River, below the eastern front of the Cascades. When I first knew it almost two decades ago, it was an isolated groove, most of it too cold for apples, dotted with a couple of one-saloon towns and a few small ranches. My friends Cathy and Jim and their four kids lived there, in sweet if seldom profitable communion with the land. Cathy could stretch out on a bed of moss and feel as if its cool, soft spikes were growing right through

Photographer SANDY FELSENTHAL has covered Indianapolis, the Tenn-Tom Waterway, and New Hampshire for NATIONAL GEOGRAPHIC.



Easing into the workday, commuters take the 35-minute ferry ride from Bainbridge Island across Puget Sound to fog-cloaked Seattle. Touted for its slower pace, the state's largest city warily welcomes newcomers fleeing the rapid, uncontrolled

growth of other West Coast metropolises. Seattle residents recently passed—by a wide margin—a measure that limits the height and size of new office buildings erected in the downtown area through the 1990s.

"People in Seattle don't live to work; they work to enjoy their lives," says Kristi Elliott Jones, who suns on her balcony in Queen Anne, one of the city's most desirable neighborhoods. Newcomer Jones created a magazine in order to stay in the city of her choice. Like many a Seattleite she shops for fruit, vegetables, and seafood at the Pike Place Market (right). The warren of shops and restaurants was almost lost to the wrecking ball in the 1960s.

JOE MCNALLY (ABOVE)

her. The kids moved the sprinklers in the hay meadow and then saddled up to check the cattle. To be on a horse every day!

When the ranch went, as small ranches often do, my friends went too; it's hard to make it in the Methow. And there are a lot of Methows in Washington.

NEARLY A MILE HIGH, and north nearly to Canada, I switchbacked up a trail in North Cascades National Park. My quest was a vision of glacial sculpture, of ridges flaked by ice until they resembled Indian stone knives, of vertical walls cupping obsidian lakes. I scrambled up a bladed ridge and gazed out at snowy Mount Triumph (there is a Mount Despair beyond) and the Picket Range, glittering white. With equal grandeur the panorama swings southward, to mountains named Torment and Forbidden, rising from ice fields like enameled fangs. These are not lofty peaks, seldom topping 8,000 feet. But some call them our most magnificent, our Alps. I wouldn't argue.

Much more familiar is that "round snowy mountain" British Capt. George Vancouver named for Adm. Peter Rainier in 1792. What can sweeten the spirit more than the sunrise sight of Rainier beaming like a scoop of orange sherbet? What is more delicious than raspberry Rainier at day's dying? What is Paradise?

Paradise is 5,400 feet up Rainier's slope, a place of paintbrushed meadows, with an old lodge soaring on great timbers. For me the trails from Paradise lead to purgatory—up steep ridges. Freighted with climbing gear, two hundred souls attacked those ridges on a summer Saturday. I surrendered to the thin air at 10,000 feet; a handful of more determined trekkers went on the next day to the glaciered summit, 4,411 feet farther into the sky.

Mountains shape not only the weather but also the Washington mystique, begetting the Mountaineers, a venerable outdoor club; the twin brothers Whittaker of Mount Everest fame; and REI, the outdoor equipment co-op.

Lou Whittaker, now in his 60s, laid-back and loquacious, has climbed Mount Rainier 175 times, has taught climbing to many others there, has brought down the bodies of friends

CORNER PRODUCE

Seattle's police shift gears

"Taking a kid under your wing is natural when you find him hanging around a tough neighborhood," says officer Victor Maes, one of 22 police officers with Seattle's special mountain-bike patrol (above). In an area rife with drugs (right), he counsels a street-savvy 11-year-old.

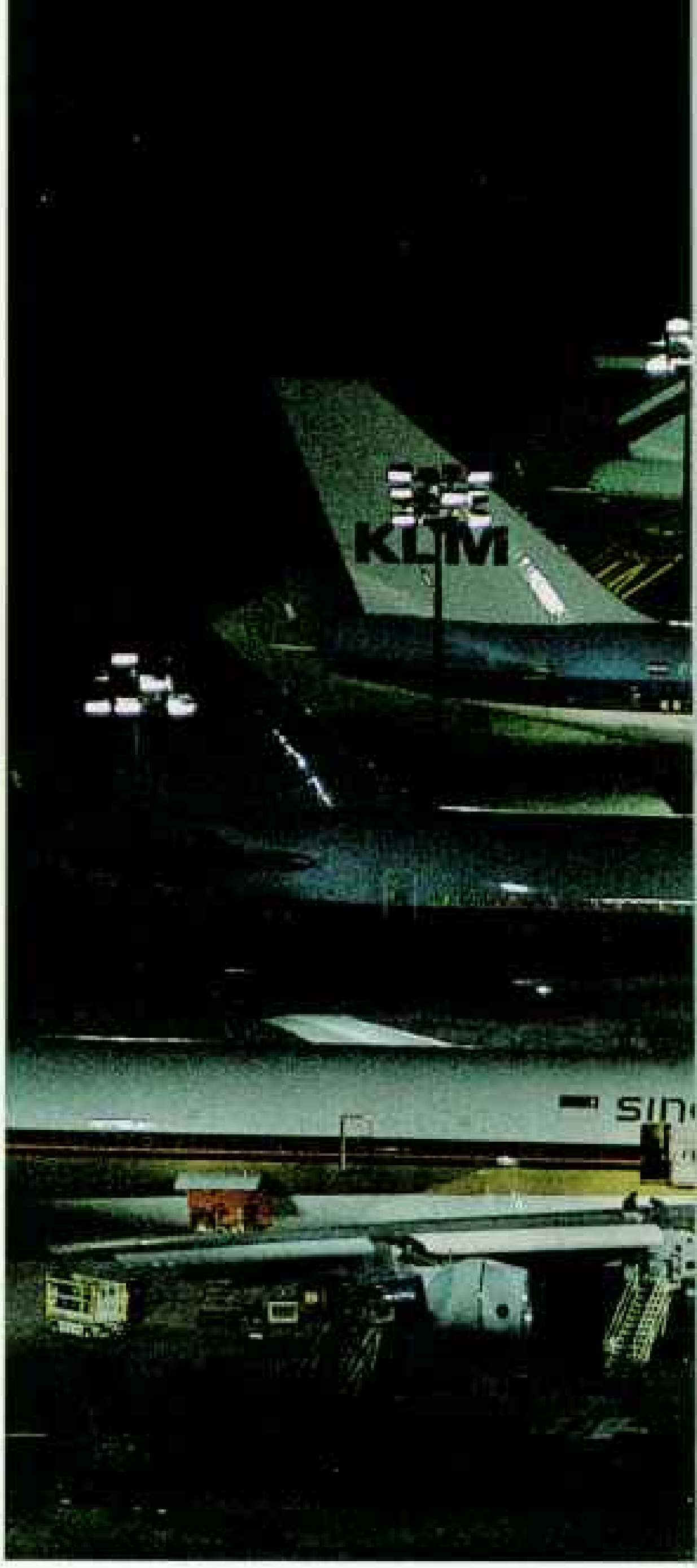
The bike squad is the brainchild of officers Paul Grady and Mike Miller, who became frustrated two years ago with the limitations of patrol cars and foot beats. "We had problems getting to the crime scene in a car because of traffic, and pursuing someone on foot was like playing cat and mouse," Grady said. "Mountain bikes allow us to patrol high-crime areas and sneak up on offenders quickly and quietly."

First to respond to a call from the multiethnic International District, bike-squad officers team up with another police unit to apprehend Filipino gang members (below).


Seattle
Police
SEATTLE
POLICE

In gleaming formation outside the world's largest airplane factory in Everett, new Boeing 747-400s undergo last-minute detailing before delivery. The largest employer in the Puget Sound area, Boeing grapples with success as workers strive to meet a 68-billion-dollar backlog of orders while facing pressures to maintain quality control. Mark Ludington (below) adds a personal touch-up to the engine of a jumbo jet destined for the People's Republic of China.

BOTH BY JOE MCNALLY



smothered in avalanches. For both Lou, who led teams on Everest in 1982 and 1984, and his brother, Jim, the first American to reach the summit in 1963, as well as for many other American Everest climbers, Rainier was the ideal training mountain.

"You can get 50-below-zero weather here, as cold as Everest," Lou said. "And the training is incredible for the aerobic need, the craving for oxygen, that you have on Everest."

Lou and Jim both got their start in a Boy Scout program. Colleges also offered climbing courses. There are fewer such opportunities now, because liability insurance premiums are so high. But you can still learn to climb with the Mountaineers. The club, 11,500 strong, ponies up an annual insurance premium of $60,000 to cover all its activities, including climbing courses that enroll several hundred each year.

I spent a weekend in the Cascades at the club's Meany Ski Hut. Named for a longtime club president, it *was* a hut once. Volunteer carpenters added rooms and inserted another floor, creating space for 104 bunks—and a crib. The beds are usually full on weekends.

Some of my bunkmates rose to a sharp ridge on the volunteer-maintained rope tow, then skied down icy slopes. I cross-countried on old logging roads, under a sky so blue it blazed. That night volunteers (always, the volunteers!) crowded into the kitchen to make dinner. I slathered the garlic bread—19 loaves.

The first Mountaineer to earn a coveted Six Peaks pin for ascents in one season was Lloyd Anderson, who climbed Rainier, Adams, Glacier, St. Helens, Baker, and Olympus in 1930. Climbing gear was expensive: $20 for an ice

ax, in Depression times! Then Lloyd got one from Austria—for $3.50. Friends asked him to buy for them too. Such was the genesis of Recreational Equipment, Inc. (REI).

Grizzled climbers fondly remember the small co-op store quartered over a Seattle restaurant called the Green Apple Pie. The word spread, and the market for good outdoor gear at reasonable prices kept growing. REI became a huge mail-order and retail operation. With 22 stores and yearly sales of more than 180 million dollars, it's the nation's largest consumer cooperative.

THE WOODS that co-op members (and other Washingtonians) love to tramp are changing. To a visitor who had last hiked in Washington in the 1970s, opposing evolutions stand out. First, more areas have been preserved as wilderness, but large reaches of forest look like a bad case of mange—as around Snoqualmie Pass.

Sure, the Plum Creek Timber Company, heir to lands granted checkerboard fashion to the Northern Pacific Railway, had every right to fell its timber. And, yes, the planted seedlings will clothe the nakedness in a couple of


729

decades. But to whack by the square mile, up to the 4,000-foot peak tops, in a recreation area close to the Pacific Crest Trail?

Plum Creek is not the only landowner to clear-cut. On the Olympic Peninsula are other big bald spots—on lands of Indian tribes and the U. S. Forest Service, as well as on tracts managed by the state Department of Natural Resources, a two-million-acre timber lord.

CONTROVERSIES about cutting aren't new in this state that brims with environmentalists and also hosts an eight-billion-dollar-a-year timber industry with 60,000 workers. And while experts say the industry's future is assured from the vast tree plantations of Weyerhaeuser and other companies, some sawmillers as well as tree lovers are angry.

Jack Dickson, for instance, who gazes across the Pacific Rim and laments: "We're becoming a colony of Japan. We raise timber for them so they can have a better way of life." What Jack objects to is Japanese buyers outbidding him for logs. As vice president of Summit Timber Company, he'd like to see those go through his own mill instead of mills in Japan.

Summit Timber rises from a huge lumberyard in Darrington, up against the western Cascades. It's a classic timber town—the high school teams are the Loggers. At the turn of the century the majestic trees, especially soaring Douglas firs, lured immigrant Swedes and Finns. Today many who gather in Ed's Burger Barn speak with an Appalachian twang as they order the Tar Heel burger—beef and sausage patties, cheese slices, about a pint of mayo, all for $2.10. Hard times in Carolina forests sent Tar Heels fleeing to Washington's big woods in the 1920s, and as the years passed, uncle summoned nephew.

Japan, enjoying a housing boom, bore off, as whole logs, 20 percent of the commercial timber felled in Washington last year. The preferred wood is clear of knots and finely grained, from the dwindling supply of ancient giants called old growth. Buying from state lands or from such companies as Plum Creek, the Japanese pay two or three times as much as the U. S. market will bear. China and South Korea are other major log buyers, though they are not so keen on quality.

Happy to be home after 70 days at sea, a crewman of the U.S.S. Georgia greets his wife at dockside in Bangor, base for eight of the nation's ten Trident nuclear submarines. An outboard motor powers the Nirvana (above), buzzing across Seattle's Lake Union. Built by two young entrepreneurs, the home-engineered floating hot tub is heated by propane.

Foreign competition has been a death knell for small mills, many of which have closed. But for big companies fortunate enough to own old growth, foreign sales fatten dividends. Pacific Rim purchases also build schools; profits from state-owned timberlands poured 130 million dollars into education in the 1988 fiscal year.

In his own backyard—the Mount Baker-Snoqualmie National Forest—Jack Dickson has no competition from dollar-flush Japanese buyers, since Forest Service logs cannot be sold abroad. Here he confronts the environmental movement. Wilderness protection, habitat for the northern spotted owl, and other preservation measures have curbed the "allowable cut" on this and Uncle Sam's four other forests in the Cascade and Olympic ranges. And the competition is intense among mills like Jack's, fighting to stay in business.

For Darrington (population 1,020) the stakes are daunting. Without Summit Timber's 440 jobs, few customers would wolf Tar Heel burgers or buy milk at the two groceries.

To keep going, Jack bids for timber as far away as 200 miles. If he happens to get logs of the quality the Japanese like . . . well, yes, he will help improve Japan's quality of life, while turning a good profit. "The timber has to go to the market that will pay the most."

NOT ALL is conflict and frustration, however. In Olympia, the capital, people were surprised to see environmental groups and Indian tribes joining hands with government and timber-industry officials. They agreed on more stringent regulations requiring loggers on state and private lands to protect streams and lakes. Screens of trees, 25 feet wide and more, will preserve water quality and wildlife habitat.

Said a forester: "We're finding that it's easier to work with one another than to sit across the table and yell."

In supporting the new rules, the Tulalip, Lummi, and other tribes acted to protect vital

Skirting the crater of Mount St. Helens, climbers view the 900-foot steaming lava dome. The volcano, which spectacularly blew its top in 1980, was reopened to climbers in the fall of 1987; a hundred per day are permitted up the south slope between May 15 and October 31. The round-trip climb takes about eight hours.

fish habitat. Washington's 70,000 Indians have come to the fore as people proud and passionate, as activists and litigants.

Nothing has afforded them greater redress —or dignity—than a 1974 decision by U. S. District Court Judge George Boldt. On the basis of treaties made when Washington was a territory, he awarded the tribes half the catch of Northwest salmon and steelhead trout—fish upon which they historically depended. The state government kicked and screamed. Whites shot at Indian fishermen; Indian boats were turned away from docks. It was far from Washington's finest hour.

Law and order finally prevailed. During the short "seasons" when fish return to spawn, state and tribal officials monitor the catch of both commercial and sportfishermen, phoning information to a computer center. If Indians aren't getting their share, their fishing days are extended.

On the Yakima Reservation, 1.37 million acres in south-central Washington, Cecilia Eli told me that only 20 years ago the dialects of 14 scattered groups could be heard.

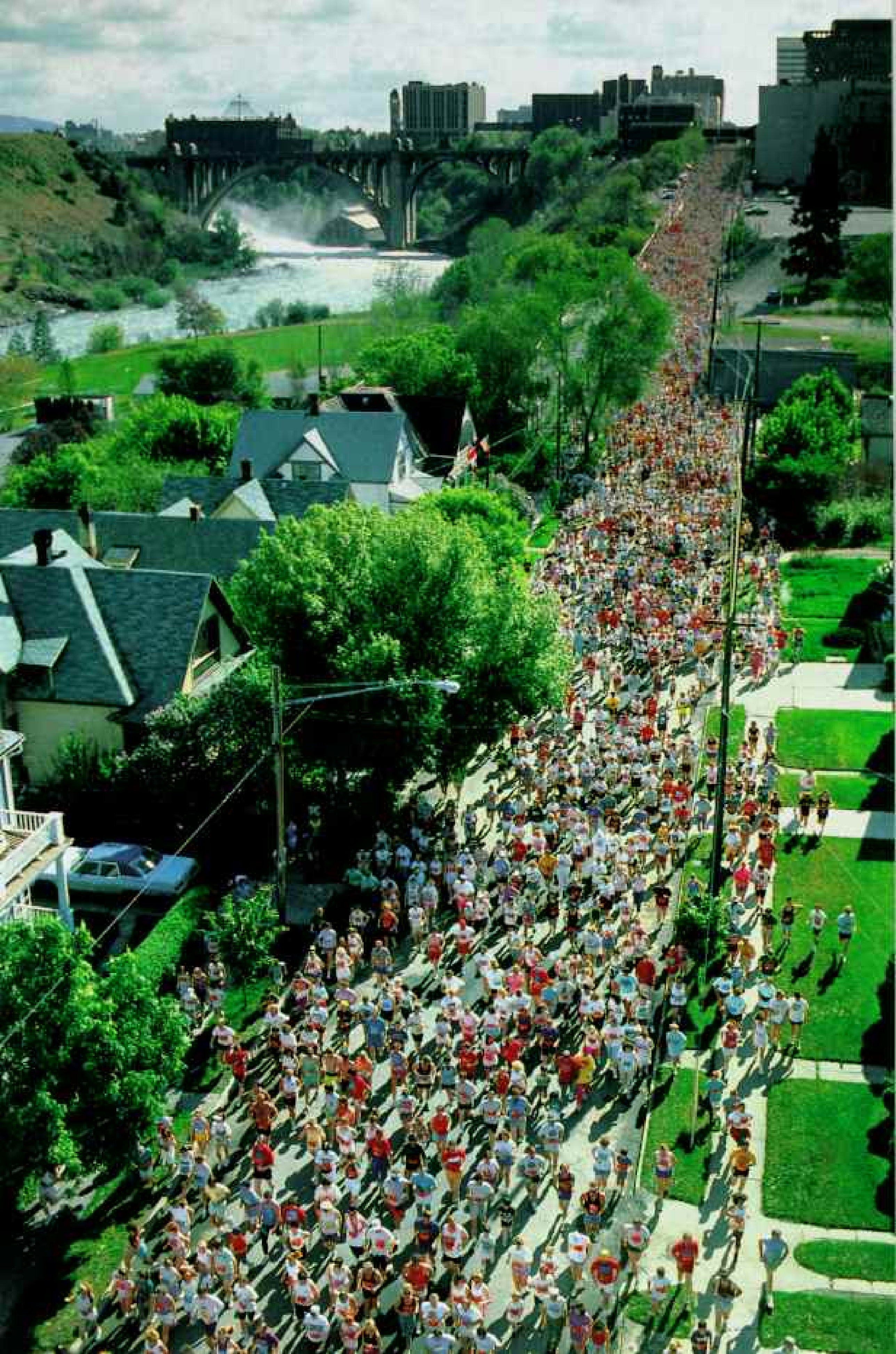
"I speak two of those languages. But we have lost ten others." She blames that on Bureau of Indian Affairs schools that punished students for speaking their own tongues. "I hated school," she says.

Cecilia now teaches those two dialects, and one evening a score of teens and adults came to the reservation high school to begin her course. She explained to them *nahme mushkyumt*, "our philosophy." The students repeated a tenet of this traditional faith: "*Thlowk toon ewa coosim*—We are all the same. . . ."

She reminded the students that whatever is

Called "the most dangerous horse race in the world," the annual Omak Suicide Race sends riders plunging down a near-vertical embankment into the Okanogan River and across to a rodeo arena. Out of control, rider number two parted

company with his horse but suffered only cuts and bruises; another rider's injured horse had to be destroyed. Animal-protection groups are fighting to halt the race, a 50-year tradition for Indians of the Colville Reservation.



on earth is the work of Tomunwethla, the Creator. And: "Never be ashamed of what you are. No matter what people may call you, they cannot take away your Indian blood." I am sure her students walked home a little taller.

THE HIGH SCHOOL STUDENTS in Richland also walk tall. Their teams are called the Bombers, and their symbol is a mushroom cloud. Some find that offensive, but not Paul Beardsley. "It spells out the fact that they built Hanford for that purpose."

Beardsley came from Oklahoma in 1943 to be a civilian guard at Hanford Engineer Works without knowing what he was guarding—one of 51,000 workers living in barracks, eating in mess halls that never closed, guzzling more beer than Seattle. He learned what it was all about only after a bomb of Hanford plutonium devastated Nagasaki on August 9, 1945.

Hanford makes plutonium no more; its production reactor went on "cold standby" last year, contributing to a 2,200-job loss in the nearby cities of Pasco, Kennewick, and Richland. But the Hanford Site remains a major scientific center; its 12,000 employees work in robotics, artificial intelligence, and waste management, among other projects.

In the 1970s Hanford was friendly territory for the ambitious Washington Public Power Supply System—WPPSS. Or, as it would be aptly called, "Whoops." Encouraged by predictions of future power shortages, WPPSS began to build nuclear generating plants with enough power to supply six Seattles. Three of the five plants were sited at Hanford.

The litany of things that went wrong extends from sloppy management and strikes to expensive retrofitting required after the Three Mile Island accident in 1979. Meanwhile, five more Seattles failed to appear. Worse, WPPSS was financing its ambitions by floating bonds on the bubble of 1970s inflation.

The collapse came in 1983, when WPPSS defaulted on bonds issued to build Units 4 and 5. It owed 8.25 billion dollars—and had yet to cook an atom. Some debt has been settled by the courts and some has been refinanced at reduced interest. Still, 5.9 billion dollars is outstanding. Who pays? The consumer.

Through the Bonneville Power Administration, the federal agency that markets electricity in the Northwest, 578 million dollars in bond interest has been billed annually to local utilities—who bill their customers. In some cities electric rates have doubled. So, many a citizen gazes with gratitude at the numerous dams on the Columbia and other rivers; thanks to their cheap power, rates in the region are still only half the national average.

One of the three Hanford-sited reactors now produces power, helping to pay the debt. I walked inside unfinished Unit 1, where 2.5 billion dollars had been invested when work stopped in 1982. In its great chamber, where atoms ought to be spinning, only a spider spun. A scrawled comment summed up Whoops: "Born under the wrong sign." But the agency hopes that someday its two unfinished plants can be put to work.

ON MAY 18, 1980, in the Cascade Range in southwestern Washington, mother nature displayed a power that made man's nuclear efforts seem puny. At 8:32 a.m. an earthquake registering 5.1 on the Richter scale shook loose a bulge that had been swelling like a boil on the north side of volcanic Mount St. Helens. Suddenly more than half a cubic mile of mountainside came roaring down. The volcanic vent spat a torrent of tephra—grainy ash and rock—that darkened the sky 18 miles up and 120 miles away. Lahars, or mudflows, fed by melting snow and ice, gushed downward. A powerful hot breath toppled forest giants in a 230-square-mile area; searing winds killed timber 18 miles distant. Fifty-seven persons died; damage and cleanup costs totaled hundreds of millions of dollars.*

The mountain, once a graceful cone, is now flat topped, with a great yawning maw. The landslide and eruption cost it 1,300 feet of its height. Small earthquakes still occur, recorded on seismometers watched by the U. S. Geological Survey. "It's possible St. Helens has had its last eruption for decades or centuries," declared the Survey's Don Swanson. "On the other hand, this could be just a hiatus."

*See "St. Helens: Mountain With a Death Wish," GEOGRAPHIC, January 1981, and "St. Helens Aftermath," December 1981, both by Rowe Findley.

Curb to curb and beyond, more than 55,000 athletes pound the pavement in Spokane's Lilac Bloomsday Run. The 12-kilometer event is the world's largest timed race. Running, walking, or in wheelchairs, most participants are in it for the fun of the great outdoors.

PHIL SCHOFIELD

Scientists on the scene soon after the catastrophe discovered that not everything died. Huckleberry bushes and small trees survived under snow. Some of the rodents lived through it in their burrows.

Most plants and animals that were present before the blast are now represented, though some are few in number. Snakes, for example, are scarce. Herds of elk and deer have returned; bears and a mountain goat have been sighted. Winds blew in seeds and insects.

Biologist Bob Lucas still marvels at steelhead trout he found swimming in rivers clogged with silt a month after the blast. Apparently they had survived in less affected tributaries and returned to the main streams after the water cooled—though it still was as thick as a chocolate milk shake.

But in the you-betcha state, even adversity can be put to use. Already richly endowed with tourist attractions, Washington now has one with a different appeal. A million visitors a year come to gaze benumbed at the devastated landscape, now preserved in a 110,000-acre national volcanic monument.

IF 14 INCHES of precipitation falls on eastern Washington in a year, it's a deluge; in many areas six or eight is usual. But to travel this region is to view a sky full of rainbows as irrigation systems fling sustenance at an assortment of crops. Wheat (often the biggest money-maker), potatoes, lentils, mint, hops for beer, asparagus, alfalfa, a dozen kinds of fruit, including fine wine grapes and half of the nation's apples—with 300 sunshiny days, eastern Washington is a cornucopia. Just add water (and nutrients), and you've got yields worth more than three billion dollars a year.

Above the Columbia and north of Wenatchee, Don Heinicke's orchard spreads along benches left by Ice Age dams. From the river he draws enough water in a year to cover his 274 acres of trees to a depth of four feet.

Don spends a million dollars a year to grow apples. In the spring, for example, he hires the pollinating services of 350 hives of bees at $22 a hive; the job's too big for the locals. Packing and shipping cost another million. With such expenses "you can't afford to make a mistake any more," Don said—as Washington orchardists learned this year at a cost of perhaps 140 million dollars. Many growers sprayed with a chemical called Alar to regulate apple growth; it slowed development so that the fruit didn't become mushy and helped keep apples on the limb until picking.

When news reports earlier this year linked Alar to cancer, a quarter of Don's 1988 crop was still in storage, waiting to be sold. Apple

Gathering close to the fire, migrant workers camp along the Yakima River. Lured by advertisements for immediate employment, thousands arrived to have their hopes dashed—the 1987 apple harvest was delayed by unseasonably warm weather. Charging that the Washington Apple Commission knew that the weather would postpone the harvest but continued to advertise anyway, pickers filed a class-action lawsuit that is still pending. Orchards in the Yakima Valley (top) help make Washington the nation's number one apple producer.

JOE MCNALLY

prices plunged by five dollars a bushel and more, even though the cancer risk from Alar apparently is minute. Yet Don suffered a significant loss in vanished profits, as did other Washington growers.

More problems: "The pickers have to be trained," Don said. "You have to make sure they pick with the stems left in, so the apples stay fresh." Don hires retirees—an ex-logger, a former telephone-company executive—but most pickers are Mexican.

Manuel Sanchez came illegally at first—as did nearly all Washington's pickers. He worked hard; Don liked him. Manuel told me: "Don say, next year bring somebody else." Manuel brought a brother and a cousin. "I keep it in my family. Then I get my friends."

When the new immigration law passed in 1986, Don completed papers to help 15 of his workers become legal aliens. Manuel and others brought their wives and children.

"They're not going to be satisfied with just seasonal work," Don prophesied. "Pretty soon they'll open grocery stores, clothing stores. They're going to be *here*. And I think they're going to be good citizens. They'll bring back some of the work ethic we once had."

AT LUNCH a German businessman posted to Seattle offered a Teutonic judgment of the city: "It will never amount to much—people don't work on weekends." Indeed, Seattle does not aspire to the title of "ulcer capital of the world," but it is a saver and a striver.

Consider Pike Place Market, a national treasure where farmers bring gorgeous vegetables and mongers cry the virtues of crab and oyster. When developers craved the four blocks of shops and the priceless view of Puget Sound, the citizens rescued all of it with a bond issue. Then they applauded the preservation of Pioneer Square, where the city took root. Then they went sea kayaking or skiing or to the

A mushroom cloud is the proud emblem of the Richland High School football team—the Bombers. A booster in war paint wears his pin on a kamikaze headband. Antinuclear proponents are not popular in Richland, which for more than 40 years has depended on the neighboring Hanford nuclear facilities for jobs.

Couples in Rosalia, a small town near the Idaho border, dance in the local firehall (left) during an annual festival called Battle Days.

opera or down to the International District for dim sum or sushi.

Seattle's culture has been greatly enriched by the Pacific Rim. Hmong and Mien refugees from Laos are the latest in a procession of Asian immigrants that began with Chinese laborers before Washington had statehood.

Among older Japanese painful memories linger of the removal to inland locations during World War II. Many oldsters still will not speak of it, although the Seattle community began the campaign to win redress from the federal government—granted by Congress last year. Younger Japanese believe discrimination lingers too, denying them the executive suite—in this city that trades goods worth billions with Japan.

And Chinese? They're thriving. Newcomers from Hong Kong, Taiwan, and Vietnam revivify the culture, and community acceptance of the Chinese shows in politics. In 1961, when a Chinese first stood for election to the city council, Ruby Chow stuffed fortune cookies in his behalf; if you went out for foo yong, an endorsement of Wing Luke topped off the meal. Luke won the election.

Other Chinese went to judges' benches and the legislature. The soaring beehive hairdo of Ruby herself became familiar in the King County council, where she served 12 years—the rare Chinese woman holding elective office in America.

One night I went to the Luck Ngi Music Hall for an operatic jam session. Luck Ngi means Happiness. Years ago the people who gathered on Saturday night arrived weary from waitressing and washing dishes. Now, housewives mingle with entrepreneurs. They sing arias about love and honor while musicians strum and saw the *young kum* and the *yee ieu* and thump the *yee yum gu*. It is lovely.

No person enriched the Seattle region more than a fellow who arrived in 1908. His father, born in Germany, had prospered in timber in Minnesota. The son had come west to buy timber—and then took a fearsome risk. He learned to fly *aeroplanes*. Then, in 1916, William Edward Boeing, Sr., helped by a friend, built two seaplanes.

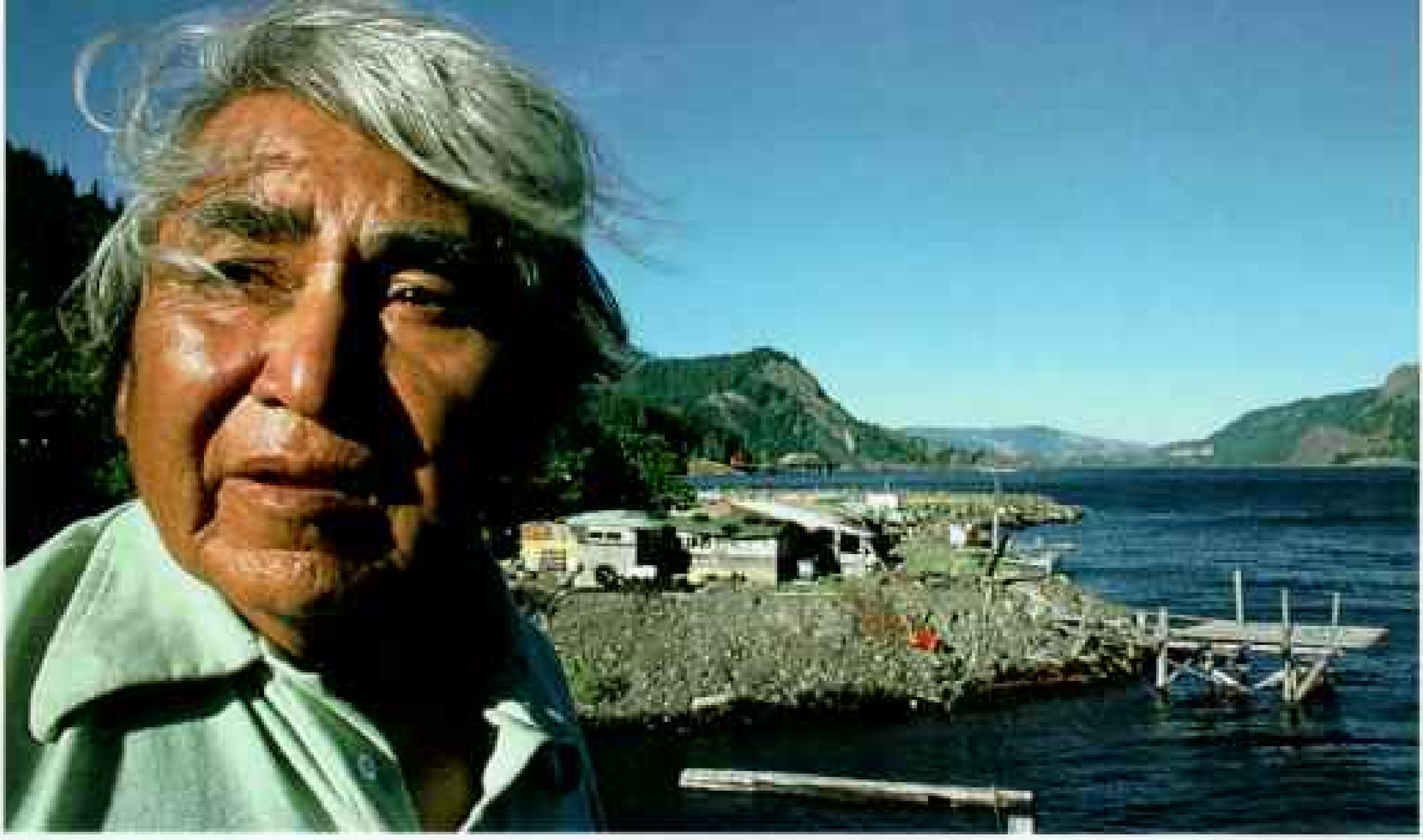
Thus began the Boeing Company. In lean times after World War I it made furniture. But the engineers, many of them homegrown, also developed advanced craft. In 1933 the Boeing 247 became the first modern airliner to carry passengers (all ten) in comfort, with good speed (155 mph).

Though Bill Boeing had studied engineering, building planes was far from his only interest. He acquired fledgling airlines and airmail contracts and was a skillful investor. In 1928 he created a potentially huge conglomerate, combining his holdings with several kindred enterprises, including Pratt & Whitney, the engine maker.

United Aircraft & Transport Corporation—William E. Boeing, chairman—would be

Fed by melting winter snows, Palouse Falls plunges 198 feet over an escarpment as the Palouse River meanders on its way to join the Snake. Star attraction of

Palouse Falls State Park, the torrent diminishes to a small cascade in summer. This canyon and that of the Snake expose lava that welled from fissures eons ago.



short-lived, viewed as a dangerous trust by Roosevelt New Dealers. In 1934 Congress legislated against conglomerates, forcing the firm to break up. Bill Boeing reacted by getting out—selling every share of his aviation stock.

Meanwhile his engineers in Seattle, working for a revised board of directors, were responding to a call from the Army Air Corps for a multiengine bomber. Their craft, ready in 1935, was the prototype of 12,726 B-17 Flying Fortresses that in World War II would blast the homeland of Bill Boeing's father.

Japan too suffered destruction from Boeing craft, especially from the B-29 Superfortress, which delivered fire storms to Tokyo and nuclear death to Hiroshima and Nagasaki. Now Japanese companies are major Boeing suppliers, building, for example, fuselage sections for wide-body 767 jetliners. A few years ago Boeing and a Japanese consortium were set to share the cost, perhaps two billion dollars, of developing a highly fuel-efficient propfan craft. Then fuel prices moderated, airlines lost interest, and the collaboration was shelved.

Facilities in the Seattle area—in Kent, Auburn, Everett, and Renton—hum with Bill Boeing's legacy. Despite metal-fatigue problems in some of its older craft and allegations that quality control has sometimes been lax, Boeing's airliner business is booming as it never has before. This and military- and space-hardware sales, and even computer services, pour more than 100,000 Boeing paychecks into the Seattle economy.

"FIFTY THOUSAND," he said. Nosy, I had just asked a computer-software developer how much he earned. Not bad for a 27-year-old. But it isn't unusual in the 15 buildings of Microsoft, cascading into trees in the suburb of Redmond. My well-compensated friend sat in a room with five others about his age, all degree holders in mathematics or computer science from such institutions as MIT and Caltech.

And all casual: jeans, sweaters. "We like your tie," one said politely.

Jabe Blumenthal allowed, "I used to keep a suit hanging in my office, for when IBM came." One of the best customers for Microsoft computer programs, IBM is severely buttoned down by comparison.

Don't let the jeans fool you. There's plenty of pressure here. Just before the "drop dead date" for finishing a new program and getting it to manufacturing, software developers work around the clock to eliminate bugs.

Sometimes the delivery date is missed—as happened earlier this year with two new

Vowing to fish "whenever I want," Yakima Indian David Sohappy (top) returned home to the Columbia River after 20 months in prison for selling salmon illegally. Although federal courts ruled that Indians are allowed half the total catch of harvestable salmon and steelhead trout, regulations dictate the number of fish that can be caught and when. Sohappy contends that fishing at will is his native right. Only the Yakima can subsistence fish along the Klickitat River gorge, where an Indian catches fish with a traditional dip net (left).

Once a giant among giants, a 600-year-old Douglas fir in the Olympic National Forest succumbed to Rick Fitchett's 54-inch chain saw in 15 minutes. At 37, timber faller Mike Ladouceur (facing page) is considering flying for an air taxi service instead. "After 16 years the job takes its toll on you," he says. Here he and three-year-old daughter Jessie cruise a meadow on a minibike.

versions of a word-processing program. Those delays cost Microsoft's chairman, Bill Gates, 175 million dollars in paper losses when Microsoft stock fell nearly 14 percent.

Shed no tears. Gates is still a billionaire on the strength of the company he founded with a fellow math whiz, Paul Allen. Gates was 19 in 1975 when they wrote a program for an early microcomputer. The personal computer took off, using Gates-Allen languages and, later, that workhorse operating system MS-DOS.

While Microsoft grew as much as 70 percent a year, the Seattle area exploded into a major software center. "There was a kind of developing energy," Jim Knopf said. "Technical people were here, printers got used to doing technical manuals—it built on itself."

Ex-IBM technician Knopf started his own company to produce computer programs called ButtonWare—button being the translation of his German name. He *gives* his wares away. "We bypassed the advertising campaign," he said. "Our advertising was, 'You guys copy the disks and share them. And if you like the shareware, would you please send $70 for a manual and any updates?' "

So far, 150,000 have.

ANOTHER BRAIN TRUST sprang up in biotechnology, stimulated by research at two Seattle institutions, the University of Washington School of Medicine and the Fred Hutchinson Cancer Research Center, leaders in the field. In his office in a converted warehouse on the Seattle waterfront, Stephen Duzan recalled that when he was looking for a new business in 1981—having sold a company that produced food packaging—he was introduced to two Hutchinson scientists who talked about the "T-cell growth factor" and a strain of cells that might lead to drugs useful against cancer by stimulating the immune system. "They gave me some references to check," Duzan said. "About half were Nobel Prize winners."

Drs. Christopher S. Henney and Steven Gillis joined Duzan in creating Immunex Corporation. In compensation for their research at Hutchinson, the center's faculty endowment fund was made an Immunex shareholder. Stock issues raised 98 million dollars for Immunex. Some of that went to develop Interleukin-2, a drug shown effective in tests for treating certain cancers. Immunex expects the drug to win government approval for marketing in a year or two.

Immunex, NeoRx, IMRE, Microprobe, Panlabs—few persons have heard of the Seattle biotechnology companies and their arrays of scientists (55 Ph.D.'s at Immunex alone). "The large pharmaceutical companies were slow to adopt this new technology," Duzan said, "so new companies could get a toehold." Potential sales if Interleukin-2 goes to market: hundreds of millions of dollars.

Thirty-five miles south of Duzan's waterfront office, the light chop of Commencement Bay laps against the wharves of Tacoma. When Washington got statehood in 1889,

Savoring the remnants of the day, children perch on a large piece of driftwood to watch the sunset off La Push on the Olympic Peninsula. Touted as one of North America's last unspoiled frontiers, Washington's coastline is now a favorite tourist attraction. For the people who live there, it is the only place to be.

Tacoma was the chief Puget Sound port. It had a railroad, and thus union with the rest of the country, before Seattle. After transcontinental rails reached Seattle, Tacoma watched cargoes and jobs go north.

It took Tacoma years to shed its jealousy of higher-rising Seattle—if it has. But Tacoma has become a pleasant workingman's city, willingly floating bonds to build schools and save old buildings. And it will seldom snare you in a Seattle-style traffic jam, save when Bruce Springsteen plays the Tacoma Dome.

On the waterfront, Tacoma remains a keen competitor. I was standing in the pilothouse of the tug *Henry Foss* when something like a floating apartment building appeared at the mouth of Commencement Bay. This was the *Arild Maersk*, more than two football fields long, stacked five stories high with freight containers. As *Henry Foss* nudged the Danish-operated visitor against the dock, trucks revved up to accept those containers and their multimillion-dollar Oriental treasure—VCRs and microwaves from Japan and Korea, shirts

and raincoats from Singapore and Taiwan.

Transferred to freight cars just a couple of hundred feet away, these goods would soon be in American markets. *Arild Maersk* departed in less than 24 hours, carrying lumber, machinery, and frozen French fries.

No matter which deepwater port shippers use—and Washington has nine others that handle such cargoes as grain, logs, and wood pulp—the U. S. trade deficit is writ large on the wharves. Some farm machinery and automobiles depart from Tacoma and Seattle, and of course Boeing sells aircraft worldwide. But imported cars and other manufactures are to a large extent swapped for such raw materials as timber and grain. As port officials see things, that's a problem that must be addressed in that other Washington, the one on the Potomac.

Whatever the outcome, Washington State begins its second century on a rising Pacific tide. Port officials see a future assured not only by the major trading partners of today, such as Japan and Korea; they expect to hear also from the (presently) less developed Pacific Rim nations. Burma and Bangladesh, for example, have large labor forces waiting to be tapped. And Indonesia stands fifth in the world with 180 million people.

When these nations come, Washington will speedily remove their cargoes and send them on to the hinterland. And yes, it will sell them some apples—you betcha! □

Superpowers Not So Super in Geography

By GILBERT M. GROSVENOR
PRESIDENT AND CHAIRMAN OF THE BOARD

THE RESULTS ARE IN from the first survey of geographic knowledge ever conducted in the Soviet Union, and the statistics are disturbing—not only for the Soviet Union but also for the United States. Compared to nine other nations, the Soviets as a whole did not score well at all. Asked to identify 16 places on a world map, they averaged only 7.4 correct answers, ranking with Mexico at the bottom of the survey. Soviet youth, however, did much better than their U. S. counterparts, sharing fourth place with Canadians and Italians (charts, opposite). U. S. youth came in last.

"Perhaps more important," said Neil Upmeyer of the Gallup Organization, Inc., "Soviet youth scored considerably better than their elders, while American youth did not." In fact, Americans were the only nationality whose 18- to 24-year-olds did worse than those over 55.

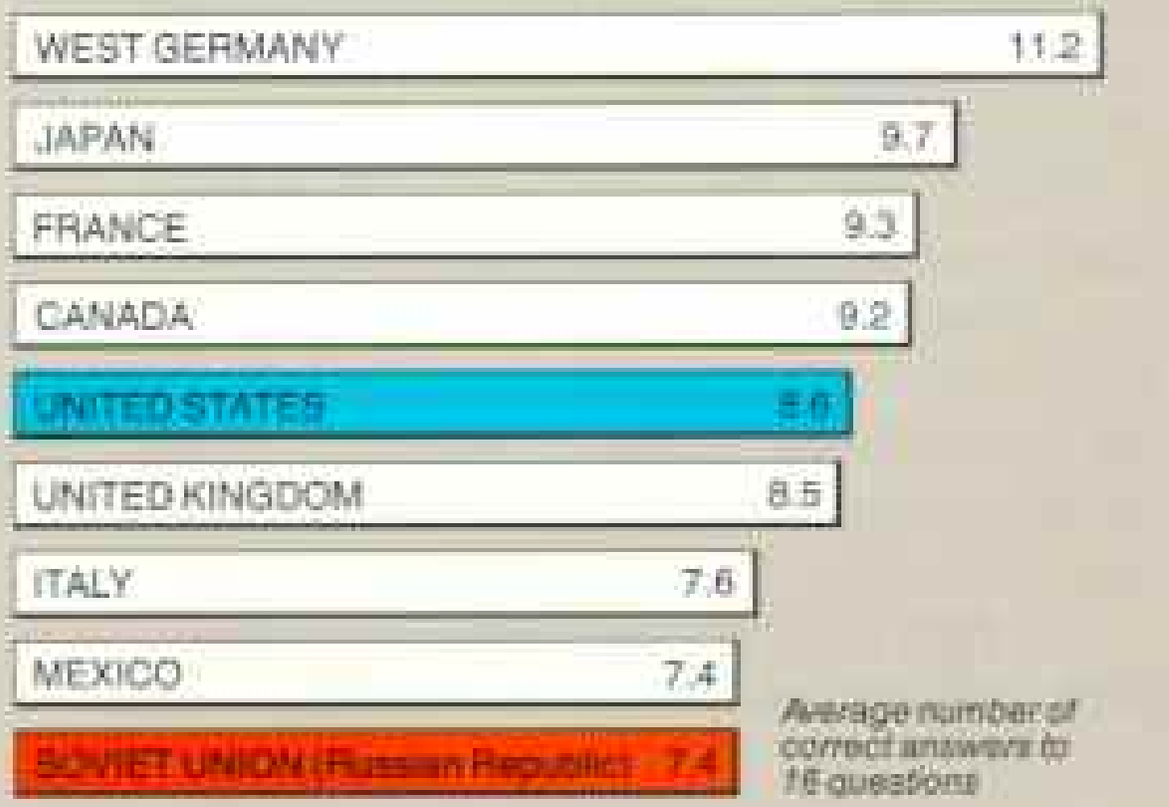
The joint U. S.-Soviet survey was conducted by Gallup with the Soviet Academy of Sciences. It underscores, in my mind, the importance of the many Society projects in 1989 aimed at increasing public awareness of geography and improving its instruction in the classroom.

- The National Geography Bee, which attracted a million student participants across the United States.
- The *Jason* Project, which thrilled scores of classes at Society headquarters and other auditoriums with live telecasts from the bottom of the Mediterranean Sea.
- National Geographic Kids Network, which introduced hundreds of science classes to one another in four nations.
- The National Geographic Society Education Foundation, which raises support for a nationwide network of geography teachers.

Taking time from a busy day, a Soviet housewife in the city of Kursk answers questions about geography for a survey by the Gallup Organization and the Soviet Academy of Sciences. More than half of the 1,500 Soviet citizens interviewed said they considered it "absolutely necessary" to know something about geography to be considered a well-rounded individual. Yet the group as a whole placed at the bottom of nine nations previously polled. Soviet youth scored significantly higher than their elders.

ROMAN PODOSKI

Americans outscored Soviets in identifying places on a world map . . .

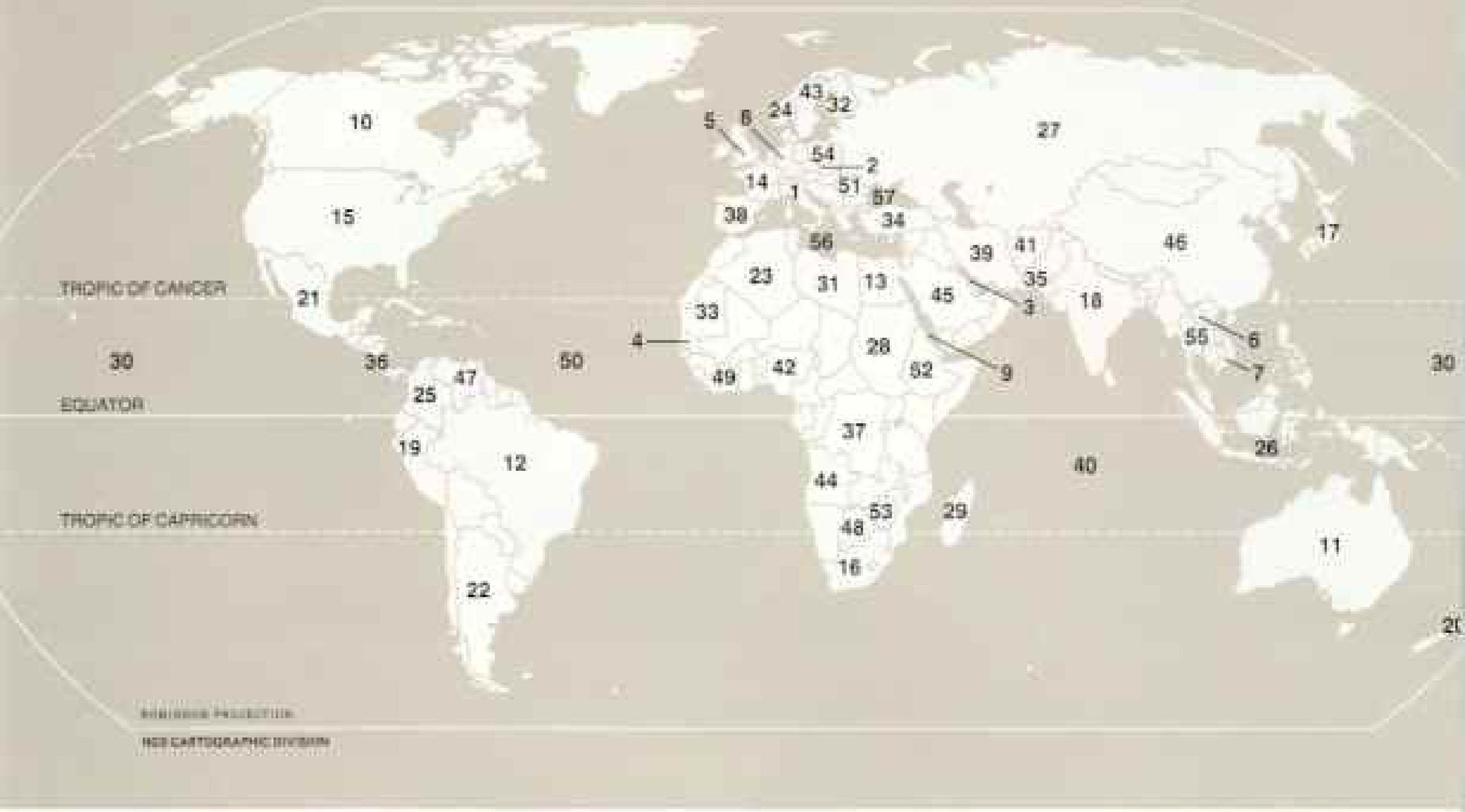


Average number of correct answers to 16 questions

. . . but younger Americans, ages 18-24, scored far below their Soviet counterparts.

NGS CARTOGRAPHIC DIVISION

Take the Gallup geography test



In all but a few details the Soviet survey was identical to those done in the other nine nations. Because working in the Soviet Union is difficult, it was impractical to cover the whole country. Instead 1,500 people were interviewed in Moscow and Kursk, a city of 425,000 people 300 miles south of the capital, to provide a typical sampling of knowledge in the Russian Republic.

"Results from the survey point to a startling superpower comparison," said Gallup's Upmeyer. "Americans and Soviets have demonstrated an astonishing lack of awareness of the world around them."

An extra question for the Soviets, because of their recent involvement in Afghanistan, revealed that only four in ten could locate that country (No. 41 on the map above), just as only a third of Americans could find Vietnam. Some 40 percent of the Soviets did not recognize the Pacific Ocean, as compared to 23 percent of Americans polled.

To be fair, Upmeyer noted, "the poor overall showing by the Soviets is a consequence of low scores among those over 55, who grew up in difficult times without adequate educational opportunities." As I see it, younger Soviets have come a long way toward knowing the world around them.

THERE WAS ENTHUSIASM in the eyes of 55 finalists in the first National Geography Bee at Society headquarters in May. Students from 13,000 schools, grades 4 through 8, took part. "You're all winners," Senator Bill Bradley of New Jersey told the nervous youngsters as they awaited the final round of questions. "By your interest and your ability you are helping to say that geography is important and geography is fun."

No one had to talk Jack Staddon of Great Bend, Kansas, into having a good time. Asked by moderator Alex Trebek to describe himself, the six-foot-six 15-year-old quipped, "Well, I'm the shortest person in my class. I'm the *only* person in my class." Jack attended the Great Bend Seventh-day Adventist Church School, which had a student body of six.

When it came down to the deciding questions, Jack put his self-confidence to good use. "Name the flat intermountain area located at about 10,000 feet in the center of the Andes," said Trebek. "Altiplano," Jack scribbled, clinching the Bee championship and a $25,000 college scholarship.

"It's nice to win," Jack remarked later, a big smile on his face. "But even if I

Asked to locate 16 places on a world map, Swedes were most successful among ten nations surveyed. You may test your own geographic literacy by taking the quiz below; to match the Swedes, you must give 12 correct answers.

Showing grace under pressure, 15-year-old Jack Staddon (right) of Great Bend, Kansas, won first place and a $25,000 college scholarship at the National Geography Bee in May. A million students across the U. S. took part in the competition.

LOCATE THE FOLLOWING

Write in the corresponding number that locates each place. Correct answers below right

		HOW PERSONS IN OTHER COUNTRIES DID *Percent of correct answers*		
		SWEDEN	U.S.	SOVIET UNION
____	United States	83%	88%	68%
____	Soviet Union	92	76	87
____	Central America	51	55	27
____	Japan	64	46	58
____	Canada	82	86	59
____	France	79	48	41
____	Persian Gulf	54	25	24
____	Mexico	60	81	31
____	Italy	90	88	62
____	Sweden	93	25	37
____	United Kingdom	91	47	52
____	South Africa	77	49	42
____	West Germany	78	29	38
____	Pacific Ocean	58	77	59
____	Egypt	56	28	28
____	Vietnam	48	32	32

ANSWERS: United States (15), Soviet Union (27), Central America (36), Japan (17), Canada (10), France (14), Persian Gulf (3), Mexico (21), Italy (1), Sweden (43), United Kingdom (5), South Africa (16), West Germany (8), Pacific Ocean (30), Egypt (13), Vietnam (7)

didn't, I'd thank the Lord anyway. It gives you practice in how not to win."

Michael Shannon, a 13-year-old from Reading, Massachusetts, won second and a $15,000 college scholarship. Kieu Luu of Landover, Maryland, 14, earned a $10,000 scholarship for third place. About 35,000 schools have signed up for next year's Bee.

WATCHING giant video screens in a dozen museums across the U. S. and Canada, more than 150,000 kids—including 25,000 at Society headquarters—saw the robot submersible *Jason* explore a volcano and shipwreck on the Mediterranean seafloor in May.

It was a broadcast that almost didn't take place. A few days before, the cable connecting *Jason* and its support vehicle to the surface snapped, dropping both to the bottom. A camera sled located the two, which were then recovered with a grappling hook.

"Our journey to the Mediterranean has been anything but uneventful," said Dr. Robert D. Ballard of Woods Hole Oceanographic Institution. "The voyage became a nonstop exercise in problem solving."

Such improvising came as a surprise to 18-year-old John Wildgrube of Stafford, Virginia, who was sent by the Society to be one of five students on the research vessel *Star Hercules*. "It gave me a better understanding of how science operates, how people work together to achieve a goal."

But it was well worth the effort. Not only did Ballard and his team take viewers to the scene of distant research, they also stimulated discussions in the classroom. Students talked about ancient trade routes in the Mediterranean. They did experiments on the corrosive effects of salt water. They discussed the geosynchronous orbits of satellites used to relay the video signal.

Besides being one of the sites for the *Jason* broadcast, the Society also lent a hand with related social studies lessons. An EXPLORER documentary on the project will appear this spring. Major support also came from Quest Group Ltd., Electronic Data Systems Corporation, Turner Broadcasting System, Inc., the National Science Foundation, and Jason Museum Network.

"HELLO," the message began. "We live in the largest city of the U.S.S.R. Its name is Moscow." Thus did the boys and girls of School #57 introduce themselves to

SUBSEA GROUP LTD. (ABOVE); ANNIE GRIFFITHS BELT

With a gentle touch, the remotely operated submersible Jason *prepares to recover a fourth-century amphora from the bottom of the Mediterranean Sea as thousands of students look on in auditoriums across the U. S. and Canada. Led by Dr. Robert D. Ballard (right), who spoke to students live from the research vessel* Star Hercules, *the* Jason *team investigated the deepest known ancient shipwreck site, half a mile below the surface.*

thousands of others in the U. S. and three other countries in the first unit of National Geographic Kids Network.

A computer-based science program for grades 4 through 6, Kids Network lets students compare data with others far away. In the first six-week unit, students gathered statistics about pets. This information was sent to a central computer, and the results came back in the form of maps and graphs. These were used to answer such questions as, do city kids keep different pets from country kids? (The answer: not really. Dogs, cats, and fish were favorites all over.)

"They're not learning about pets only," said Monica Bradsher, managing editor for software. "They're learning how to make predictions, how to collect data, and how to collaborate. They're learning that *where* you live has a lot to do with *how* you live."

Fourth and fifth graders at Henderson Intermediate School in Starkville, Mississippi, were so excited about the message from Moscow that they sent the Soviet children a baseball—not any old baseball, but a prized one autographed by their heroes on the Mississippi State University team.

Under development for four years, Kids Network is a collaborative project of the Society and the Technical Education Research Centers (TERC) of Cambridge, Massachusetts, with support from the National Science Foundation and Apple Computer, Inc.

AMONG THE SOCIETY'S other new educational programs in 1989:

☐ GTV, a unique system combining a personal computer with a laser disc to help teach American history from a geographic perspective. Available to grades 5 through 12, GTV consists of two videodiscs with 34 thought-provoking video segments that let students and teachers produce their own shows. GTV was created in collaboration with Lucasfilm Ltd. and will be offered in February.

☐ The Weather Machine, computer software that allows students to analyze actual weather data from the U. S. and Canada on colorful computerized maps. Other software packages: Project Zoo, an interactive visit with animals for grades 3 through 5; and the Golden Spike, a computer time machine for grades 5 through 9 that takes students back to the 1860s to relive the days of America's first transcontinental railroad.

☐ Interactive features on PRODIGY, an online computer service created by Sears and IBM. Exploring such places as Serengeti National Park, Paris, Alaska, the Himalaya, the land of the Maya, and Vietnam, the Society makes available each month to PRODIGY subscribers information about the peoples, wildlife, and issues of a region, and a chance to comment on these issues.

TAKING the Geographic's message into the classroom is the mission of the Society's Geography Education Program. Graduates of the fourth Summer Geography Institute—along with those from 28 state institutes and the first Instructional Leadership Institute—will conduct 1,900 workshops in this school year for 53,000 other teachers.

At the same time we at the Society and the 35 state geographic alliances are working closely with governors and state legislators at the policy level to promote geography in school curricula. Recent revisions in social studies requirements in Kentucky emphasize the importance of geography in grades 4 through 6. The University of Tennessee added a year of either world geography or history to admission requirements, and the University of Colorado at Boulder requires a year of high school geography for students entering its College of Arts and Sciences.

National Geography Awareness Week was another big event in schools across the U. S. In recognition of such efforts, the National Governors' Association in August presented me the Chairman's Award for Excellence in Education.

To help support these many programs, the U. S. Department of Education and state governments have stepped forward with financial aid, and more than 1,500 corporations, foundations, and individuals have made contributions and pledges of 2.8 million dollars to the National Geographic Society Education Foundation. Bell Atlantic Corporation made the largest donation to date, a grant of $750,000.

This represents, in my view, a most generous response to a national problem. You can be sure, in the months ahead, as we search for further solutions, we will do all we can to continue the successes of 1989. □

Golden Bamboo Lemur **Genus:** *Hapalemur* **Species:** *aureus*
Adult size: Length, 78cm; tail, 39cm **Adult weight:** Approx. 1.2kg
Habitat: Ranomafana rain forest in eastern Madagascar **Surviving number:** Unknown
Photographed by Konrad Wothe

Wildlife as Canon sees it

First identified in 1986, the golden bamboo lemur is one of three rare species of bamboo lemurs inhabiting a narrow band of mountain rain forest in eastern Madagascar. Each of these lemurs, the only primates known to live nearly exclusively on bamboo, has its own specialized feeding habits. One eats primarily the leaves, another the pith of the trunk, while the golden bamboo lemur eats the tender shoots. The recent discovery of the golden bamboo lemur in the Ranomafana rain forest prompted measures to create a national park that would protect what remains of this once extensive forest. The national park would help ensure the survival of these special lemurs as well as the abundant flora and fauna unique to the region.

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

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

A Year in the Life of Planet Earth

THE NATIONAL GEOGRAPHIC SOCIETY

LAST DECEMBER, as we celebrated the Society's first 100 years, I promised we would dedicate our second century to encouraging a better stewardship of the planet. The events of 1989 have certainly dramatized the importance of that goal.

JANUARY: An Argentine Navy supply ship ran aground and capsized in Antarctica, releasing some 170,000 gallons of fuel.

FEBRUARY: The Soviet government ordered 20 villages in Byelorussia evacuated because of lingering radioactive fallout from the 1986 explosion at Chernobyl.

MARCH: The tanker *Exxon Valdez* ran aground in Alaska's Prince William Sound, causing the largest oil spill ever in U. S. waters.

APRIL: Air pollution reached new levels of danger in Mexico City, where world health officials said harmful ozone had risen dramatically between 1986 and 1988.

MAY: High levels of acid rain—as high as those over Europe or North America—were detected over the rain forests of central Africa, caused by massive man-made fires on the savanna.

AUGUST: Peace talks failed in Sudan, where relief agencies had stockpiled food against famine.

All the news, mind you, was not bad; 1989 was also the year when world leaders—for the first time in recent memory—turned their full attention to international environmental issues.

In Helsinki in May, 80 nations adopted a declaration agreeing to phase out the production and consumption of chlorofluorocarbons (CFCs) by the year 2000.

In June, President George Bush introduced a plan to strengthen the Clean Air Act in the United States.

In July, the leaders of seven democracies issued a communique in Paris stating the "urgent need to safeguard the environment for future generations." Australian Prime Minister Bob Hawke announced a program to plant a billion trees across his nation during the next decade.

It was a tough year for the environment in 1989, with oil spills, wildfires, and acid rain in Africa. But there was good news as well: The world's leaders acknowledged a new sense of urgency.

Air pollution, deforestation, overpopulation, eroding soils, unsafe water: To coordinate our coverage of such vital concerns, we created an environment division in this magazine in 1989 and named Senior Assistant Editor Noel Grove to head it.

Among our reports this year were articles on the decaying forests of Switzerland, the hazards and benefits of radiation, new parks in the Himalaya, and new forest preserves in the land of the Maya. In coming months we will cover the aftermath of the Alaska oil spill, global warming, transportation of hazardous materials, the logging of old-growth timber, and the need for urban parks and greenways.

Our concern for the environment appeared in other Society activities as well. In February our TV Special examined the plight of the world's elephants. An EXPLORER documentary on the potential impact of oil exploration on Alaska's Arctic National Wildlife Refuge will air January 28.

Society books in 1990 will cover earth's rain forests and shorelines, and WORLD magazine in February will begin a new series on the environment, starting with a report on disappearing wildlife.

As part of National Geography Awareness Week in November, we co-hosted a student environmental summit at Society headquarters with the Environmental Protection Agency. Winners of the President's Environmental Youth Awards were given the opportunity to meet with national public policymakers.

Looking back over 1989, I am saddened by the damage humanity inflicted upon our planet. But I am also encouraged by the many signs that governments are finally prepared to do something about it. When that happens, you can be sure we'll bring you the good news—with pleasure.

Gilbert M. Grosvenor

FALSE-COLOR VIEW WITH DATA FROM NOAA SATELLITES GMS-2 AND GOES-EAST, COURTESY UNIVERSITY OF WISCONSIN AND NOAA; SSEC/PIC PROCESSING BY EARTH SATELLITE CORPORATION

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Members Forum

San Diego

San Diego (August 1989) has the second worst ozone pollution in the country. Its bay has been rated by EPA as the most toxics-polluted harbor on the West Coast. Raw-sewage spills closed portions of Mission Bay Park for more than a hundred days in 1987. Parts of Balboa Park are overrun with homeless people. If readers still think that weather is everything, they're welcome to join us. Bring money, though. The median price of a single-family house is $180,000.

MIKE CORNFORTH
San Diego, California

Such complaints remind author Neil Morgan of the Hell-on-Earth Club, which insisted that San Diego was foredoomed by earthquake, fire, and pollution. Oceanographer Roger Revelle helped found the club in the 1930s in a clearly unsuccessful effort to discourage in-migration.

I gasped when I saw the young men, representative of our American youth (pages 180-81): potbellied, slump shouldered, overweight. Let's hope that the Navy can make men of these out-of-shape recruits—for their sake and ours.

MRS. CLAIR S. LEDGER
Arcadia, Louisiana

I'm sure the sorry posture [of the recruits] will be greatly improved after boot training.

SAM C. BATTLES
Keene, New Hampshire

JERRY HUTCHINGS

Recruits from Company 135 were shown in the August issue on their fourth day in training, exhausted and suffering culture shock. Eight weeks of rigorous training—from academics to physical fitness (above)—earned this group top honors in all areas and a coveted brigade award.

The picture on pages 188-9 was discouraging to boaters concerned with water safety. The giant slingshot can deliver a missile, such as a water balloon, with devastating force. What may be considered harmless fun has resulted in permanent injuries. Such activity became illegal in California January 1, 1988. We urge you to warn all boaters, particularly in California, that the throwing of objects, especially by mechanical means, can subject the perpetrators to legal penalties and civil liabilities.

ROBERT J. HOFFMAN
Recreational Boaters of California
Redwood City, California

Everyone should know that balloons can be mistaken for jellyfish by many sea creatures and if swallowed are often fatal.

JUDITH T. UEHLEIN
Alexandria, Virginia

Little mention was made of one of San Diego's greatest success stories: the Tijuana Trolley. The light rail line was built entirely with state and local funds and covers 90 percent of its operating costs from the fare box. The line is so popular that a new line east to El Cajon is being added, and a third line north is being planned.

JAMES E. DAVIES
South Bend, Indiana

Neil Morgan wrote about a woman in a red dress handcuffed after customs inspectors discovered she was carrying a trunkload of marijuana. On June 5, 1989, she was tried in Federal District Court in San Diego and convicted of charges of importing a controlled substance and possession with intent to distribute. On August 7, she was sentenced to two years' imprisonment and three years' probation.

ALLAN J. RAPPOPORT
District Director
U. S. Customs, San Diego

Black Women

Brian Lanker's piece, "I Dream a World," is a long-deserved tribute to the endurance and strength of black women of the United States. It is encouraging for my generation to see such recognition that in 1950, when my father's membership began, may not have been acceptable. It reminds us that with the proper effort and choices, change can be effected.

MARY L. DAVIS
Oconomowoc, Wisconsin

I was so moved because I am a 22-year-old black woman who hopes one day to serve as a representative to the United Nations. This photo essay made me realize that achieving this goal, as unreachable as it may seem now, is not impossible. America's existence is based on many heroic

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STEPHANIE A. MOODY
Detroit, Michigan

Best of all for me was the inclusion of Brig. Gen. Sherian Grace Cadoria. I met then Lieutenant Colonel Cadoria at Fort McPherson, Alabama, in 1978, when she was evaluator for our reserve unit on annual training. I thought then, I think now: I have never met a finer officer. Thanks for bringing those exceptional lives into our lives.

JAMES P. COOKE
Lincoln, Nebraska

You should have balanced Faye Wattleton of Planned Parenthood with somebody like Mildred Jefferson, the black physician who is a leader of the National Right-to-Life Committee.

ROBERT F. MCNAMARA
Rochester, New York

The article makes no apologies for Angela Davis having joined the Communist Party. Communism is not a system that promotes freedom and individual rights but rather takes away those qualities of life. The inclusion of Ms. Davis in a lineup of black women who have been fighting for freedom and respect for the individual is inappropriate, ironic, and negative.

JOHNNY GIESBRECHT
Rosthern, Saskatchewan

As much as I appreciated the sentiments expressed by the women we heard from in Brian Lanker's piece, I winced at Alice Walker's comment denigrating "the white males we have elected. . . ." I would hope she would recognize that emphasizing the race or gender of those she would criticize smacks of the very prejudices these women have worked so hard to erase.

SCOTT MCNULTY
Minneapolis, Minnesota

The American Federation of Arts is bringing the Brian Lanker exhibit to art museums nationwide. It opens in Birmingham in January 1990, Denver in April, Sioux Falls in July, Lawrence, Kansas, in September, and Albuquerque in December. For details and the 1991-92 itinerary, write AFA, 41 East 65th St., New York, New York 10021.

JILLIAN SLONIM
New York, New York

Elephant Talk

Reading Katharine Payne's fascinating article, I was reminded that some 20 years ago I was riding an elephant in the Terai jungle of Nepal when I heard, so low-pitched as to be almost inaudible, a vague thudding like that of a distant diesel generator. It turned out to be from my elephant expressing fear of a nearby rhino whose scent it had caught. As more evidence of animal communication comes to light, perhaps we need to revise our concepts of their levels of intelligence.

ARMAND E. SINGER
Morgantown, West Virginia

Old Havana

I left Cuba in 1960 when the country still enjoyed the remains of the "capitalist warehouse." The pictures reveal a country totally deteriorated. Prior to the communist takeover in 1959, the people enjoyed one of the highest living standards in Latin America; now it has one of the lowest.

LEONARDO GRAVIER
Coral Gables, Florida

To make Castro out to be a rather jolly-uncle type, "joking" and "twinkling" his way through a three-hour conversation with the Editor is to ignore the brutalities of the regime, where block captains keep a beady eye on each resident's activities, and where some of the most terrible political prisons in the world exist. Also, though it is reasonable to expect a Cuban spokesman to put Castro's attitude toward artists in a good light, it is misleading to accept that idea, given the book *Against All Hope* by Armando Valladares and his statements in Geneva last year about the condition of artists and dissidents in Cuba.

MRS. MAX KAMPELMAN
Washington, D. C.

The comparison between Castro and José Martí is untenable. Between Martí's humanitarian and democratic convictions and Castro's Marxist totalitarian tyranny, there is as great an abyss as between George Washington and Lenin.

RUBEN J. SAEZ
Bandon, Oregon

It is Castro who wraps himself in Martí's name on the basis of parallels he sees. Martí would have recoiled from a Marxist dictatorship as he did from the Spanish overlordship of his native land.

More Loons

A correspondent in August seemed proud that Canada has used her new dollar to memorialize the common loon. A mere token gesture! On this side of the border, we have long recognized the true value of the common loon and have elected any number of them to high positions of public trust.

FRANCES SPENCE
Jacksonville, Florida

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

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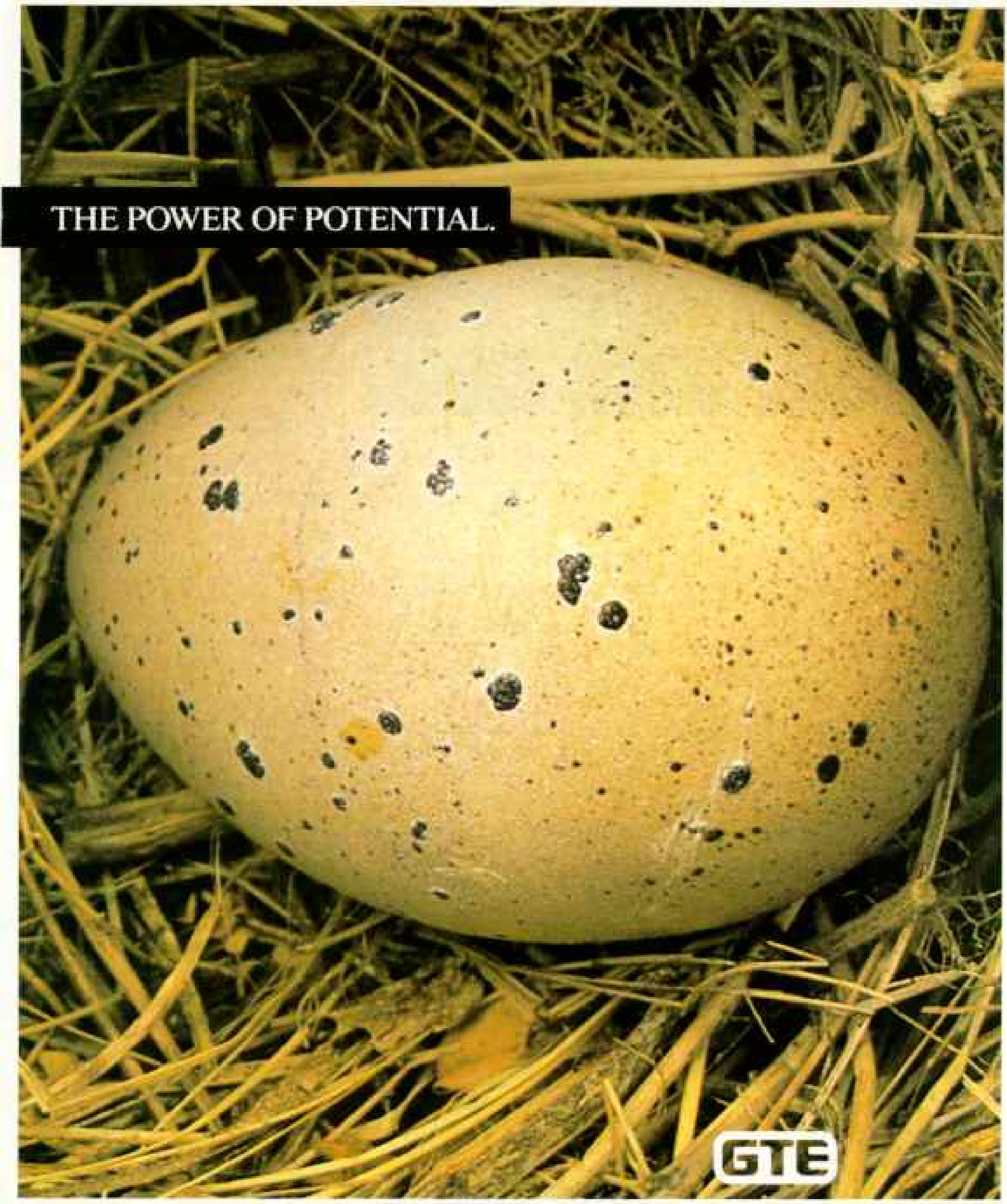

THE POWER IS ON

DECEMBER 1989

GEOGRAPHICA

NATIONAL GEOGRAPHIC MAGAZINE

BURNETT MILLER

Muli: In the Footsteps of Joseph F. Rock

The indomitable Joseph F. Rock thrilled a generation of NATIONAL GEOGRAPHIC readers with tales of his explorations of isolated areas of China and Tibet in the 1920s and '30s. Two of his striking accounts were about journeys to Muli, just over the Tibetan border in China's Sichuan Province. There a local king and Tibetan lamas lived beside the route pilgrims took to nearby holy mountains.

Early this year Los Angeles lawyer Peter Klika led a group in an attempt to re-create Rock's travels. With the aid of the Chinese Mountaineering Association they went to Muli, their trucks bouncing over rough logging roads that wound along gorges several thousand feet deep.

Rock's account made much of bandits who held sway over the pilgrimage routes. Klika and his group saw no bandits, but many Tibetans carried rifles—probably to protect their yaks from wild animals.

"The monastery has been rebuilt, and the palace's exterior has been restored," reports Burnett Miller, a 65-year-old Sacramento businessman who was on the expedition. Six lamas and several acolytes greeted the group, who were apparently the first Westerners in Muli since Rock's day. The monks served tea, walnuts, pears, and cakes; the visitors gave the monks copies of the GEOGRAPHIC with Rock's articles and photographs of Muli (above). "They were overwhelmed," says Miller.

When the Trees Cry, Do the Beetles Hear?

Think of thirsty trees crying for help. Then think of insects hearing those cries—and attacking the relatively defenseless trees. It sounds bizarre, but it may be true.

Scientists have recently learned that some plants emit ultrasonic chirps when their vascular systems come under stress from drought; the chirps increase as stress intensifies. Robert A. Haack, a U.S. Forest Service researcher, began to wonder if those chirps—more formally known as ultrasonic acoustic emissions—are heard by bark beetles, insects that attack ailing trees and proliferate during a drought.

Haack thought that the emissions might explain how the insects can tell an unhealthy tree from a healthy one. He and his colleagues spent a year recording the chirps. When they slowed down the recordings to hear the emissions, "they sounded like bongo drums or popcorn popping," Haack says.

The team developed a method of duplicating the chirps and transmitting them through plant tissue. Now they're offering bark beetles a choice between branches with chirps and branches without them. The results are not definitive, but early data indicate that most insects prefer chirping branches to chirpless ones.

JOHN W. HUNTER (ABOVE); JOSEPH D. LAVENBURG

Eating Clay Tablets as an Act of Faith

In the town of Esquipulas in eastern Guatemala stands a basilica with a carved wooden crucifix known as the Black Christ. The shrine attracts pilgrims, who often buy clay tablets with religious symbols (below). Others buy them in markets in Belize, Honduras, El Salvador, and elsewhere in Guatemala (below left). The tablets are meant to be eaten.

The practice of earth-eating, or geophagy, is widespread in Africa, Mexico, and Central America. Three Michigan geographers, supported by the National Geographic Society, studied clay-tablet eating in Central America, where the clay almost invariably comes from pits outside Esquipulas.

The geographers found that women are the main consumers of the clay tablets, especially during pregnancy to counteract morning sickness and ensure a safe delivery. The team reported that although there may be some nutritional benefits, eating the clay is essentially an act of faith. They asked one woman: "Do they do you any good?"

"Of course they do," she replied. "I have eight children!"

Further proofs of Mazda performance.

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These pictures say more about Mazda performance than any statistics from the proving grounds.

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U Chit Wain
(Mandalay, Myanmar)

Mayo Estrada
(Florida, USA)

Joseph A. Paolozzi III
(New York, USA)

Stuart Dee
(British Columbia, Canada)

Magnús Bjarnfinnsson
(Hafnarfjördur, Iceland)

Joseph Rasenberg
(Terbeyden, the Netherlands)

Burkhard Hillert
(Main, West Germany)

Second Prize Winners

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Brendon Hall (Victoria, Australia)
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Gertrude Dolezchal (Wien, Austria)
Rauch Helmut (Tulln, Austria)
Klaus Weinert (Steyermuhl, Austria)
Beda Widmer (Tarrenz, Austria)
Peter Wunsch (Innsbruck, Austria)
Lief Bure-Lermont (Eben, Belgium)
Rain Ackerman (Manitoba, Canada)
Joyce Gauci (British Columbia, Canada)
Yves Hawkins (Quebec, Canada)
Franz Richer (Ontario, Canada)
Peter Zierhofer (Ontario, Canada)
William Zierhofer (Ontario, Canada)
Michael Knudsen (Mandelstrup, Denmark)
Flemming Rack (Silkeborg, Denmark)
Adam Szabo-Illok (Budapest, Hungary)
George eM. Szasz (Nagyalad, Hungary)
Sig Joy (Chandigarh, India)
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JIM RICHARDSON, WEST LIGHT

Buffalo Bill Returns to Medal of Honor Roll

It took 72 years, but Buffalo Bill Cody's name has been restored to the roll of Medal of Honor winners.

As a scout with the Third Cavalry in Nebraska, Cody (GEOGRAPHIC, July 1981) earned the medal on April 26, 1872, during a skirmish with a band of Sioux who had stolen seven horses.

In 1917, soon after Cody died and congressional legislation had clarified the criteria for awarding the medal, a review board ordered the names of Cody and four other scouts stricken from the Medal of Honor roll because they were civilians and thus ineligible for the medal.

With the aid of Wyoming's senators, Cody's grandson, William G. Cody (above), petitioned for reinstatement of his grandfather's name. In July the Army Board for Correction of Military Records ruled that "for all intents and purposes, Cody was a soldier" and recommended that he and the other scouts be restored to the Medal of Honor roll. Army officials agreed.

The medal itself has been in the Buffalo Bill Historical Center in Cody, Wyoming, since 1983, when the museum acquired it from a collector. Paul Fees, a curator, says that no one knows why Cody parted with the medal.

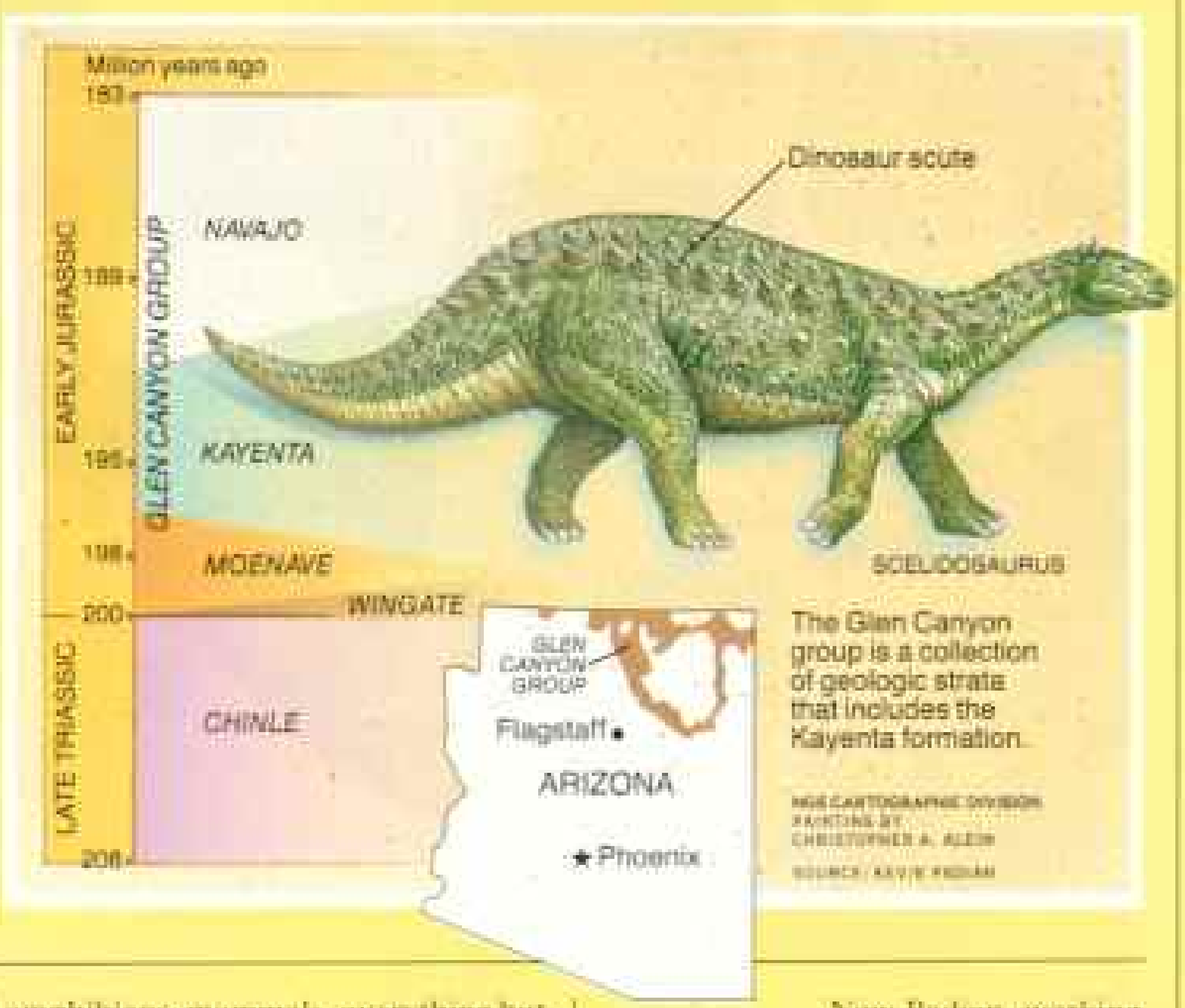
A New, Long Look at Mid-Atlantic Ridge

Since it was first discovered in 1873 by the British survey ship H.M.S. *Challenger*, the Mid-Atlantic Ridge, an underwater volcanic mountain range that stretches from Iceland almost to Antarctica, has been studied with increasingly sophisticated scientific tools.

Perhaps the best known survey was Project FAMOUS (French-American Mid-Ocean Undersea Study), centered southwest of the Azores (GEOGRAPHIC, May 1975). In FAMOUS, oceanographers intensively probed a hundred-kilometer-long stretch of the rift valley—a crack along the crest of the ridge where new ocean floor is continually created.

Early this year a team of scientists from Woods Hole Oceanographic Institution and the University of Washington surveyed a 900-kilometer-long section of the rift valley south of the FAMOUS area. They used devices that produce detailed "pictures" of large chunks of ocean floor, precisely measuring deep-sea contours, magnetism, and gravitational changes. Their study produced vast amounts of data "so extensive that you don't know where to start," says one participant.

The team found patterns of low-gravity "bull's-eyes" all along the rift valley. Their presence proved what many scientists had speculated: that centers of volcanism exist at regular intervals, 40 to 50 kilometers apart.



Dating the Kayenta, Sorting Out Evolution

To scientists like Kevin Padian of the University of California, Berkeley, the boundary between the end of the Triassic period and the beginning of the Jurassic period, about 200 million years ago, was "one of the most exciting times in land vertebrate history." By then almost all the modern land animal groups—reptiles, amphibians, mammals, everything but birds—had made their debut on the evolutionary stage. But it's sometimes hard to know whether fossils are from the Triassic or the Jurassic and therefore difficult to sort out the pace and shape of evolution.

Consider the piece of desert in northern Arizona that geologists call the Kayenta formation. Many significant fossils have been found in Kayenta rocks, but scientists have disagreed about which period they come from.

Now Padian, working with National Geographic Society support, thinks he knows. His study of scutes—bony, armor-like protrusions found on certain dinosaurs—indicates the Kayenta fossils are from the Jurassic period.

Padian compared scutes from the Kayenta with those discovered in England from a tank-like dinosaur called *Scelidosaurus*. Mollusk fossils found with *Scelidosaurus* reveal that it lived only in the Jurassic period.

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LOUIS PSIHOYOS, MATRIX

Lighting the Way to a Jet-lag Solution

Exposure to bright light can speedily alleviate jet lag and may combat insomnia and sleep disorders that plague shift workers, according to a study by Dr. Charles Czeisler and Dr. Richard Kronauer, both of Harvard, published in the journal *Science*.

Czeisler and his colleagues conducted 45 experiments involving 14 healthy males that included five-hour doses of bright indoor light each day. The researchers found that the subjects' body clocks—"human circadian pacemakers," in scientific terminology—could be reset in two to three days.

Early indications that the study was on track appeared in an article on sleep by senior writer Mike Long (GEOGRAPHIC, December 1987). In fact, while working on the article, Long became the study's first jet-lag subject.

Long flew nonstop from Tokyo to New York across 11 time zones and then, suffering from an acute case of jet lag, went directly to Czeisler's laboratory at Brigham and Women's Hospital in Boston. After three daily cycles of exposure to bright light and darkness, Czeisler shifted Long's body clock from a Tokyo setting to a Boston one in less than one-third of the time it would have taken naturally.

Personalized Maps for the Masses

In the late 19th century map publisher Alfred T. Andreas found what one scholar has called "a curiously seductive way to bring maps to the common people." Andreas's scheme was a pictorial atlas—of a county or a whole state—which, for a fee, would be decorated with a purchaser's portrait, his biography, or an illustration of his farm.

Andreas's Minnesota atlas, published in 1874, was purchased by 12,000 of the state's 100,000 households. A few years ago Paul Gilje of Burnsville, Minnesota, bought one of the original atlases. Soon he and his wife were seeking out the illustrated buildings in order to photograph those still standing.

Gilje estimates that about a fourth of the atlas's houses, barns, churches—such as St. Patrick's Catholic church in Lanesboro (below left)—and stores remain. He is amazed by the atlas's accuracy and detail.

Minnesotans were proud to have their buildings depicted, Gilje believes. "It was just a few decades after Minnesota was opened to settlers," he explains, "so people were eager to demonstrate to their eastern neighbors that this was a civilized place."

Gilje often meets people who live in homes illustrated in the atlas but who haven't heard of the atlas itself. Most are astonished to see their homes in a book more than a hundred years old.

Great Lakes Pollution: Still Dangerous

Toxic pollutants continue to trouble the Great Lakes region (GEOGRAPHIC, July 1987). Birth defects in birds like this double-crested cormorant, which has a deformed beak (below), may be caused by toxins in Lake Michigan fish.

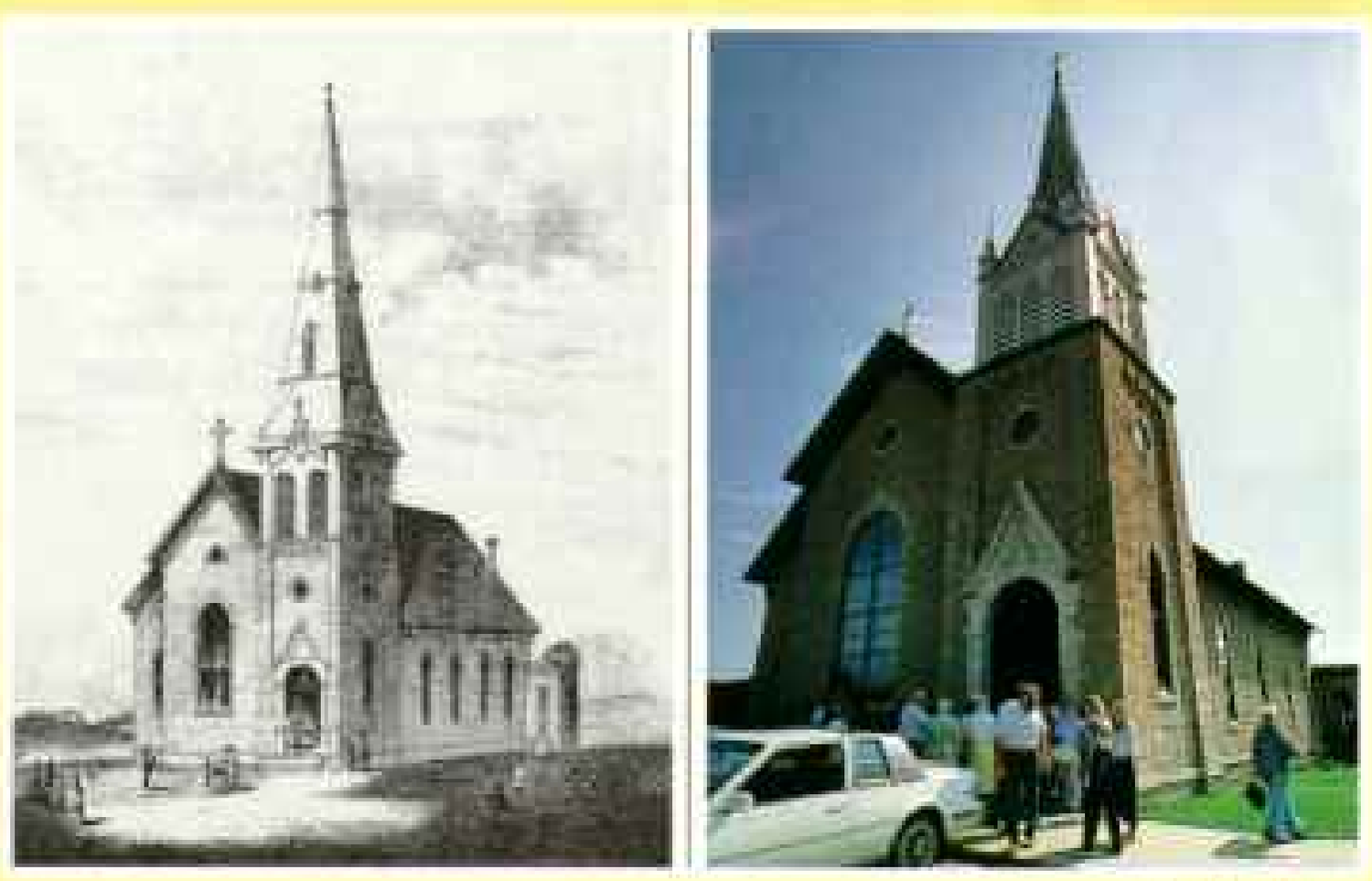
A National Wildlife Federation report warns that eating 11 servings of large Lake Michigan trout during a lifetime creates a cancer risk of one in 10,000. Under Environmental

THOMAS A. SCHNEIDER

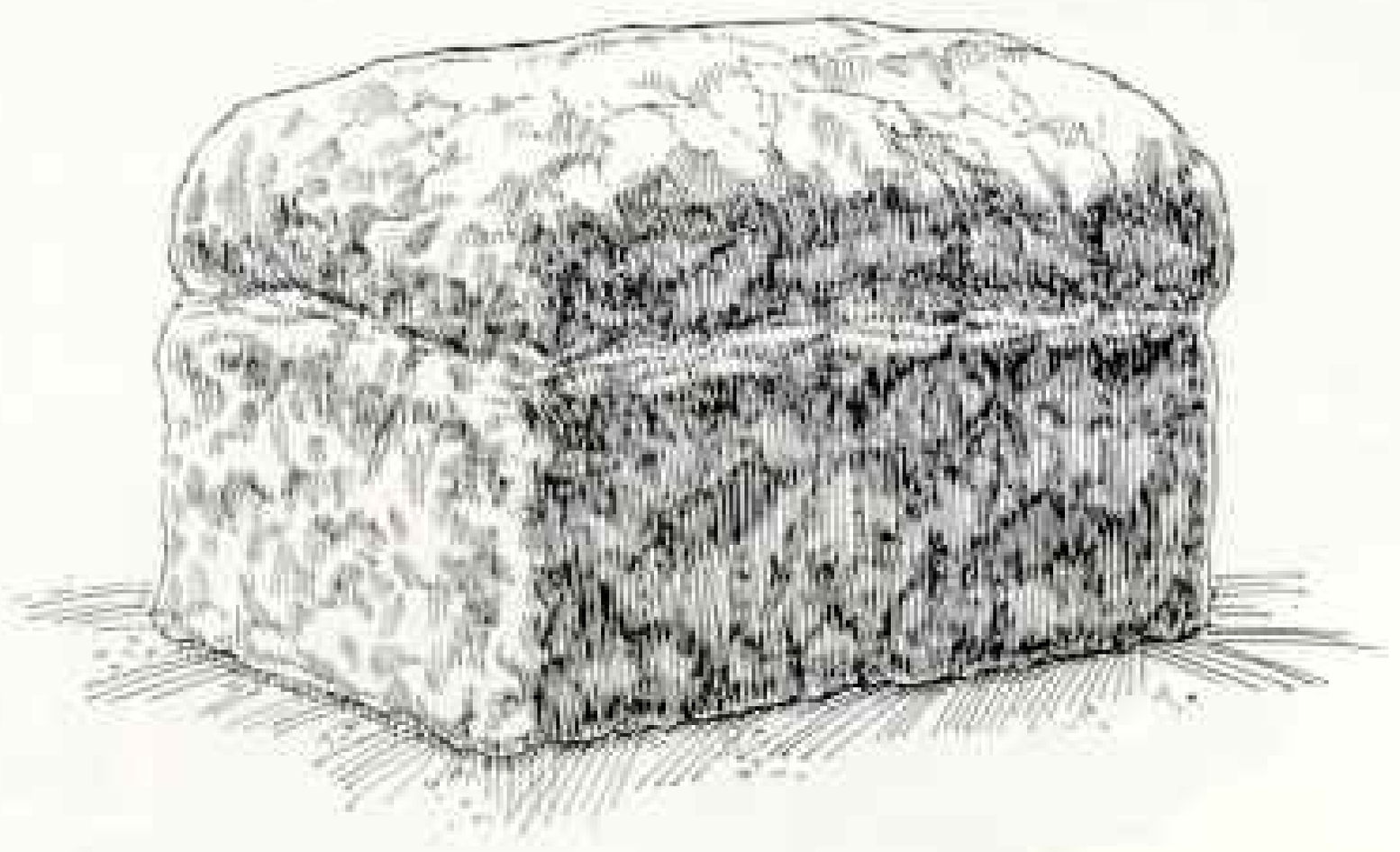
Protection Agency standards, a risk of one in 100,000 is minimally acceptable. The federation found that the risks from eating smaller trout and other species, such as perch, are much lower.

"We're not saying 'Stop fishing' or 'Don't eat fish,' " says Mark Van Putten, director of the federation's Great Lakes office. "But we are providing information so people can begin to shift their consumption. The long-term solution, of course, is to eliminate pollution."

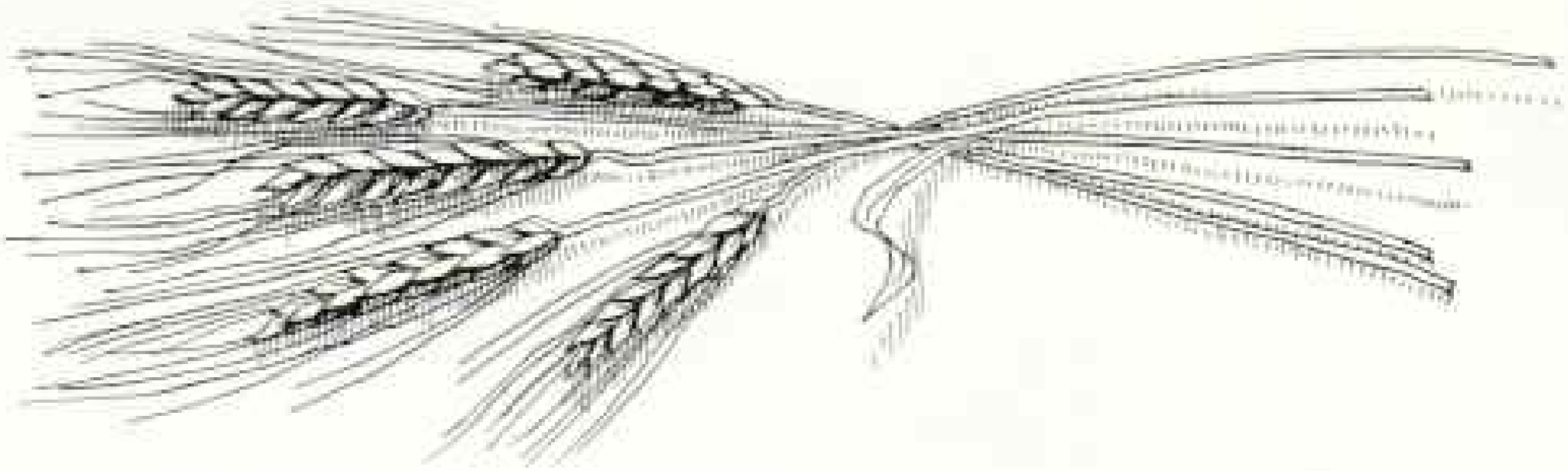
Among steps that the federation and other environmentalists consider critical to the protection of the Great Lakes is a "toxics freeze"—a policy prohibiting any net increase in the most dangerous chemicals in the Great Lakes ecosystem. Other steps include imposing uniform water-quality standards throughout the lakes and setting a timetable to reduce dumping of toxic chemicals. The goal is zero toxic discharge in the next century.



JIM BRANDENBURG



Give people bread and they feel like beggars.



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NATIONAL GEOGRAPHIC MAGAZINE

NATIONAL GEOGRAPHIC SOCIETY

"For the increase and diffusion of geographic knowledge"

THE NATIONAL GEOGRAPHIC SOCIETY is chartered in Washington, D. C., as a nonprofit scientific and educational organization. Since 1890 the Society has supported more than 3,700 explorations and research projects, adding to knowledge of earth, sea, and sky.

IN THIS LAST DECEMBER of the 1980s, we publish a new map of that bitterly contested region known for centuries as the Holy Land. The map shows modern Israel amid its neighbors—Lebanon, Syria, Jordan, and Egypt. In 101 years NATIONAL GEOGRAPHIC has published some 13 supplement maps of this area, for which we have been denounced and vilified by one or more groups as incompetent, uninformed, anti-Semitic, anti-Muslim, anti-Arab, anti-Christian. This map will be no exception, for passions in the whole region remain high and the killing and dying continue unabated.

In one of the oldest cartographic references to the region, a 3,800-year-old Egyptian potsherd refers to the city of Rushalimum, loosely "city of peace." Tragically this city—now known to most of the world as Jerusalem and to the Arabs as Al Quds, meaning "the holy"—has been perhaps the least peaceful city on earth.

Fully occupied by Israel since it took East Jerusalem and the West Bank of the Jordan River 22 years ago, the city has been under the rule of some dozen different powers since it was captured from the Canaanites by the Israelites about 1000 B.C. Except for conquests and sackings by Egyptians, Babylonians, Persians, Greeks, and Romans, in the past 3,000 years it has been held by Jews for some ten centuries, Muslims for twelve, and Christians for four. All three faiths consider it sacred. It has been destroyed and its citizens killed by all three.

Throughout the region there are dozens of sects or divisions of Jews, Christians, and Muslims, far too many of whom are well armed and willing to kill in defense of deeply felt beliefs. Inevitably many of their followers will disagree with our choice and mix of biblical and historical names and notes, our use of de facto borders as of December 1989, and the notes that attempt to explain them concisely.

We hope most of you will agree that in the face of political and religious conflicts, disagreements among historians, and contradictions within the Bible, our cartographers have produced—as one of our series of Special Places of the World—the best map available of this tragic Holy Land.

Wilbur E. Garrett

EDITOR

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KEY TO 1989

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Complete indexes of the year's articles are available free upon request. The January-June index (Vol. 175) is available now; July-December (Vol. 176) will be ready in January. The new *National Geographic Index 1888-1988* is on sale for $24.95; a deluxe edition, with slipcase and separate map index, for $34.95. A full 1989 supplement will be available in January: $1.00, free with *Index*.

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FROM SEA TO SHINING SEA, THE WILL TO SUCCEED IS PART OF THE AMERICAN SPIRIT.

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BECAUSE AMERICANS WANT TO SUCCEED, NOT JUST SURVIVE.℠

Let's dig a little deeper into the notion that much of our garbage is made up of plastics.

America's growing waste problem is monumental. We generate 160 million tons of garbage a year.

Our nation's landfills are being filled up. In five years 2,000 of our remaining 6,000 landfills will be closed.

A lot of well-intentioned solutions are being offered. One is that foam plastics, plastic bottles and plastic packaging should be banned.

The fact is that plastics make up less than 8%, by weight, of our nation's waste. Paper and paperboard make up about 36%, glass and metal about 9% each, all by weight. Plastics are naturally lighter, but still, when compressed, account for only about 20% by volume.

If plastics were banned, the need for packaging wouldn't go away. The idea is to substitute other materials which are assumed to be biodegradable, so a landfill would take longer to become full. Studies show, however, that paper and other materials decompose so slowly in today's landfills that the lives of the landfills are not extended.

Recycling must play a part.

In addition to environmentally secure landfills, and more state-of-the-art waste-to-energy incinerators, we believe that a significant answer to America's waste problem lies in recycling. Everything recyclable should be recycled. Yard waste. Paper. Metal cans. Glass bottles. And plastics.

Although plastics recycling is in its infancy, plastics are potentially more recyclable than alternative packaging materials.

In South Carolina, one company recycles 100 million pounds of 2-liter plastic soft drink bottles a year into everything from fiberfill for ski parkas to scouring pads to automobile distributor caps.

In Chicago, another company processes 2 million plastic milk jugs a year into "plastic lumber" for boat docks, park benches and fences.

What Amoco Chemical is doing.

Amoco Chemical is sponsoring a recycling program in New York State demonstrating that polystyrene foam food service containers from schools and restaurants can be recycled into insulation board for commercial construction, cafeteria trays and home and office products.

We're participating in a consortium with other major plastics manufacturers which will support construction of regional polystyrene recycling plants.

In Portland, Oregon, we renovated a 10-acre environmental learning center with a new wetlands walkway, signs, kiosks and benches made from recycled plastics.

We're encouraging the start-up of new plastic recycling efforts, helping to find new ways to collect and sort recyclables, and supporting efforts to create markets for recycled plastic products.

At Amoco Chemical, we believe we're only beginning to see the benefits of recycling. In the not-too-distant future, it can turn our solid waste from a national problem into a national resource.

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Recycling. Do It Today For Tomorrow.

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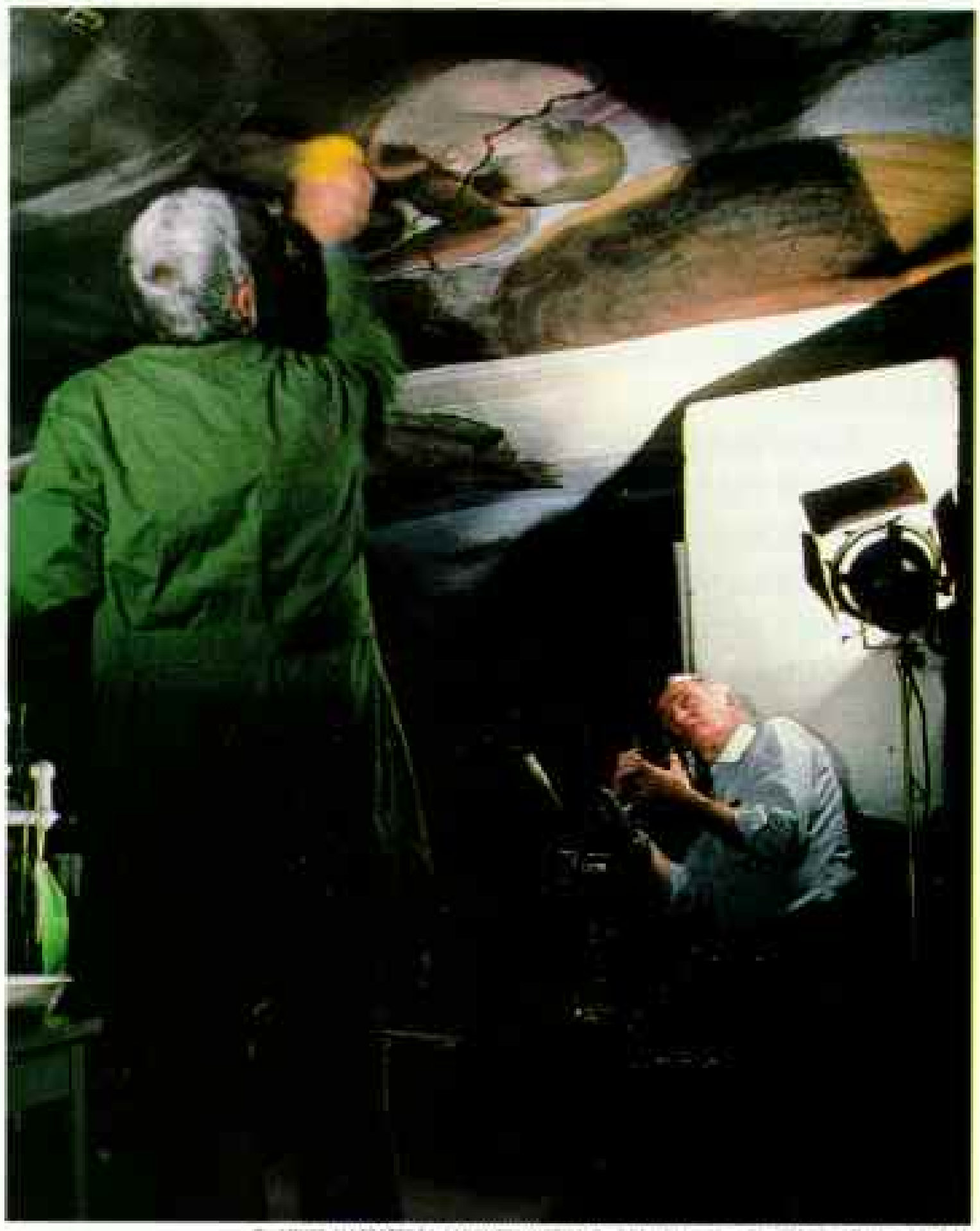
On Assignment

WHEN making close-ups of chief restorer Gianluigi Colalucci (and his slogan-on-a-button), VICTOR R. BOSWELL, JR., was back in a Sistine Chapel far cleaner and brighter than the one he photographed 20 years earlier. Then it took 20,000 watts of illumination to penetrate the gloom for one large mosaic of the entire ceiling.

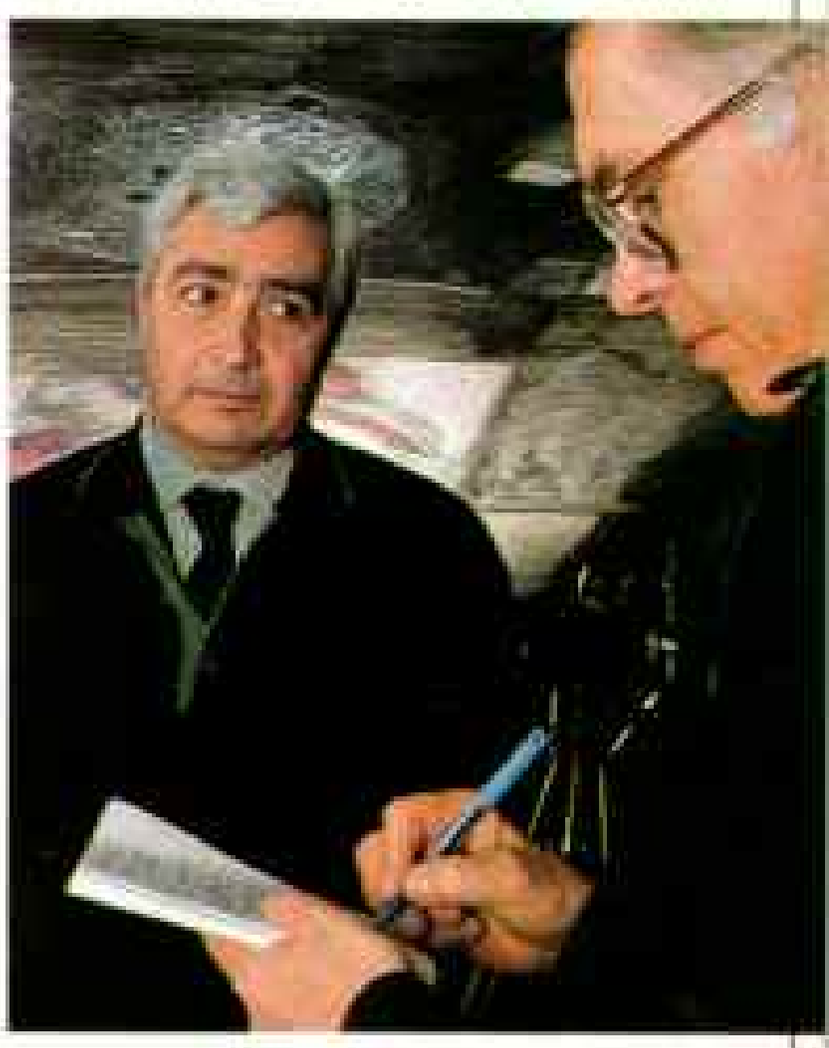
In 1989 Vic needed only one-tenth the light to make the view of the restored ceiling on pages 690-92. Long experienced in making paintings, sculptures, and other treasures come alive, he relied on his practiced eye to make adjustments for distortion, to compensate for image overlap, and to vary exposure times for different areas of the same frame. To convey the sense of being a visitor looking up some 60 feet from the floor, Vic included curves of the ceiling as it merges with the walls. There Michelangelo played his own visual games, since in the fresco some of the architecture is "real," though most is painted on.

Directing the lengthy restoration, Vatican art historian Fabrizio Mancinelli, here outside the chapel (right), has become a practicing diplomat to visiting colleagues and to the press. He and restorer Colalucci, being interviewed by author DAVID JEFFERY (far right), have with saintly patience answered a hundred questions a thousand times about Michelangelo's monumental work.

Dave found his Sistine assignment oddly like his first sight of Antarctica or of the Yellowstone fires (February 1989), an experience on "a scale and intensity to rattle your bones."



© LOUIS MAZZATENTA (ABOVE); VICTOR R. BOSWELL, JR., (BUTTON); ADAM WOOLFITT



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(Motion captured on Normal* film.)

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