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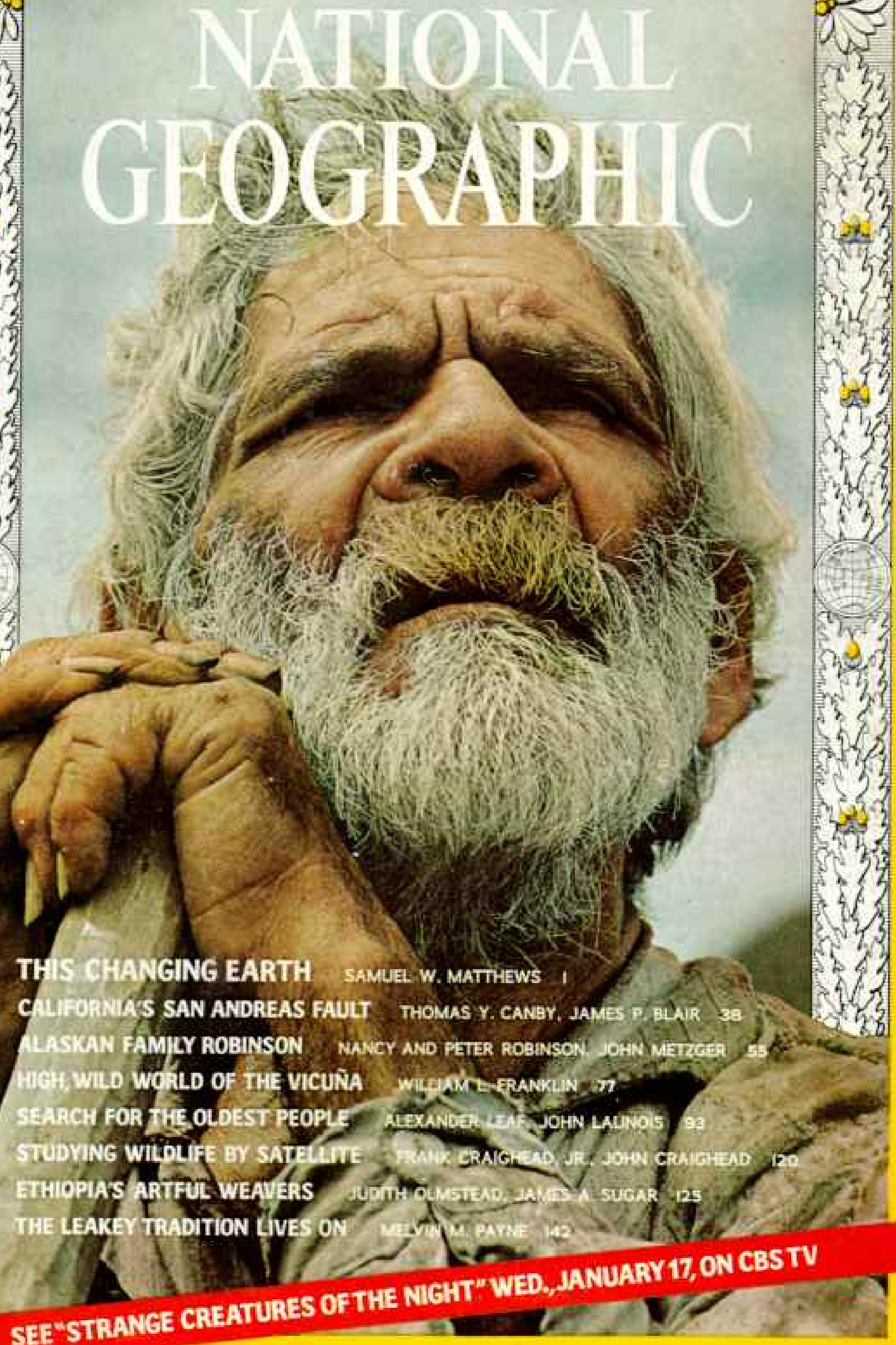

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NATIONAL GEOGRAPHIC

January 1973

The Atlantic widens, the Pacific narrows,
the Alps grow higher. Los Angeles
slides northward, and Africa splits apart.
A report on dramatic new discoveries about...

THIS CHANGING EARTH

By SAMUEL W. MATTHEWS
SENIOR EDITORIAL STAFF

BLACK, BARREN, as forbidding as an ash heap from hell, the tiny island in the open ocean oozed smoke from its cracks and crevices. Our light plane circled, gliding on the cold sea wind. We sideslipped, dropped toward a cinder beach, bounced, and lurched to a stop.

My young Icelandic pilot, Ingimar Davidsson, turned with a grin. "You're now on the very newest land on earth," he said.

He was not totally accurate, though close enough. Other volcanoes have erupted since the island Icelanders named Surtsey began spewing from the North Atlantic in November 1963. But this one had put an entirely new name on the world map, at a spot where nothing but ocean had existed before.

We had landed on a freshly upthrust peak of the 12,000-mile-long Mid-Atlantic Ridge. Here earth's solid skin had cracked apart, and orange-hot magma had flowed up from the deep interior (next page). Here, even now, the floor of the Atlantic was moving, spreading outward, carrying Europe and North America farther apart by nearly an inch a year. Here, before my eyes, the face of the world was changing.

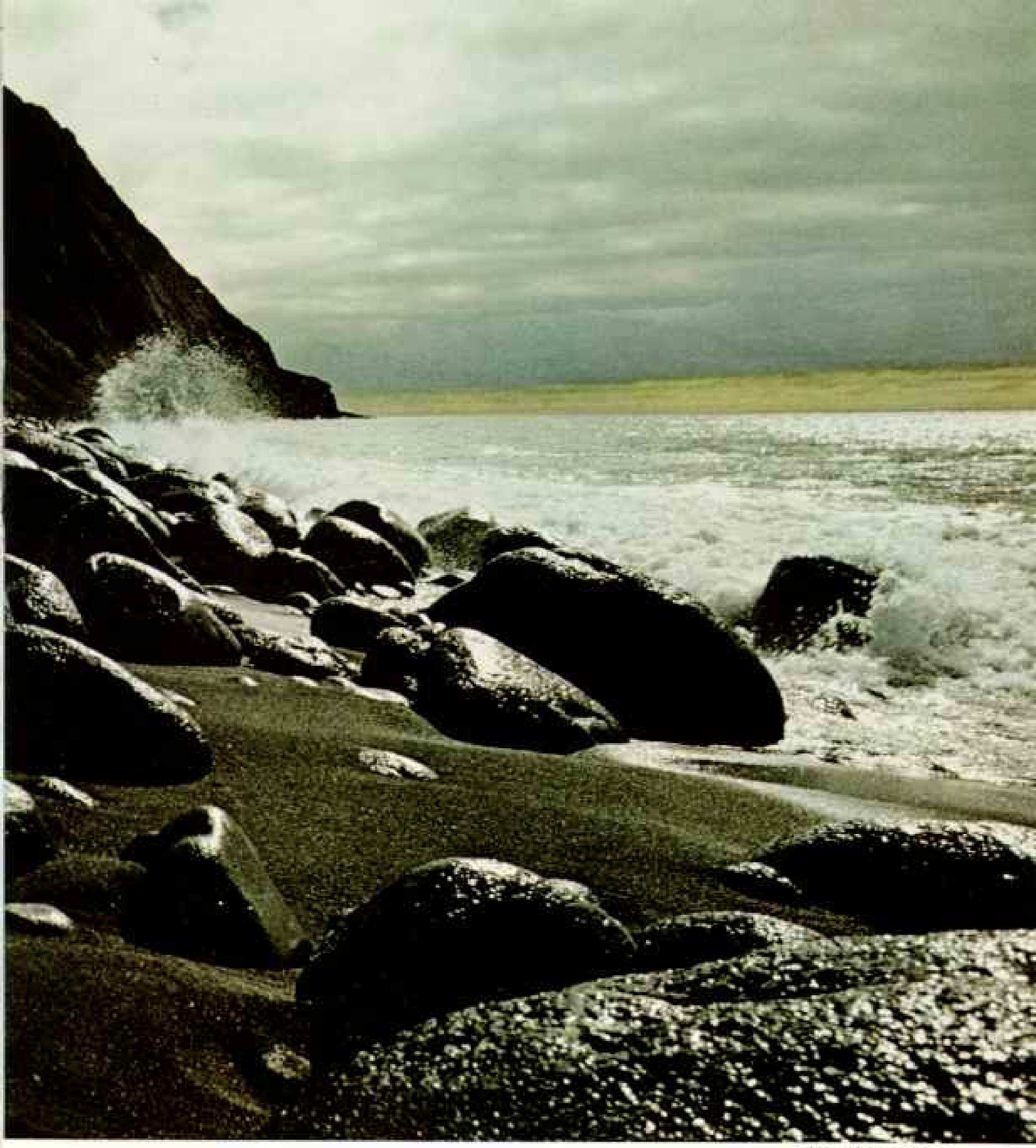
Iceland itself, the big island just north of us, was split asunder and growing measurably wider. I had seen the rift, driven across its floor in a Land-Rover, stood at a great crack (pages 32-3) where Iceland's Althing, its legislative assembly, began meeting in A.D. 930, more than a thousand years ago.

Yet that is only an eyewink in the span of

(Continued on page 7)

VIOLENT CHILD OF CHANGE, *the island of Surtsey spews lava and steam off Iceland. In 1963 it burst from the Atlantic, born of the stupendous forces ever altering the face of the earth.*

Life finds a foothold on eight-year-old Surtsey as plants sprout from seeds borne by wind, waves, or birds. The isle's emergence gave biologists a rare laboratory for observing such genesis of life on a barren speck of new land.



SURTSEY BY ANTHONY SOCCACCIO

Surging surf ground jagged lava into rounded boulders with a speed that astonished geologists attending Surtsey's birth. For the first year the island endured a seesaw battle for survival as upwelling magma, exploding on contact with the sea, threw up only porous ash that waves could easily erode. Then lava flowed out atop the cinder pile and hardened, slowly building a protective rock shield. Now a square mile in size and capable of resisting the sea's pounding, Surtsey adds a permanent new place-name to world atlases.

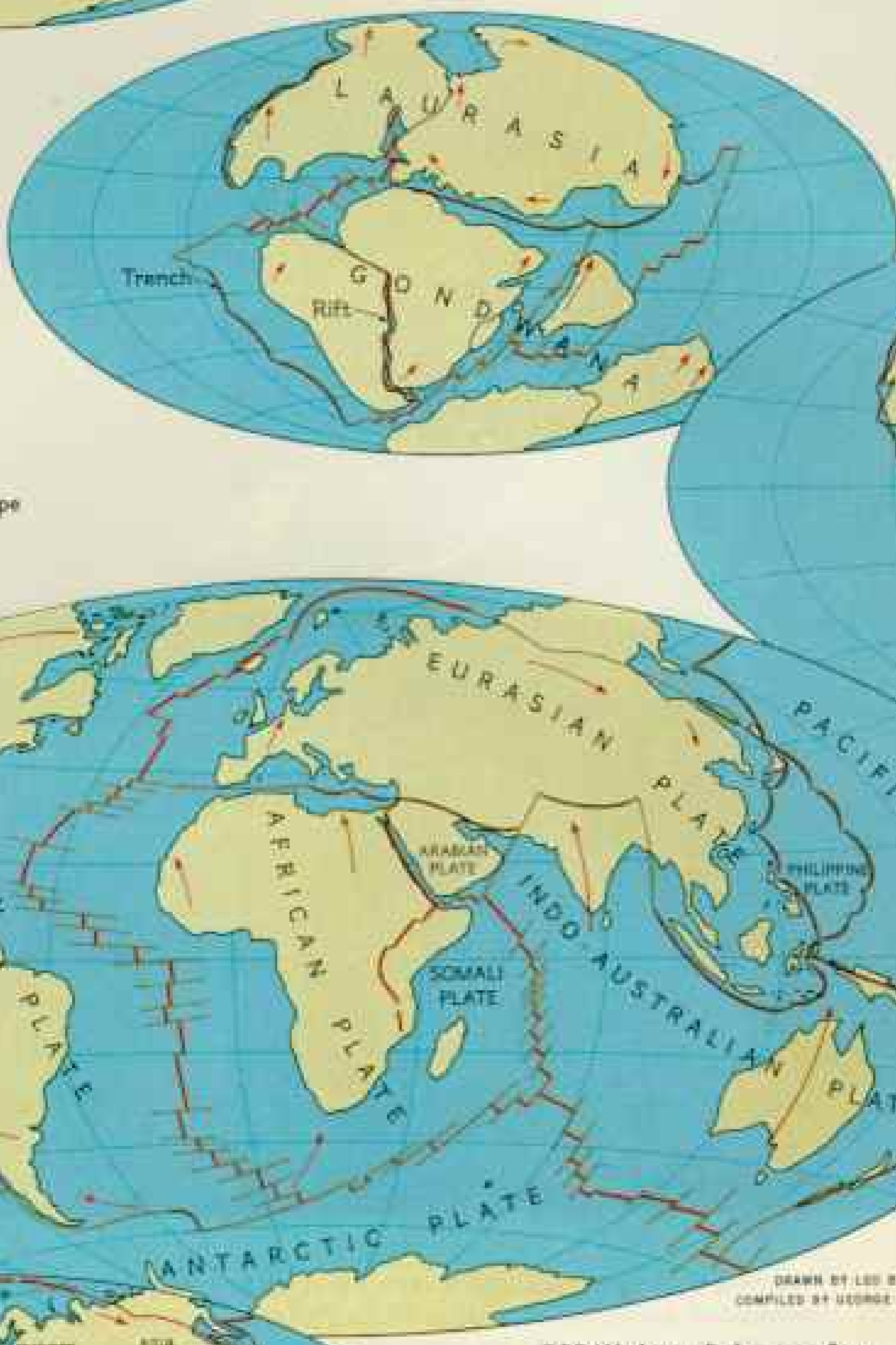
Surtsey and neighboring Iceland represent above-sea sections of the 12,000-mile-long Mid-Atlantic Ridge, a volcanic chain whose eruptions give dramatic evidence of the movements that wrack earth's crust.

How the continents

200 MILLION YEARS AGO: A single supercontinent — which geologists now call Pangaea, "all lands" — is washed by a universal ocean, Panthalassa.

135 MILLION YEARS AGO: The northern landmass, Laurasia, has split from the southern, known as Gondwana or Gondwanaland. This has also divided, with India heading north toward Eurasia.

65 MILLION YEARS AGO: The North Atlantic and Indian Oceans have taken shape (far right), and the South Atlantic widens. Australia is still attached to Antarctica.



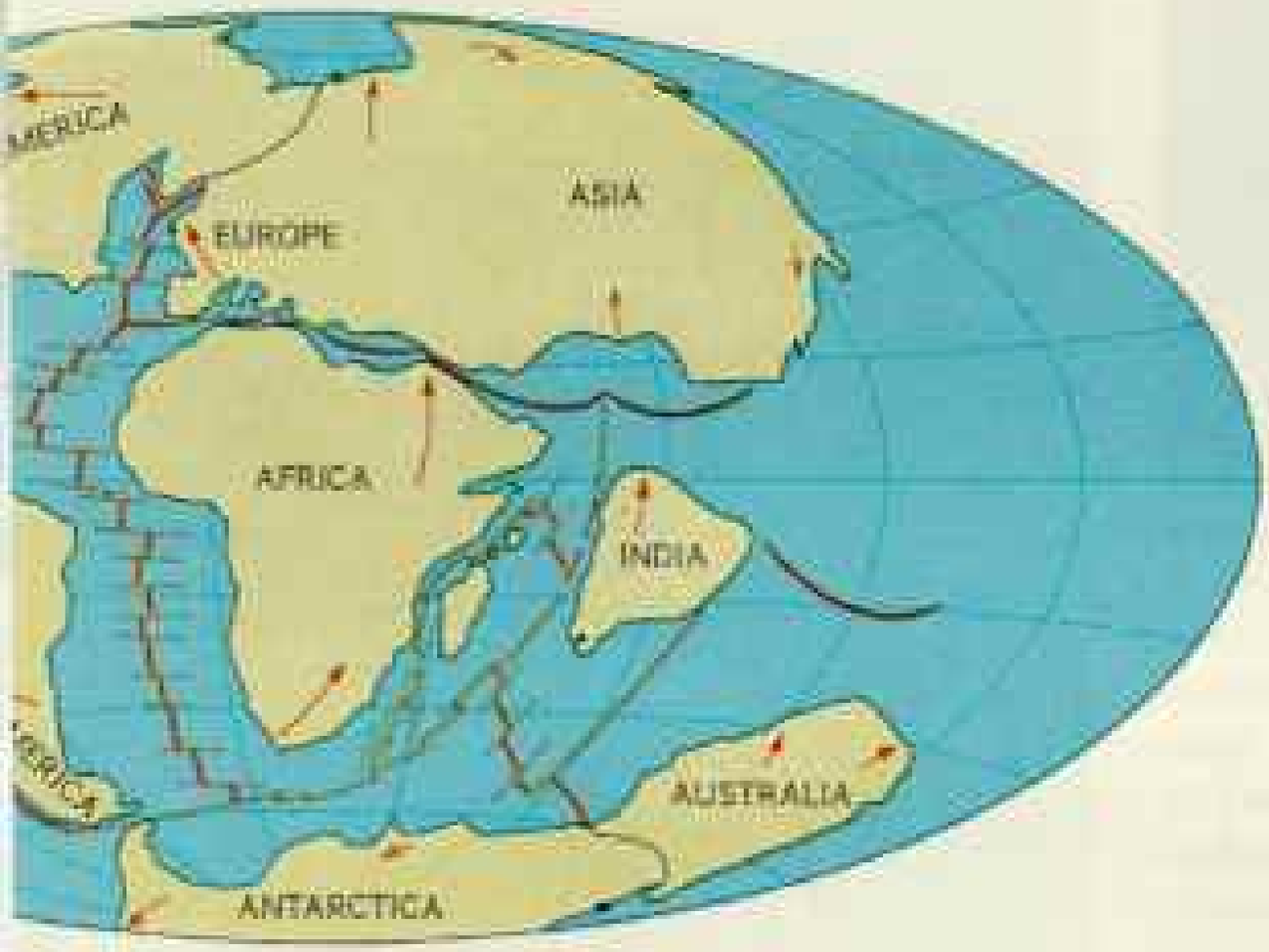
TODAY: Australia has torn from Antarctica. Laurasia has finally separated into North America and Eurasia. India has careened into Eurasia, thrusting up the Himalayas.

50 MILLION YEARS FROM NOW: Australia plows north. The Atlantic and Indian Oceans continue to widen; the Mediterranean shrinks. California west of the San Andreas Fault, detached from the mainland, slides toward the Aleutian Trench.

have drifted apart

SLOWLY AND PONDEROUSLY, the continents are traveling across the face of the planet, carrying us as passengers. In the lifetime of a man, North America and Europe will move farther apart by about his own height.

Some 200 million years ago, only yesterday in earth's time span of 4½ billion years, the land areas formed a single supercontinent. Then it broke into fragments that largely define today's continents, and they began incredible voyages across the planet. These diagrams, based on maps by Robert S. Dietz and John C. Holden



of the National Oceanic and Atmospheric Administration, trace the continents' majestic progression, and even plot their predicted positions 50 million years hence (**bottom**).

How can colossal landmasses cross the seemingly solid earth?

In the 1950's oceanographers discovered that a continuous mountain range 40,000 miles long winds through all the ocean basins. Along its crest runs a narrow rift valley, floored with hot rock. In a process known as "sea-floor spreading," material from earth's interior wells upward in these valleys. The ocean floor moves steadily outward from the rift, pulled or pushed across a less rigid layer beneath by forces still not understood. Offsetting the steady creation of new surface, other regions of the ocean floor plunge down, or "subduct," into earth's mantle along deep-sea trenches.

Earth's shifting crust, scientists postulate, is actually a mosaic of perhaps 20 great segments, known as "plates" (pages 10-11). They carry the continents and ocean basins on their backs like great rafts.

geologic time I was seeking to cross. I was making a journey across inconceivable distances of time and earth-change. I was going back two hundred million years and more, back to an age when there was only one great continent—Pangaea, meaning "all lands"—and only one ocean, Panthalassa, "all seas."

My guides were to be dozens, even scores, of scientists who study the earth. Within just the past few years these men and women have come to a startling new understanding of the shifting, shuddering, hot-hearted planet on which we ride.

Their new view of the earth is of continents drifting majestically from place to place, of mountains and island chains forming like rumples in rugs pushed together, of oceans opening and closing.

The earth's seemingly rigid crust, these geologists say, actually consists of a crazy quilt of great rafts, or "plates," that are much like huge ice floes jostling about on a frozen sea. From 30 to 100 miles thick, the plates slowly move, carrying the continents and ocean basins with them.

Sliding over a hot, semiplastic layer below, the rigid plates grind and crush together, causing earthquakes and volcanic eruptions. They crack, usually in the ocean basins where they are thinnest, and the pieces move apart. In the cracks molten rock wells up and solidifies, like new ice forming. Along other edges the plates are just as steadily destroyed. They bend downward, forming the deep oceanic trenches, and slide beneath an opposing plate or edge of a continent to be consumed within earth's interior.

IF ALL THIS sounds like utter fantasy, so it would have seemed to many serious geologists and geophysicists only ten years ago—and so it still seems to some. But the past decade has brought a sweeping revolution in understanding of the earth, a new basic grasp of the forces that shape it. The change of thought has been compared to the scientific upheavals that occurred when Copernicus showed that our planet is not at the center of the universe, Darwin postulated the slow evolution of living things, Niels Bohr described the atom.

"It is as if we have been walking the

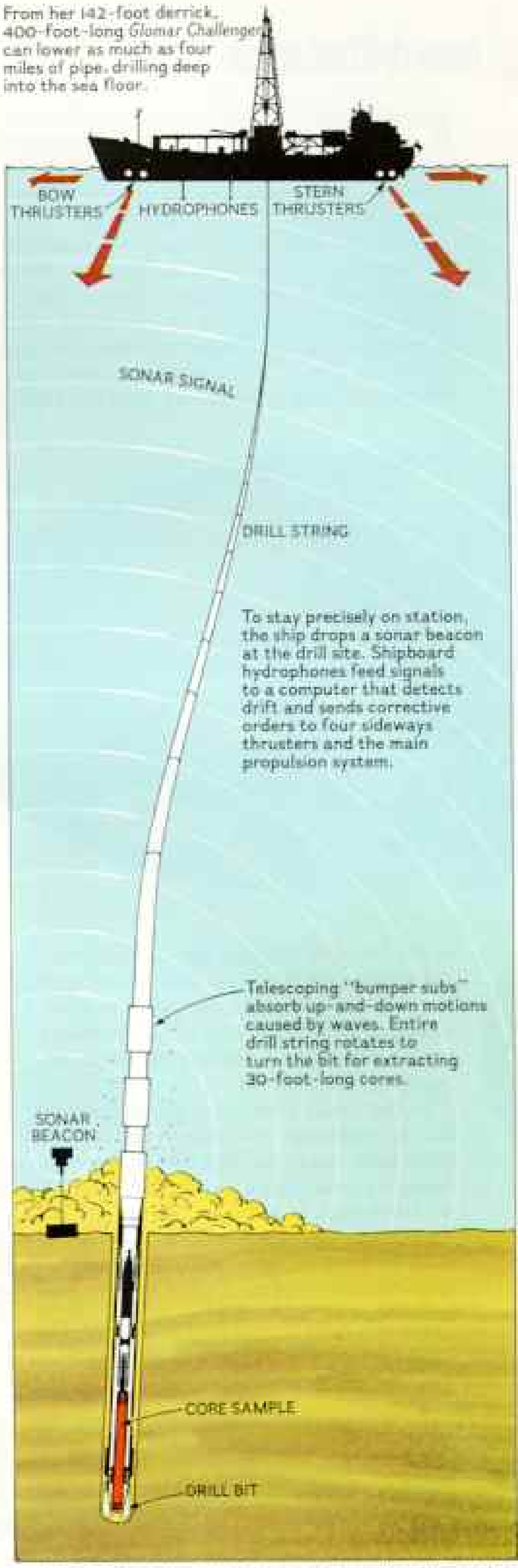
(Continued on page 12)

GORDON W. GAHAN (ABOVE AND BELOW)

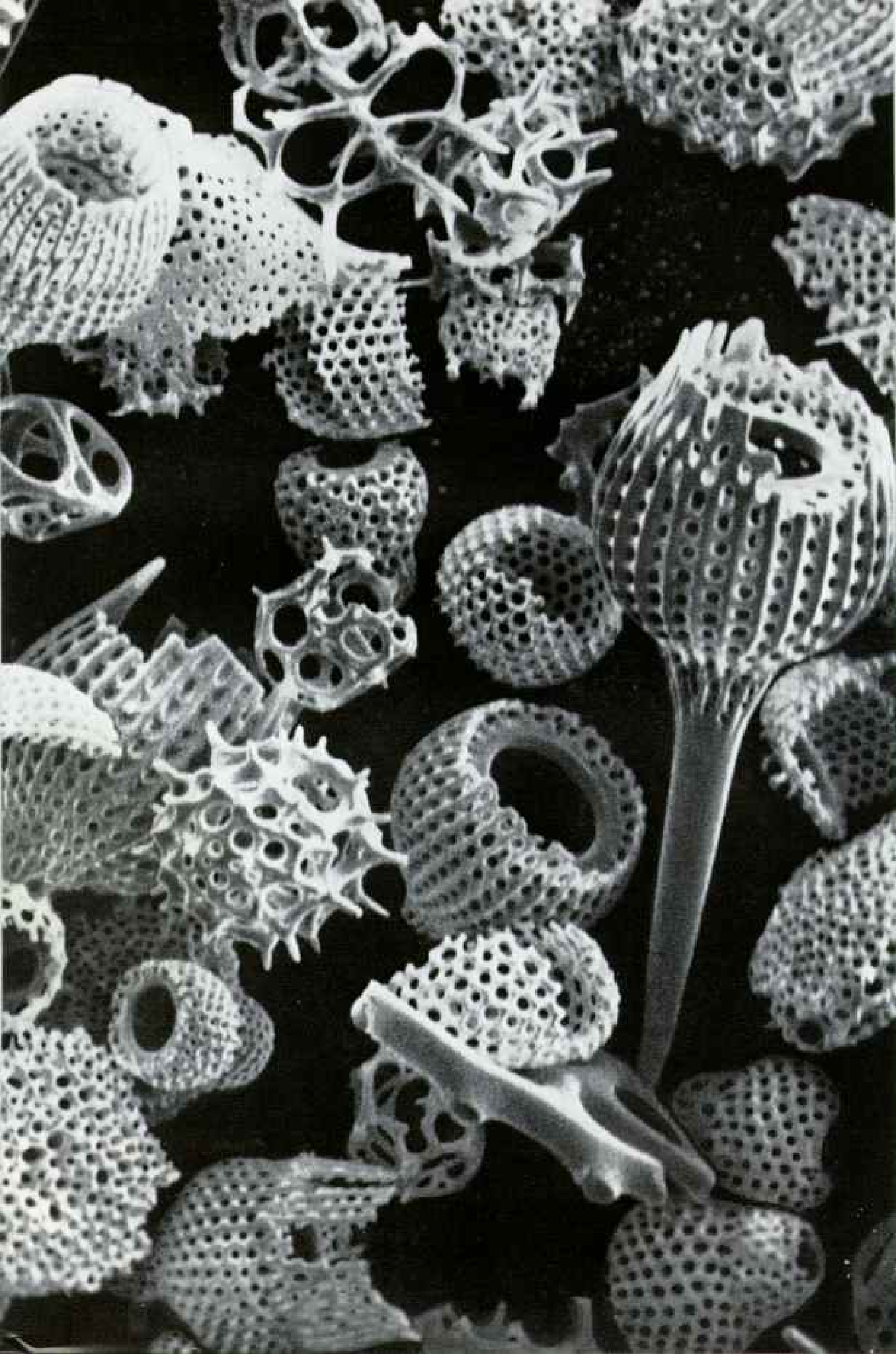
Scout of the sea floors, a floating drill rig named *Glomar Challenger* writes a dazzling new chapter in geology. Zigzagging across the oceans on the Deep Sea Drilling Project, she takes core samples of bottom sediments at depths no ship could probe before (**diagram**). Samples come up in long plastic sheaths (**above**), to be analyzed by shipboard scientists (**below**) and in laboratories ashore. By dating the skeletons of microscopic sea organisms that constantly rain down as sediments, paleontologists can determine the time at which the sea floor itself was formed. The skeletons shown opposite, magnified 320 times by a scanning electron microscope, date one part of the Pacific floor as 22 million years old.

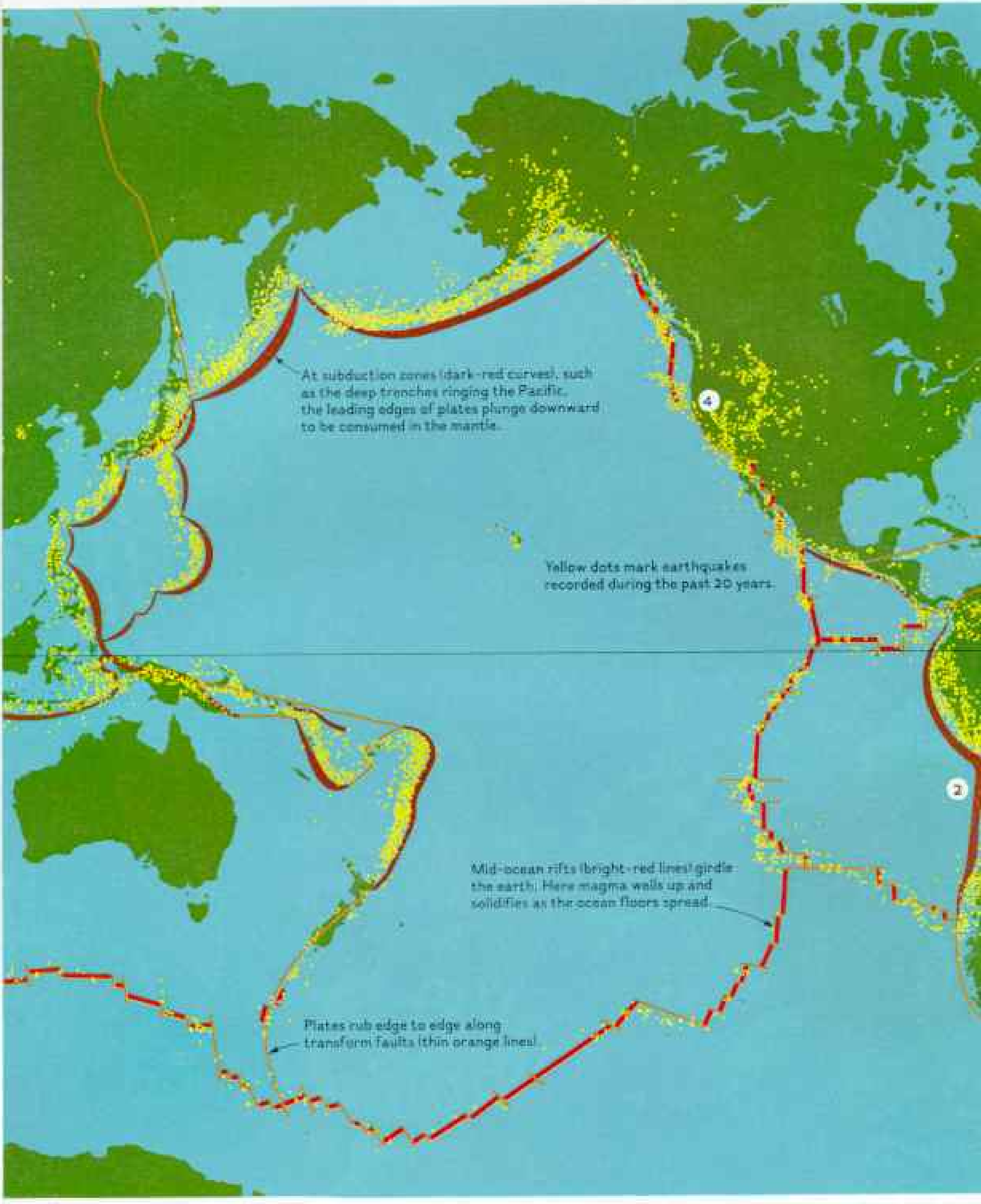
With thousands of cores hoisted in, *Challenger* has already proved that the oldest sea floors formed relatively recently—less than 200 million years ago.

From her 142-foot derrick, 400-foot-long *Glomar Challenger* can lower as much as four miles of pipe, drilling deep into the sea floor.



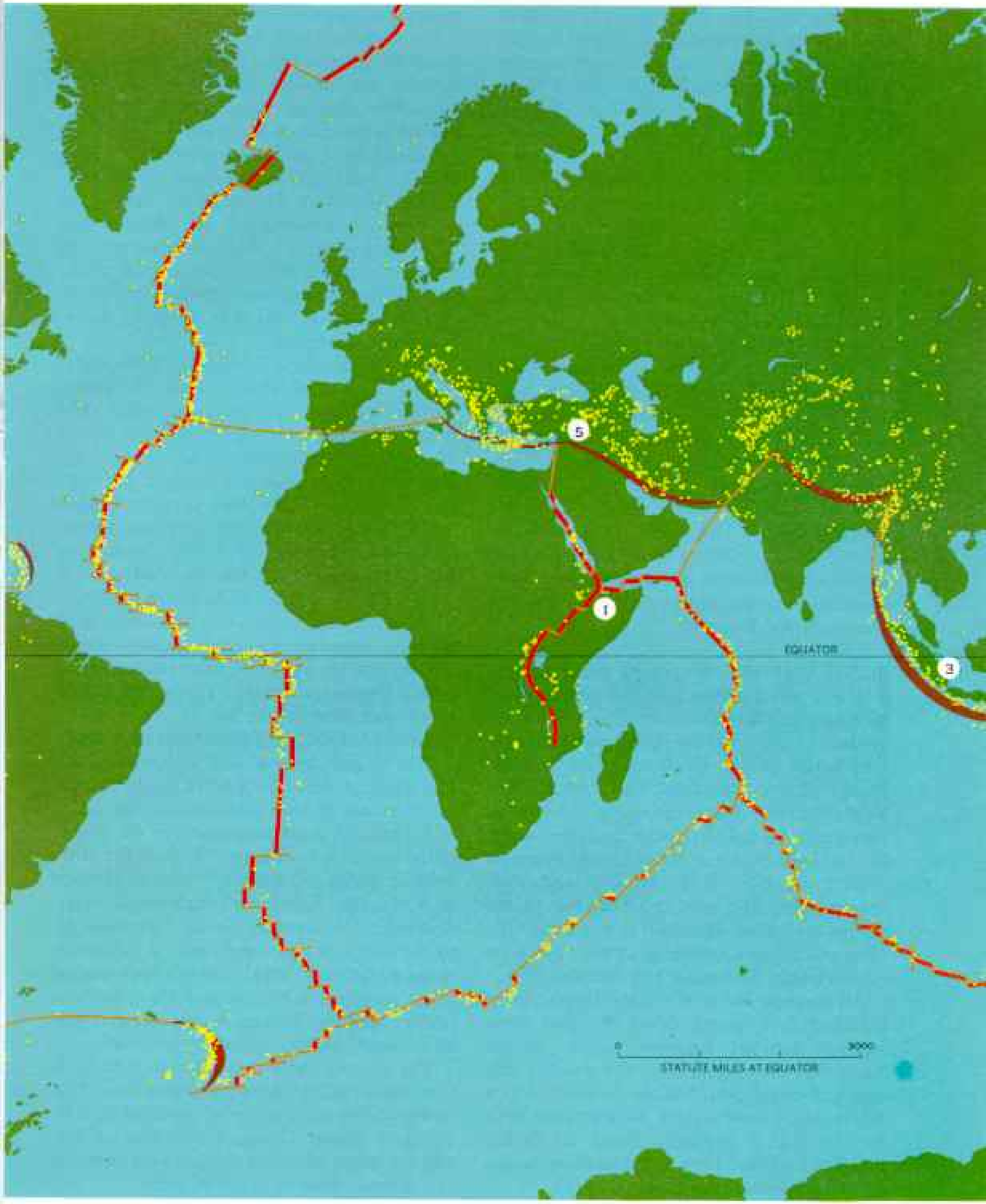
DRAWING BY STAFF ARTIST ROBERT W. NICHOLSON; PHOTOMICROGRAPH (RIGHT) BY STANLEY KLING AND ALLEN WHITE, COURTESY CITIES SERVICE OIL COMPANY





Earthquakes outline the jostling plates

WITH DRAMATIC CLARITY, belts of earthquakes and volcanoes draw the boundaries of the drifting segments of crust that pave the planet. Both quakes and volcanism torment the region of the Red Sea and Gulf of Aden (1),



DRAWING BY ALFRED ZEBARTH, COMPILED BY GEORGE W. BEATTY

where sea-floor spreading opens a new ocean (page 23). Subduction of a southeast Pacific plate beneath South America (**2**) uplifts the Andes and breeds the quakes that rock Chile and Peru. Similar subduction under the Indonesian island chain fueled the 1883 eruption of Krakatoa (**3**). Plates rubbing edge to edge caused the catastrophic San Francisco earthquake of 1906 (**4**). Collision between the Arabian plate and Asia regularly jolts Iran and Turkey (**5**).

deck of a ship, eyes down to study the deck, and have never looked up to see that the ship itself was moving," a noted Canadian geologist, Professor J. Tuzo Wilson of the University of Toronto (page 31), told his colleagues in a major address a few years ago.

"Textbooks are being rewritten," says a U. S. geophysicist, Dr. Leon Knopoff. "Teaching of geology is being totally revised."

"A great excitement pervades this field of study, yet there are diverse and contradictory opinions about the significance of the new developments," writes a distinguished Russian geologist, V. V. Beloussov.

Professor Beloussov himself still questions the extent, even the existence, of continental drift. But I heard him fairly summarize many of the arguments and new concepts, speaking in English in the great auditorium of Moscow State University before earth scientists gathered from all parts of the world in mid-1971.

From such meetings, and in countless scientific papers published in the past few years, has come recognition at last of a notion propounded in detail 60 years ago by a long-unheeded German meteorologist and theorist named Alfred Wegener.

LONG BEFORE Wegener's time, geographers had noticed that the continents—Africa and South America in particular—would fit together like a jigsaw puzzle, if only they could be moved. As early as 1620 Sir Francis Bacon speculated that their similarity of shorelines could scarcely be an accident, though he did not envision actual movement. In the mid-1600's a Frenchman, François Placet, proposed that the Old and New Worlds were first split apart by the 40-day deluge and flood described in the Bible. His idea was echoed as late as 1800 by the German scientist Alexander von Humboldt.

All through the 1800's came discoveries of identical rock layers, fossil life, and other strange matches between widely distant lands. But not until this century was the idea seriously developed that the continents as a whole might have moved. This was put forth first by a U. S. geologist, Frank B. Taylor, between 1908 and 1910, and then more sweepingly by Wegener, beginning in 1912.

In his book *The Origin of Continents and Oceans*, published in 1915, Wegener wrote: "The continents must have shifted. South America must have lain alongside Africa . . . the two parts must then have become increasingly separated over millions of years."

He proposed that the continents, blocks of lighter granitic rock, must somehow plow through the heavier basalts of the ocean floors like gigantic ships, driven by forces related to the spin of the earth.

Conservative geologists reacted far from mildly. In the 1920's a president of the prestigious American Philosophical Society in Philadelphia pronounced the whole idea "utter, damned rot!" Wegener, after refining and republishing his evidence several times, died in 1930 during a meteorological expedition to Greenland. He was generally disbelieved and derided.

A few wide-minded geologists, though precious few, took his idea seriously. A Briton, Arthur Holmes, espoused continental drift in the late 1920's; he developed the theory in a textbook, *Principles of Physical Geology*, that is still unsurpassed in its field. A South African, Alex. L. Du Toit, compared landforms and fossils and came to the unshakable conclusion, expressed in a 1937 book, *Our Wandering Continents*, that his country must once have been attached to South America.

Most scholars, professors, and students of geology, however, finding too many inconsistencies in the evidence, scorned and all but forgot Wegener's theory. There the matter stood until after World War II.

Then an explosion of knowledge took place, thanks in part to new and sophisticated instruments, some developed to sound the sea floors, others to record earthquake waves.

A chain of huge mountains in the midst of the oceans was charted. "Though the Mid-Atlantic Ridge was known," Bruce C. Heezen of Columbia University's Lamont-Doherty Geological Observatory told me, "we woke up to the fact that the oceans held a mountain range 40,000 miles long." The huge submarine ridge, mapped by Heezen and his colleagues under Maurice Ewing, winds around the globe much like the seam of a baseball.

The oceanic ridge is divided in turn by a thin, deep valley along its center line. The extent of this rift was first recognized by geophysicist Marie Tharp, a colleague of Dr. Heezen (page 30), while the two were charting the Atlantic floor in detail in 1953.

"Not only was the rift clearly visible on bottom profiles," Bruce Heezen said, "it coincided almost exactly with the map of mid-ocean earthquakes. Several years later, when supersensitive seismometers were set up to

detect underground nuclear tests, they confirmed the distinct pattern of shallow sea-floor quakes. These precisely defined the rift and the great faults, or transverse breaks in the ridge, between sections of the rift."

Similarly, earthquakes were known to cluster along some continental edges and chains of islands, particularly around the Pacific's "Ring of Fire" (pages 10-11). Here they sometimes occur far deeper, following steep slopes to depths as great as 450 miles.

Earthquakes are caused by rock breaking suddenly. Something was happening along the ocean rifts and those deep slopes.

Could it be that through the rifts in the ocean floor the very stuff of earth's interior was welling up to form new crust, solidifying and moving outward? Could the sea floors be spreading, carrying or pushing the continents ahead of them?

At the other end of this great conveyor system, could old crust be disappearing in the deep trenches and under continents? Was this what causes the deep earthquakes, rumples up the island arcs and mountain ranges, and sets off volcanoes?

Among those who advanced this idea of sea-floor spreading, writing landmark papers about it a decade ago, were the late Harry H. Hess of Princeton University and Robert S. Dietz (page 31), then of the U. S. Navy Electronics Laboratory. Hess presented his conclusions very tentatively, calling his article "geopoetry." But many other geologists and oceanographers were listening. More evidence was needed.

IT CAME, in simplest terms, from the compass. Earth's magnetic field—the lines of magnetic force running between north and south poles—influences the magnetism of rock as it cools from molten form or accumulates as sediment on the floors of lakes and seas. In effect, rock layers formed in past geologic ages keep permanent records of the direction to the magnetic poles at the time.

As measured on different continents, however, rocks of the same age seemed to point to poles in different places.

"The problem could be solved only by assuming the continents themselves had moved," Ian Dalziel, a Scottish geologist now at Lamont-Doherty, told me. "That's basically what one British team, at the University of Newcastle upon Tyne, did. They demonstrated continental drift by matching pole positions. The poles as recorded in England's rocks, for example, could be precisely matched to North America's by closing up the Atlantic."

Five years ago, flat on my face on a rock outcrop in Antarctica, I watched a young red-bearded geologist, Thomas O. Early, use a compass and level to orient rock samples to today's magnetic field, before breaking them free to seek evidence that the southernmost continent has moved. It has, although far less than other landmasses.

Paleomagnetics, as the science is called, has produced even more startling facts.* One is that the planet's magnetic field has reversed, flip-flopped north and south, many times—at least 171 times in the past 76 million years.

The reversals were confirmed in the early 1960's in rocks in many parts of the world. They could be dated by fossils and radioactive isotopes. A time chart was developed, showing when the reversals occurred. The chart now extends back 160 million years.

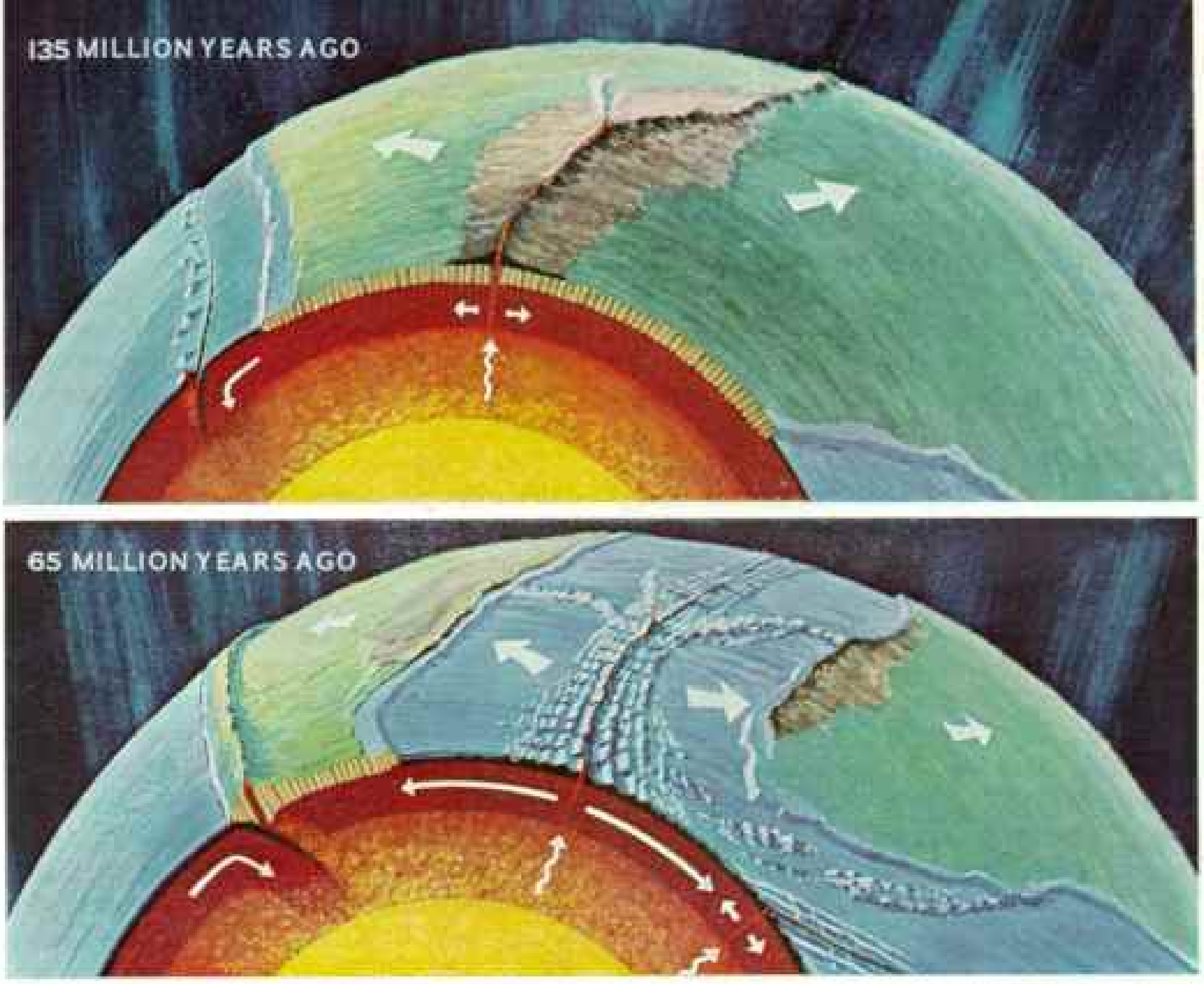
Meanwhile, seagoing magnetometers—long, slender torpedolike instruments—had been developed and were being towed by research ships back and forth across the oceanic ridges. The squiggly tracings they produced showed striking variations in magnetism on both sides of the rift valleys.

It occurred to two young British investigators, Frederick J. Vine and Drummond H. Matthews of the University of Cambridge, that if new crustal rock was indeed cooling and solidifying at the ocean rifts and spreading outward, a record of the magnetic flip-flops would lie there in the sea floor, as if on a vast tape recorder.

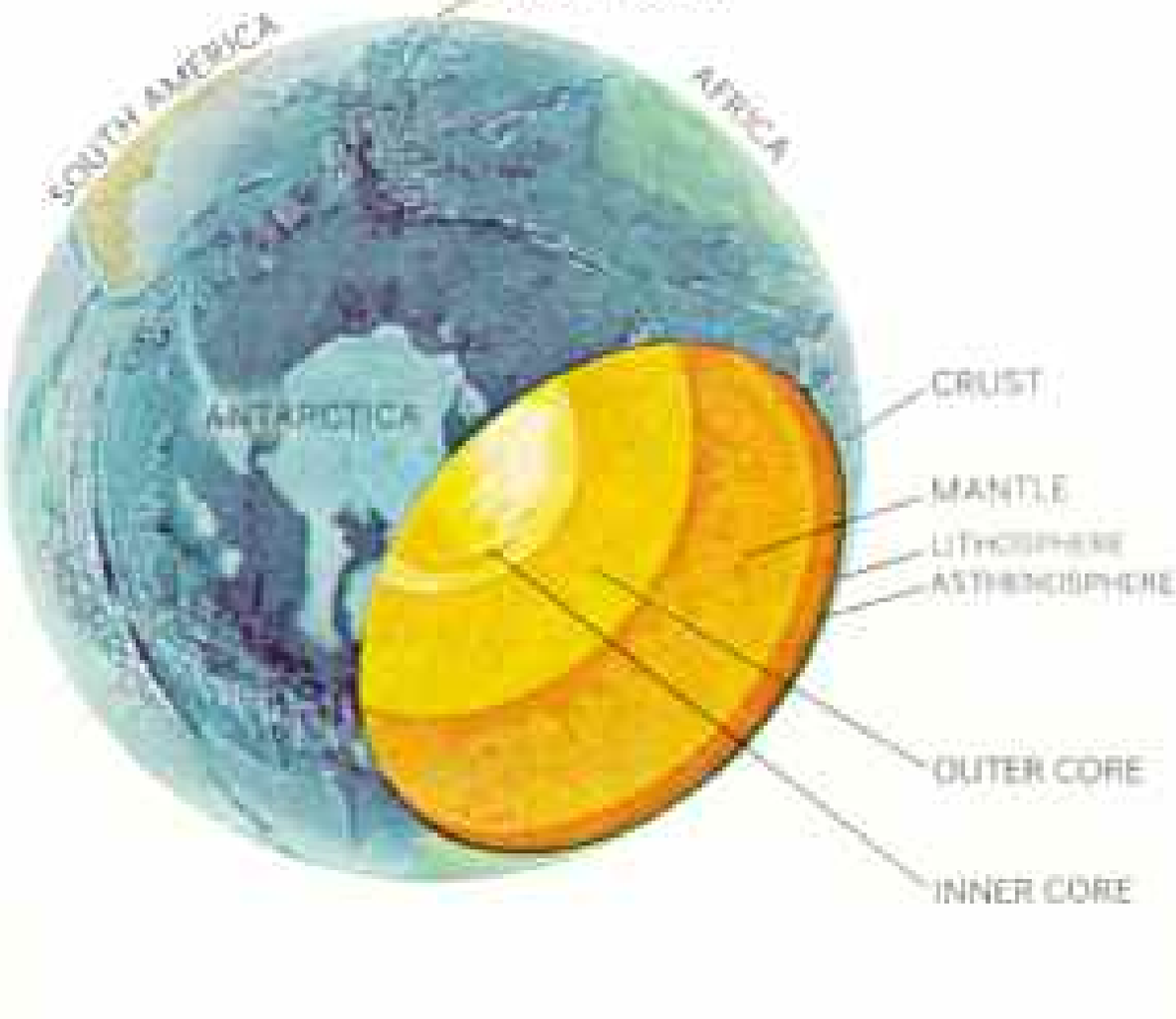
So it proved. Sea-bottom magnetism not only showed the reversals in parallel stripes along the ocean ridges, but also detected them on both sides of the ocean-floor rifts, like mirror images. If, for example, a sharp reversal was found 500 miles east of the Mid-Atlantic Ridge, a matching stripe would lie 500 miles west. By measuring the distances from the rift to reversals whose ages were known, the oceanographers could read how fast the sea floor was spreading.

The ingenious method worked wherever it was tried. The Atlantic Ocean was shown to be opening at one to two inches a year. Parts of the Pacific floor, particularly off South America's earthquake-wrenched west coast, were moving four times that fast.

*See "Magnetic Clues Help Date the Past," by Kenneth F. Weaver, NATIONAL GEOGRAPHIC, May 1967.



PAINTINGS BY STAFF ARTIST LLOYD K. TOWNSEND, BASED
ON CONCEPTS OF ROBERT S. DIETZ AND JOHN C. HOLDEN, NOAA



Unzipping the South Atlantic, a rift begins to divide South America and Africa 135 million years ago (**top**). The American plate subducts under the Pacific plate, far left. A hot spot, or plume, spews molten lava from deep beneath earth's crust (**diagram at left**).

By 65 million years ago (**middle**) the continents have spread 2,000 miles, trailing lava from the hot spot to form submarine ridges. The subduction zone has reversed; now the Pacific floor plunges under South America.

Today's South Atlantic, 4,000 miles wide, still spreads nearly two inches a year.

National Geographic, January 1973

Since the original paper by Vine and Matthews appeared in 1963, much more magnetic evidence has been gathered. The new data make it possible to date when various parts of Pangaea split and began moving apart.

"North America and Africa separated 180 to 200 million years ago," says Walter C. Pitman III of Lamont-Doherty matter-of-factly. "A rift between Africa and South America appeared about 135 million years ago. Finally, North America parted company with Europe only about 80 million years ago."

Wegener's single great protocontinent split first into two blocks (pages 6-7). In the north was Laurasia, consisting of the ancient landmass of North America (called Laurentia) plus Europe and Asia. In the south was Gondwanaland, or Gondwana (named for a geologic region of India), made up of Africa, South America, Antarctica, Australia, and India, which then lay far south of Asia. The Tethys Sea, an arm of the great ocean Panthalassa, extended westward between them.

Then South America began sliding westward. Africa parted from Antarctica. India broke free and sailed 5,000 miles north. It collided with Asia only some forty million years ago. The collision uplifted the high Tibetan Plateau and raised the Himalayas.

IT WAS not only the wavy lines of magnetic variations and flip-flops that proved to most doubters in the 1960's that drift had taken place. Other evidence piled up.

A British team at Cambridge, under the geophysicist Sir Edward Bullard, used a computer to demonstrate the fit of Africa and South America. They compared not today's coastlines, but the 3,000-foot depth line along the continental slopes, where they fall away into the deep ocean basins.

Geologists from the Massachusetts Institute of Technology and the University of São Paulo in Brazil, led by a then-self-professed "anti-drifter" named Patrick M. Hurley (page 30), went a step further. Using radioactive-isotope dating techniques, they compared rock strata on the west shoulder of Africa and along the east coast of South America. The rock layers and ages matched precisely, even to bands of iron ore, tin, and gold.

In Antarctica, in 1967 and again in 1969, explorers made what the National Science Foundation reported as "one of the truly great fossil finds of all time." From rock outcrops in the ice-locked Transantarctic Mountains, they brought home fossil fragments of land creatures from the age of dinosaurs.

The animals, among them a sheep-size reptile known as *Lystrosaurus* (page 17), a so-called "index fossil," were the first vertebrate land animals ever found in Antarctica. They were identical to those known to have lived in Africa, India, and China 180 to 225 million years ago. They could not have crossed even narrow spans of open ocean.

"The fully developed presence of *Lystrosaurus* in Antarctica," reported Dr. Edwin H. Colbert, a renowned paleontologist who also once doubted continental drift, "indicates that Antarctica and southern Africa were joined along a broad front. The same is true . . . for peninsular India . . . making of them essentially a single land."

BUT THE MOST convincing evidence of all came home in mud and rock drilled from the floors of the world's oceans by a gangly, improbable seagoing drill tower named *Glomar Challenger* (page 8).

In August 1968 began a most remarkable expedition in scientific exploration, the Deep Sea Drilling Project. It was an outgrowth of the abortive Mohole Project of the early 1960's, which was originally proposed to drill entirely through the outer crust of the earth.

Glomar Challenger was designed by a California offshore oil-drilling company, Global Marine Inc., to lower more than 20,000 feet of pipe in the open ocean, bore into the sea floor, and bring up bottom cores, or samples. The technical feat has been likened to drilling a hole in a New York sidewalk with a strand of spaghetti dangled from the top of the Empire State Building.

Federal funding was provided through the National Science Foundation. The project was planned by the JOIDES group—Joint Oceanographic Institutions for Deep Earth Sampling—and directed by the Scripps Institution of Oceanography in California.

On her very first leg *Glomar Challenger*—which proudly carries the name of the historic H.M.S. *Challenger* oceanographic expedition of the 1870's—struck indications of oil under 12,000 feet of water in the Gulf of Mexico. Oil-bearing structures had never before been thought to exist under such depth of water.

On the third drilling leg, the ship proved that the Atlantic Ocean was indeed growing wider. Late in 1968 she left Dakar, on the western hump of Africa, and sailed south to

the crestline of the Mid-Atlantic Ridge. There, on both sides of the central rift valley, she drilled hole after hole.

Christmas Day, at 3:30 a.m., a key core sample came up the drill pipe. It showed clearly the boundary between sediment and basement rock. And the age—or, more accurately, the youth—of fossils at the basement confirmed the grand theory.

"The proof of sea-floor spreading... seemed to be in our hands," reported the expedition co-leader, Dr. Arthur E. Maxwell of Woods Hole Oceanographic Institution in Massachusetts. As had been predicted, the ocean floor was youngest at the mid-ocean divide. The fossils grew progressively older the farther the drill ship moved outward, in both directions. The sea floor on each side was sliding away from the Mid-Atlantic Ridge at nearly an inch a year.

FOUR YEARS and nearly 400 holes later, *Glomar Challenger* is still drilling the hard skin of the earth. She has shown that the ocean floors are far younger than the continents. The oldest sediments yet found in any of the oceans were laid down only some 160 million years ago. In contrast, rocks found recently in Greenland have been dated at 3.98 *billion* years old.

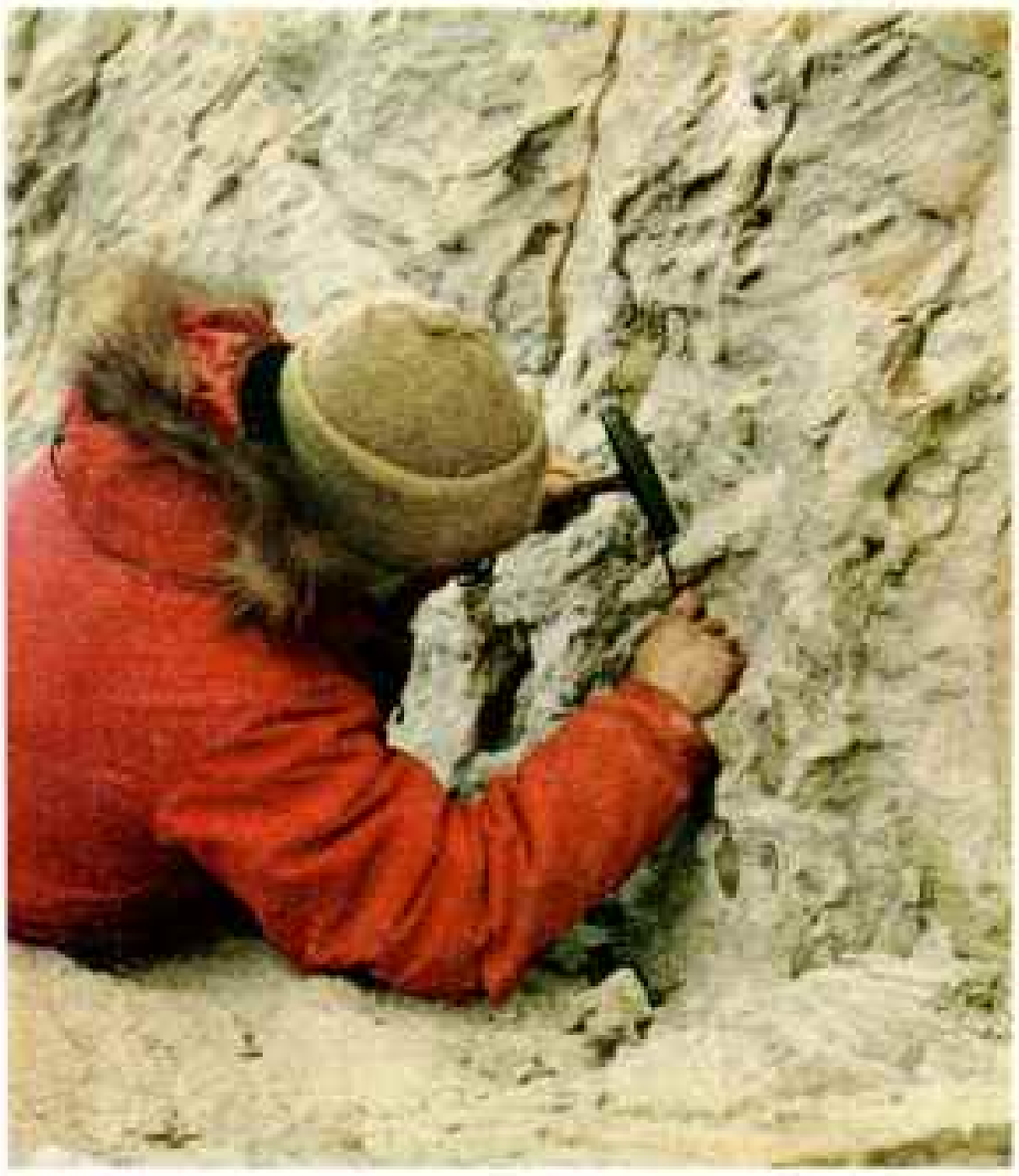
If earth's total age, now estimated by geophysicists at about 4½ billion years, is taken as a single 24-hour day, today's ocean basins are thus scarcely an hour old. By the same measure, our cave-dwelling ancestors were hunting their prey less than a second ago; the past 500 years is but a hundredth of a second, and a 50-year working life is only one-thousandth of a second.

EARTH'S PAST AS ONE DAY

24 hours = 4½ billion years
1 hour = 180 million years
1 minute = 3 million years
1 second = 50,000 years

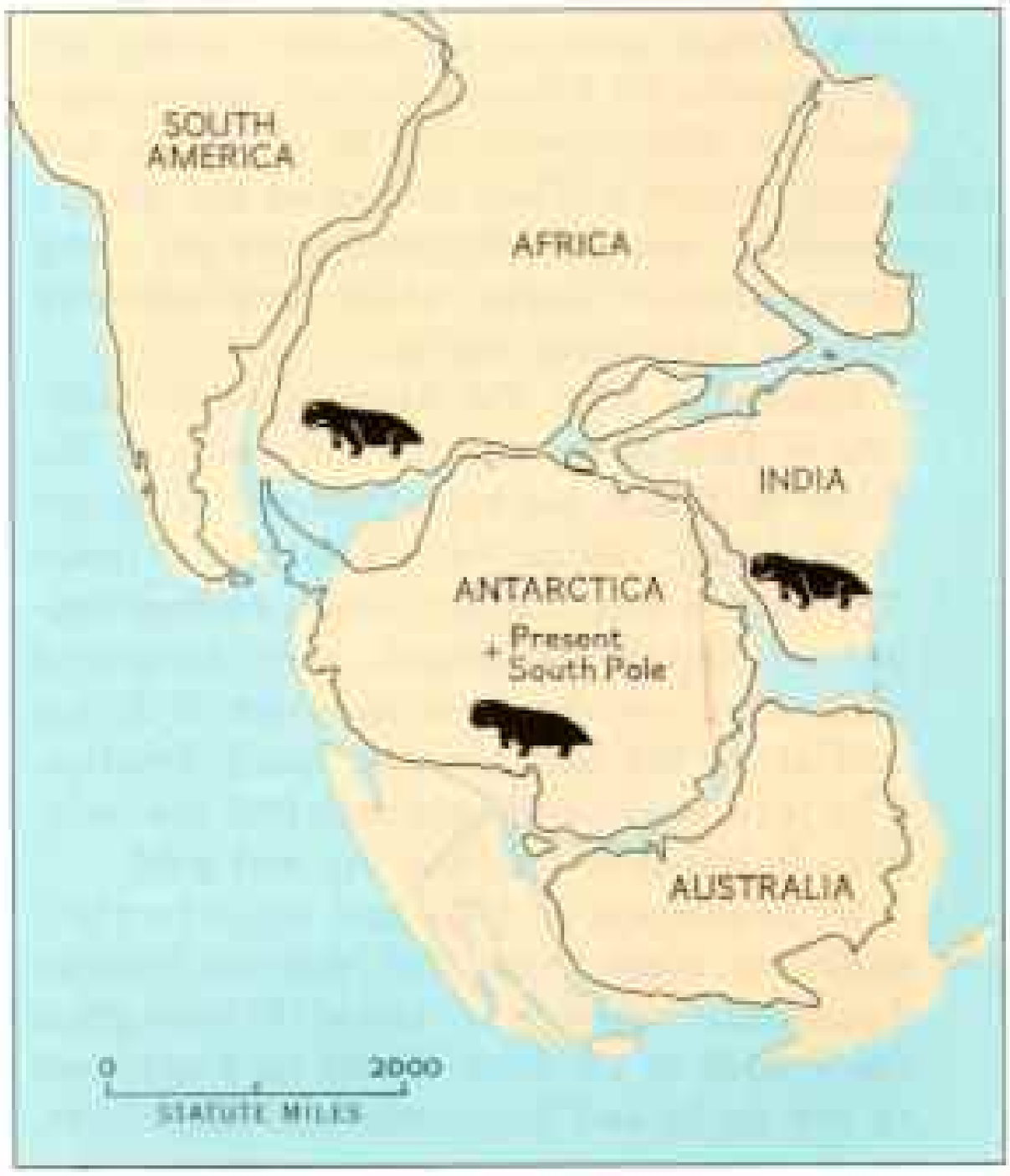
Glomar Challenger in 1970 proved that Africa, slowly but inexorably moving northward, is closing the Mediterranean Sea. Volcanic eruptions, such as Mount Etna's in 1971 (pages 18-19), as well as the violent earthquakes that shake Greece and Turkey, are but incidental shivers in this collision of plates. The gradual compression folds and displaces the Mediterranean's floor and lifts the Alps ever higher.

Six million years ago—two minutes in our one-day time scale—the Mediterranean was a two-mile-deep dry valley floored with salt, the drill ship discovered. Walled off from



U. S. NAVY

Key pieces of a geological puzzle came from Antarctica's Coalsack Bluff (**above**), only 400 miles from the South Pole. Here a team of United States paleontologists discovered fossils of the extinct reptile *Lystrosaurus* in 1969. Its remains also occur in Africa and India, which together with Antarctica, South America, and Australia made up ancient Gondwanaland (**below**).



Onetime resident of Gondwanaland, sheep-size *Lystrosaurus* proves that Antarctica once was part of a much larger southern landmass. Remains of the reptile, which flourished 200 million years ago, abound in South Africa and India. Not until the discovery at Coalsack Bluff did paleontologists know it also inhabited Antarctica. Because the creature could not have crossed a wide span of salt water to reach Antarctica, that continent, with Africa and India, must have been part of Gondwanaland, which later split and dispersed.

W. J. BREED AND E. H. COLBERT; WOOD BY MARGARET M. COLBERT

the Atlantic by a mountain range across the Strait of Gibraltar, fed only by a few rivers, the sea had evaporated completely.

"As climate changed," Dr. William B. F. Ryan of Lamont-Doherty said after drilling the Mediterranean's floor in many places, "brine pools and lakes at the low points filled and dried up many times." The process formed salt beds thousands of feet thick, salt typical of evaporation in desert heat.

Then the dam broke, perhaps in an earthquake. The Atlantic poured back in a cascading waterfall the like of which the world has not seen since (painting, pages 20-21). Seawater flooded 750 miles up the Nile Valley.

Russian engineers drilling beneath today's Aswân High Dam found successive layers of fresh- and saltwater sediments in a deep gorge cut into Nubian granite by the river as it flowed to a sea far lower than today's. Their discovery supports Dr. Ryan's view that the mountain dam across Gibraltar may have formed and broken a number of times.

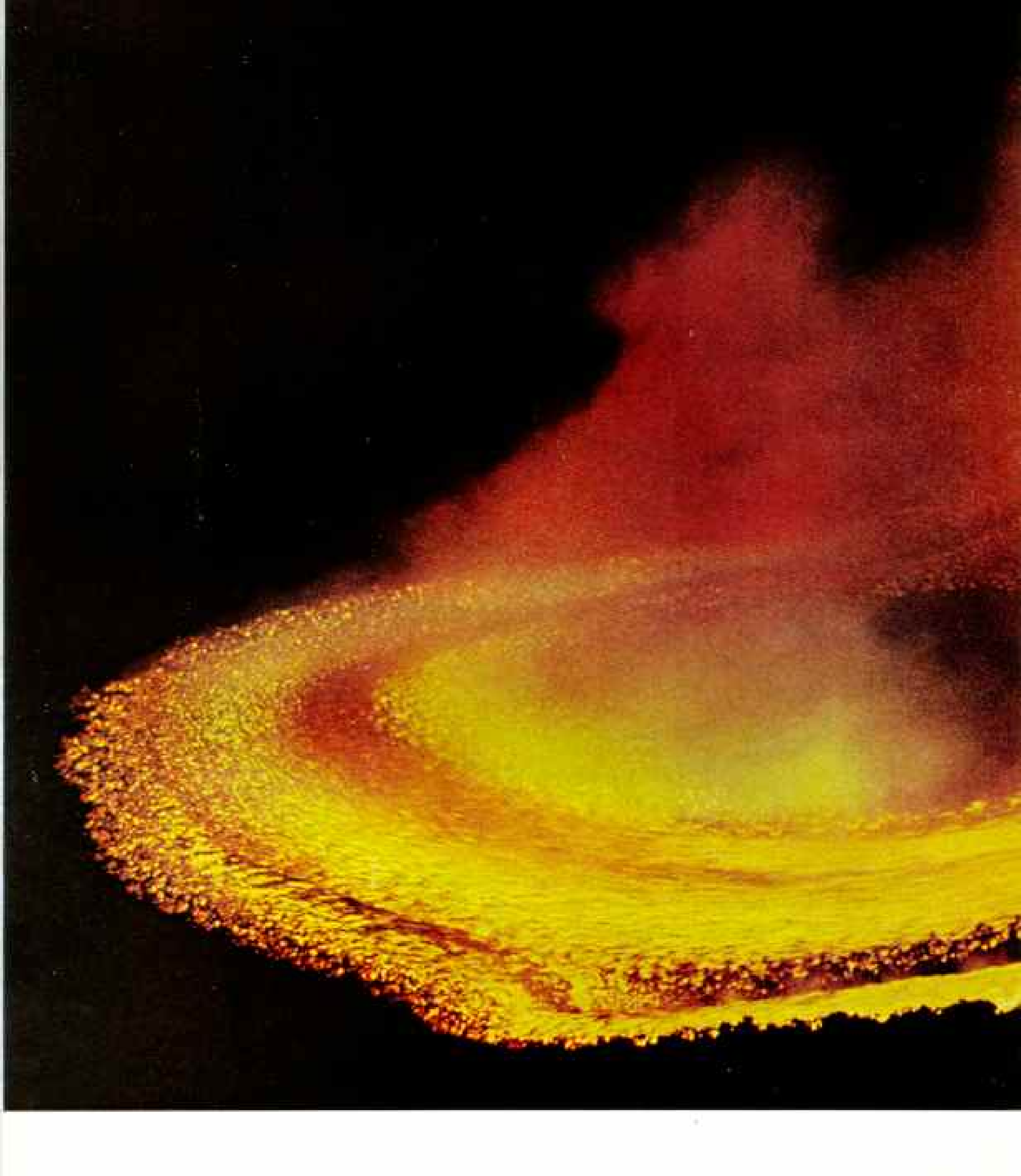
Long before this—450 million years ago, or a tenth of our earth-age day—a polar ice dome lay over what is now the Sahara. It left ice-carved grooves still clearly visible in the bedrock of the Algerian desert.

"Paleomagnetism shows that this region must have been at the South Pole, even though it's now 30° *north* of the Equator," says Dr. Rhodes W. Fairbridge of Columbia University. "Algeria, in fact, has drifted some 8,000 miles north around the curve of earth."

When today's Sahara lay at the South Pole, however, the Equator (as indicated by fossils) ran diagonally across North America. The two land blocks that are now Africa and North America must thus have been 6,000 miles apart, a quarter of earth's circumference. Yet they lay tight together 250 million years later, as part of Pangaea, before today's Atlantic began to open.

The conclusion is clear: There was at least one earlier Atlantic, and perhaps more. This

(Continued on page 24)



Hot blood of the living earth loops down Sicily's Mount Etna during a 1971 eruption. Flocking to the display, spectators watch as a tide of lava threatens the village of Fornazzo (**right**); some even darted forward to take scorching souvenirs from the edge of the relentless flow.

The ancient Greeks revered Europe's tallest volcano as the workshop of the gods. Towering two miles high, Etna has erupted countless times over the ages, with violent activity often lasting for years. Geologists now know that Sicily and the entire Mediterranean lie along the boundary of the colliding African and Eurasian plates. Crust of the African plate, diving under the Eurasian, melts in the hot mantle and then squirts back to the surface, erupting through vents such as Etna, Vesuvius, and Stromboli.

BOTH BY GIANNI CORTIGLI.

Gibraltar's gigantic cascade

A SALT WATERFALL TEN MILES WIDE plunges thousands of feet down stairstepping cataracts, from the open Atlantic into the Mediterranean. Today's Rock of Gibraltar tops a jagged cliff at far right. The thundering spectacle occurred some five million years ago, according to discoveries by geophysicist William B. F. Ryan aboard *Glomar Challenger*.

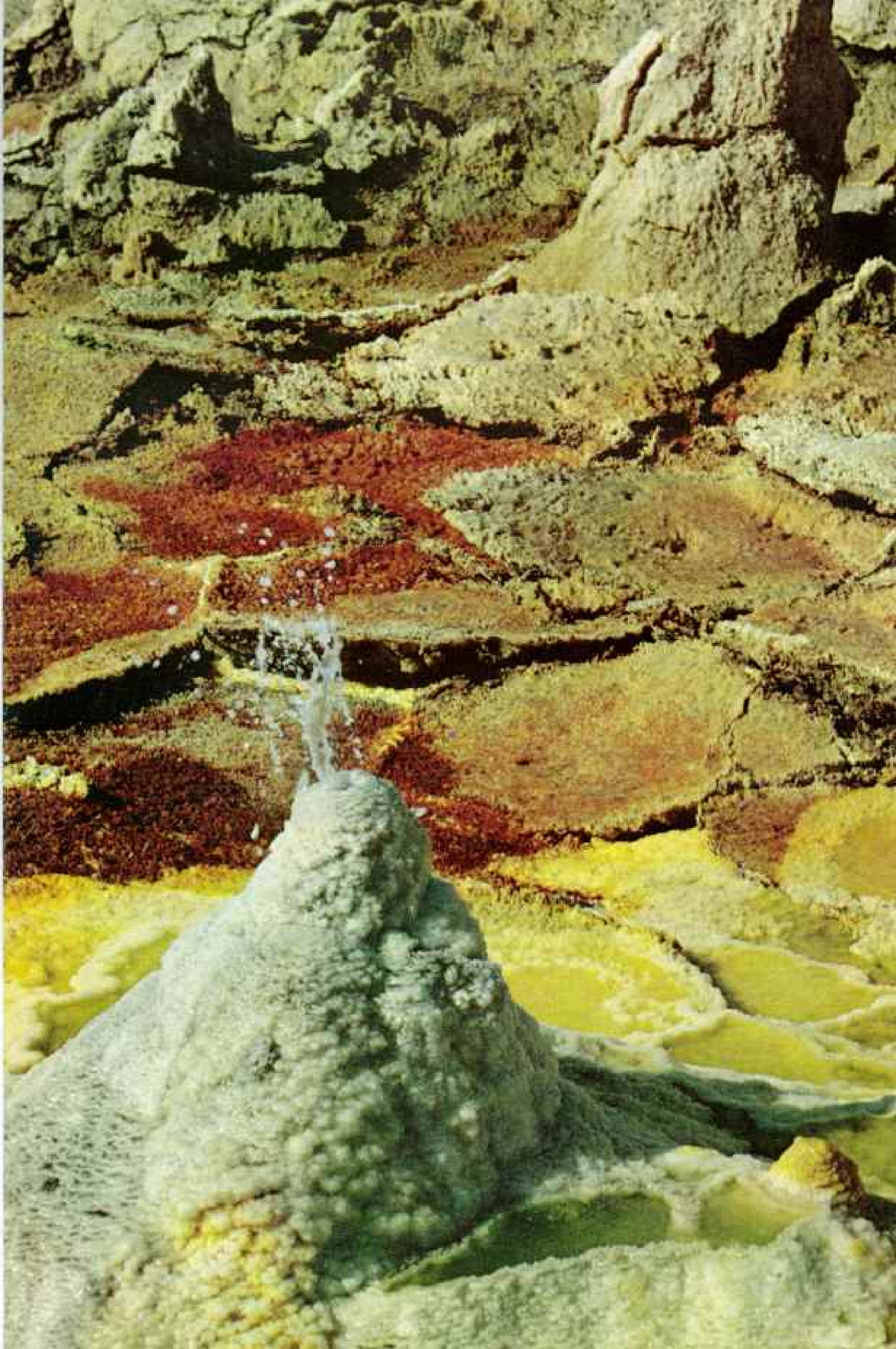
Drilling into the Mediterranean floor revealed vast salt beds as much as a mile thick, which could only have formed on hot, exposed tidal flats. These meant the Mediterranean repeatedly dried up, then filled again. Dr. Ryan concluded that the colliding African and Eurasian plates must have periodically pushed up a mountain dam across the Strait of Gibraltar. Then the sea would evaporate and become desert—until the dam yielded again (**diagrams at right**).

FIRST CRACK in a mountain wall appears 5 1/2 million years ago, as rainfall and streams gnaw a channel and admit a growing trickle from the Atlantic. Salt encrusts the dry basin's floor, and desert blights its sides. Core-sample minerals indicate temperatures may have reached a searing 160° F.

PAINTINGS BY STAFF ARTIST ROBERT C. MAGIS

SHATTERING THE BARRIER in a huge washout, the cascade sweeps away soft sedimentary mountain rock and soil. Soon the torrent will evolve into the majestic falls at top. The entire refilling may have taken only a century; it would have dropped world sea level about 40 feet.

STRAIT TODAY lies level between the Pillars of Hercules. But even now earthquakes and faulting show the African and Eurasian plates are slowly swinging together, pushing up mountains that may close the gate and cause the Mediterranean to begin drying up again.



Toiling where the Red Sea once rolled, Ethiopians pry up slabs of salt in the sweltering Danakil Depression. As recently as a few thousand years ago uplifting land walled off the Danakil from the rest of the sea; trapped waters then evaporated, leaving vast salt deposits and a lurid landscape of volcanic cones and rifted terrain.

In geology's fantasyland, a knee-high geyser cone spouts a fresh coating of brine on salts flooring the Danakil Depression. This onetime arm of the Red Sea may eventually flood again. Today it gives geologists a rare view of sea-floor spreading on land.

Dipping nearly 400 feet below sea level, the Danakil Depression lies in a wild region of active volcanoes, gaping fissures, and frequent earthquakes known as the Afar triangle. The triangle marks the convergence of three great fracture zones: the Red Sea, Africa's Great Rift Valley, and the Gulf of Aden.

Birth of an ocean shows vividly (**right**) in a Gemini 11 photograph taken from 400 miles up. Arabia, upper, has torn away from Africa, widening the Red Sea, left, and the Gulf of Aden. Ethiopia's Afar triangle lies inland at lower left.

DAVID A. ROSS, WOODS HOLE OCEANOGRAPHIC INSTITUTION

Layer cake from the deep, a sample of mud from the Red Sea floor tells of vast wealth more than a mile down. Iron tints both the blue-gray and the reddish-brown layers. Off-white band near top holds sulphides of lead, copper, zinc, gold, and silver. The richest sediments concentrate in hot brine pools that reach 140° F. Experts estimate a 30-foot-thick layer in one 50-square-mile pocket to be worth nearly 2½ billion dollars.

earlier Atlantic closed between 450 and 350 million years ago. The collision rumpled and uplifted the long parallel ridges of the Appalachians of North America.

"What we find when we unravel the rocks and sediments of the Appalachians," Dr. John Dewey of the State University of New York at Albany points out, "is a pattern that looks just like the floor of the Atlantic Ocean."

The same rocks and foldings continue in the Caledonian mountain chain that crosses Scotland and runs up the Scandinavian Peninsula. Similarly, geologists see the equally time-worn Ural Mountains as a collision front between a separate Europe and Asia when they came together to form Pangaea.

Tuzo Wilson was among the first to postulate an earlier Atlantic that closed, then reopened. In that dim before, says Wilson, Ireland and northern Scotland were part of North America, attached to Newfoundland. Part of Florida lay in Africa.

WHILE THE ATLANTIC and Indian Oceans opened, the Pacific shrank. The Americas slid west, the huge Eurasian block and Australia drifted east. The Pacific's floor, meanwhile, was being consumed in the great trenches around its rim. At the same time new sea-floor rock was welling up and solidifying along a mid-ocean rift.

Thus, though it may be the survivor of the original world ocean—Panthalassa—even the Pacific is floored with rock and sediments far younger than the continents that rim it. The oldest sediments *Glomar Challenger* found lay in the northwest Pacific—deposited scarcely 160 million years ago.

Because of the upwelling of nutrient-rich waters in the Pacific's equatorial zone, planktonic life thrives there. As the tiny creatures die, their limy skeletons rain down unceasingly, building a deep band of soft white calcium carbonate—chalk—on the sea floor.

Bruce Heezen was co-scientific leader of a drilling leg on which the *Glomar Challenger* found this "chalk line" at varying distances north of today's Equator. "The only logical conclusion was that the sea bottom had moved," he told me. "The main part of today's Pacific floor has been migrating northwestward for at least 100 million years."

Tuzo Wilson in 1963 pointed to the Hawaiian island chain as dramatic proof of this movement. He and most earth scientists now see the islands as having been built by a

stationary hot spot, or plume, of superhot high-pressure material from the earth's deep interior, breaking out periodically as the sea bottom slides over it (painting, pages 28-9).

At the southeastern end of this conveyor belt, the big island of Hawaii is still violently active. Oahu, to the northwest, appears to have been born 3½ million years ago, and to have been quiet for two million years. Midway, near the far end of the chain, was built 15 to 25 million years ago.

Beyond that, oceanographers trace a line of submerged volcanoes west and north another 2,200 miles, before the chain ends at the yawning junction of the Kuril and Aleutian Trenches. The oldest of the Emperor Seamounts, near the northern end, dates from more than 70 million years ago.

Other such chains of moving islands exist. Easter and Pitcairn lie opposite each other across the East Pacific Rise. Strung out to the west are the Tuamotus and Society Islands, among them jagged Tahiti and Bora Bora.

Both east and west of fiery Tristan da Cunha in the South Atlantic, in a shallow V, progressively older submerged volcanoes extend toward Africa and South America. They form two lines of mileposts marking the movement of the Atlantic floor over the past 110 million years (paintings, page 14).

Very hot regions on the sea floor occur all along the oceanic rift valleys. In the bottom of the Red Sea, for example, lie pools of supersalty water that are as hot as 140° Fahrenheit. Normally such hot water would rise. Here it is held down by the density of its load of mineral salts, thought to be bubbling from vents in the sea floor.

Brilliantly colored layers of ooze in these hot holes, plumbed by scientists from Woods Hole Oceanographic Institution, were found to be incredibly rich in copper, zinc, iron, gold, and silver (opposite). Other such mineral-rich sediment layers have been discovered by the *Glomar Challenger* just above basement rock near other ocean rifts.

The Red Sea, its floor split by an active rift, is considered by most geologists today to be an ocean just beginning to open.

Near the southern end of the Red Sea, where another rift through the Gulf of Aden also strikes into the African Continent, lies a wild and forbidding region known as the Afar triangle (page 23). Ethiopia's Danakil Depression and the French Territory of the Afars and the Issas fall within it. Teams of geologists led by renowned volcanologist Haroun Tazieff have used helicopters to penetrate this region.

The Afar triangle, Tazieff says, was "as recently as some tens of thousands of years ago covered with seawater. . . ." Oyster beds dated by carbon 14 as some 6,000 years old are now 260 feet above sea level. A stone ax 200,000 years old was found encrusted with seashells in this blazing desert trough.

"The topography," concludes Tazieff, "has been created by violent events that have occurred in very recent times . . . and are still in progress. . . . The triangle seems to be a focal point for new oceans in the making. What is more . . . we can see it taking place."

The geologists found volcanic cones of shattered glass, material which must have been spewed and violently cooled underwater. They mapped wide-open fissures and fresh faults, explosion craters and boiling springs. They actually saw an earthquake shift the crust along a fault line.

ANOTHER OCEAN just being born is the Gulf of California, the long, narrow tongue of the Pacific that separates Baja California from the rest of Mexico. Hot spots and earthquakes occur along its bottom, and fresh volcanic cones rise near its head.

The landward extension of this sea-floor spreading rift is the San Andreas Fault system of California. West of the gulf and the San Andreas, the great plate that carries the Pacific is sliding inexorably northwestward in relation to North America.

North America itself is also moving west, but not as fast, carried like a great block away from the Mid-Atlantic Ridge. It has almost completely overridden and destroyed the eastern limb of the original Pacific floor. Thus some scientists, like Tuzo Wilson, say that the Sierra and Coast Ranges of the far-western seaboard are crumplings of the continental front where it met and overwhelmed the old Pacific floor. Volcanoes such as Shasta, Lassen, Hood, and Rainier and the caldera of Crater Lake were violent blowouts caused by the friction of this meeting.

The same overriding process uplifted the Colorado Plateau, which Wilson and others believe may lie atop an upwelling plume. The hot spot could account for the earthquakes and thermal activity in the region of Yellowstone National Park on the Continental Divide.

Other scientists dispute this grand notion.

(Continued on page 31)

Fire defies water in an extraordinary view of lava 40 feet undersea (**right**), flowing down from Hawaii's Kilauea Volcano. Photographed from only three feet away, the molten rock hisses and sizzles as it pushes into the sea. Solidifying in seconds, it forms a "pillow" of lava. The process repeats and the tongue grows, adding to Hawaii's landmass.

HOWARD SOCHUREK (ABOVE), VICTOR ENGELBERT (BELOW), AND RICHARD GRIEM (OPPOSITE)

Steaming hulk of hot lava rises 240 feet above a lake cupped in the crater of Mount Soufrière, on the West Indian island of St. Vincent. Until late October 1971, fish flourished in the crystalline lake. A few weeks later its 178° F. temperature could have parboiled the two scientists approaching the lava islet in the tiny white boat at right center. In 1902-3 a Soufrière eruption killed nearly 1,600 islanders.

Puddle of pillow lava hundreds of feet wide lies in Ethiopia's Danakil Depression. The lava's lobed contours tell that it erupted underwater, when the area lay in the Red Sea.

Assembly-line volcanoes

WITH THE PACIFIC FLOOR as a conveyor belt, a mid-ocean blast furnace has been turning out volcanoes for at least 70 million years. Thus sea-floor drift explains the remarkable chain of the Hawaiian archipelago and the Emperor Seamounts in their 3,700-mile march to the Aleutian Trench.

Geologists believe that a huge column of upwelling lava, known as a "plume," lies at a fixed position under the Pacific. As the ocean floor moves over the hot spot at about five inches a year, the upwelling creates a steady succession of new volcanoes that in turn migrate with the plate. Supporting this theory, the northwesternmost seamounts, farthest from the hot spot, show the greatest age; they probably once stood above water. Correspondingly, the big island of Hawaii must someday drift on, and a new volcano will grow at the hot spot.

PAINTINGS BY STAFF ARTIST ROBERT C. MAGIS

Aleutian Trench

Position of oldest volcano after 70-million-year drift

Midway Islands

70 MILLION
YEARS AGO

30 MILLION
YEARS AGO

TODAY

THE CHAIN now stretches the 1,500-mile length of the Hawaiian archipelago and along another 1,200 miles of submerged volcanoes. A kink in the line indicates that the Pacific plate abruptly changed course. Just when this occurred is still being debated; estimates range from 25 to 45 million years ago. Some islands advance side by side, evidence that the hot spot at times sends up paired lava outflows, creating a double chain.

Oahu

Hawaii

NATHAN BENN (ABOVE AND BELOW)

The world their laboratory, these scientists stir the revolution that sweeps geology today.

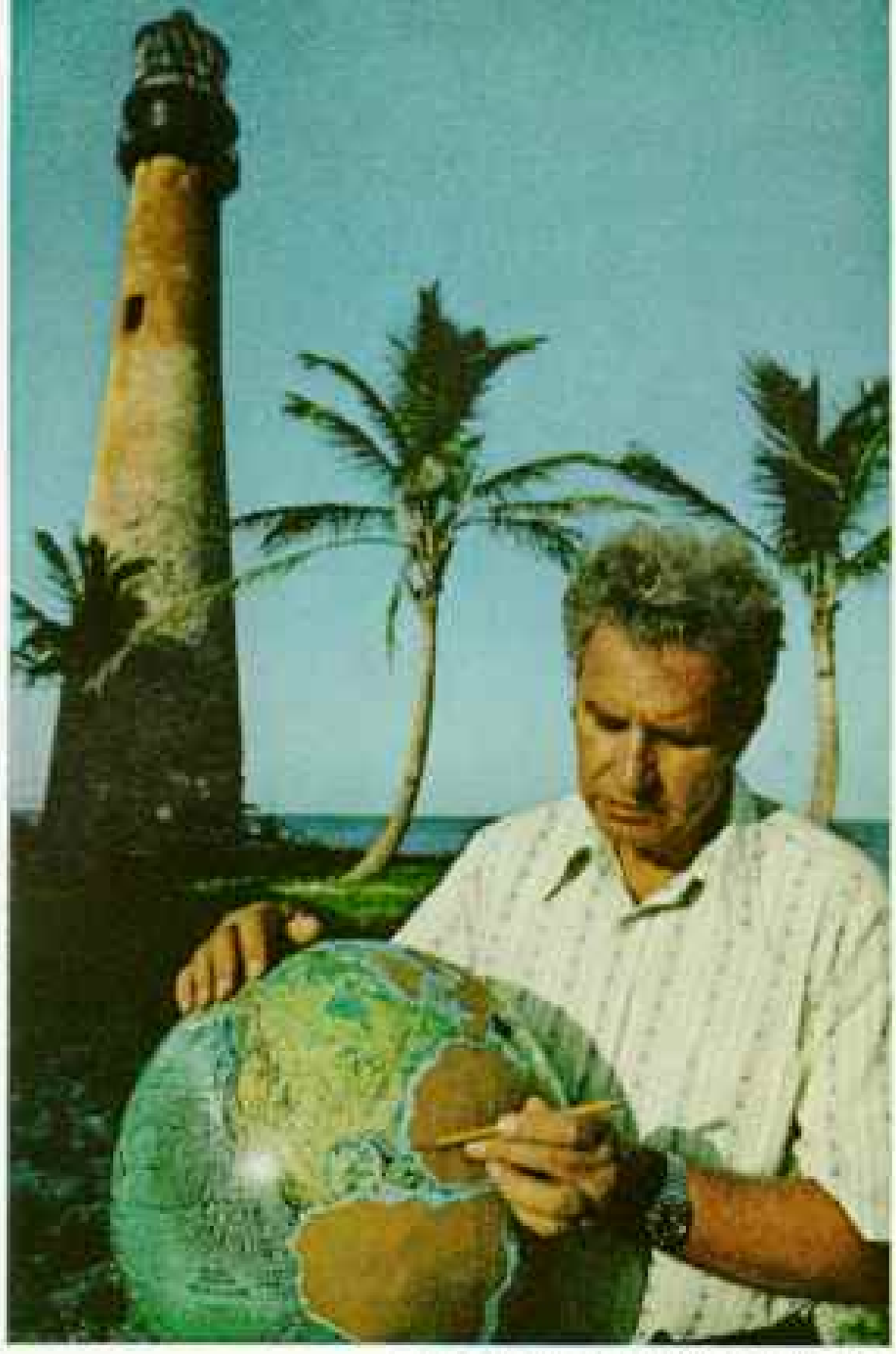
Geophysicist Bruce C. Heezen (**far left**) led the detailed mapping of the ocean floors. Here he works with Marie Tharp, who first saw that a narrow rift valley cleaves the great Mid-Oceanic Ridge.

Once a skeptic of continental drift, geologist Patrick M. Hurley (**lower left**) dated rocks on each side of the South Atlantic by use of radioisotopes. His studies confirmed that Africa was once attached to South America—and converted him to drift.

Aware that earth's magnetic field has frequently reversed direction, British geophysicist Frederick J. Vine (**below**) correctly deduced that magnetic patterns on ocean beds would substantiate the phenomenon of sea-floor spreading.

Canadian geologist J. Tuzo Wilson (**right lower**) first saw the Hawaiian Islands as proof of drift (**preceding pages**). He tries today to trace the earliest movements of continental blocks.

Earth scientist Robert S. Dietz (**right**) shows how southern Florida, where he stands, once formed part of Africa. He coined the phrase "sea-floor spreading."



GARY HEIMBERGER (ABOVE) AND ROBERT W. MADDEN

But no one denies that the San Andreas is a classic example of two great slabs of earth's crust rubbing and grinding together as they shift position (see article that follows).

Geophysicists estimate that Los Angeles, on the west side of the break, is moving toward San Francisco, on the east side, at two to three inches a year. At that rate the two cities, now 350 miles apart, will meet some ten million years from now.

PRESSURES AND FORCES along the fault, particularly where it "locks" temporarily, are beyond imagination. When the rock layers, warped and stressed past endurance, finally snap and shift, an earthquake sends out shock waves. It happens hundreds of times a day in minor tremors.

A massive jump of 15 to 20 feet destroyed San Francisco once in this century, in 1906. The odds say that such a sudden movement will happen again, somewhere along the San Andreas, before the year 2001.

Scientists in many parts of the world are intensively studying what happens when rock breaks and moves in this way. In Japan, in the U.S.S.R., in China (where an earthquake in 1556 killed 820,000 people), as well as in this country, men work with supersensitive recorders to find ways to predict quakes far enough ahead to save lives.

One way to forewarn of a quake hours, days, even weeks ahead may be to count microquakes and record their buildup—or sudden disappearance. Another may be to sense a tilt of the earth's surface, or to record rock strain with beams of light (page 40).

An instrument operating in an abandoned gold mine near Boulder, Colorado, fires a laser beam of infrared light through a vacuum tube 100 feet long and bounces it from a mirror mounted on solid rock. Patterns set up by overlapping light waves can detect vibrations or movement in the earth's crust of only 20 trillionths of an inch—the same as measuring a change of a hundredth of an inch in the distance to the sun.

"Ten years ago," MIT seismologist Frank Press said at a symposium of the National Academy of Sciences in 1972, "earthquake prediction was the province of religious zealots and outright frauds. Today it is a respectable, exciting field of research. . . .

"If earthquake prediction seems daring," Frank Press went on, "earthquake *control*

(Continued on page 36)

Rending solid lava, a fissure cleaves southern Iceland. The rift is one of many slashing a zone where the American and Eurasian plates separate along the Mid-Atlantic Ridge—like the Afar region a rare example of sea-floor spreading on dry land. Widening at nearly an inch a year, Iceland is one of the most volcanically active islands in the world. Hekla, its greatest volcano, erupted most recently in 1970.

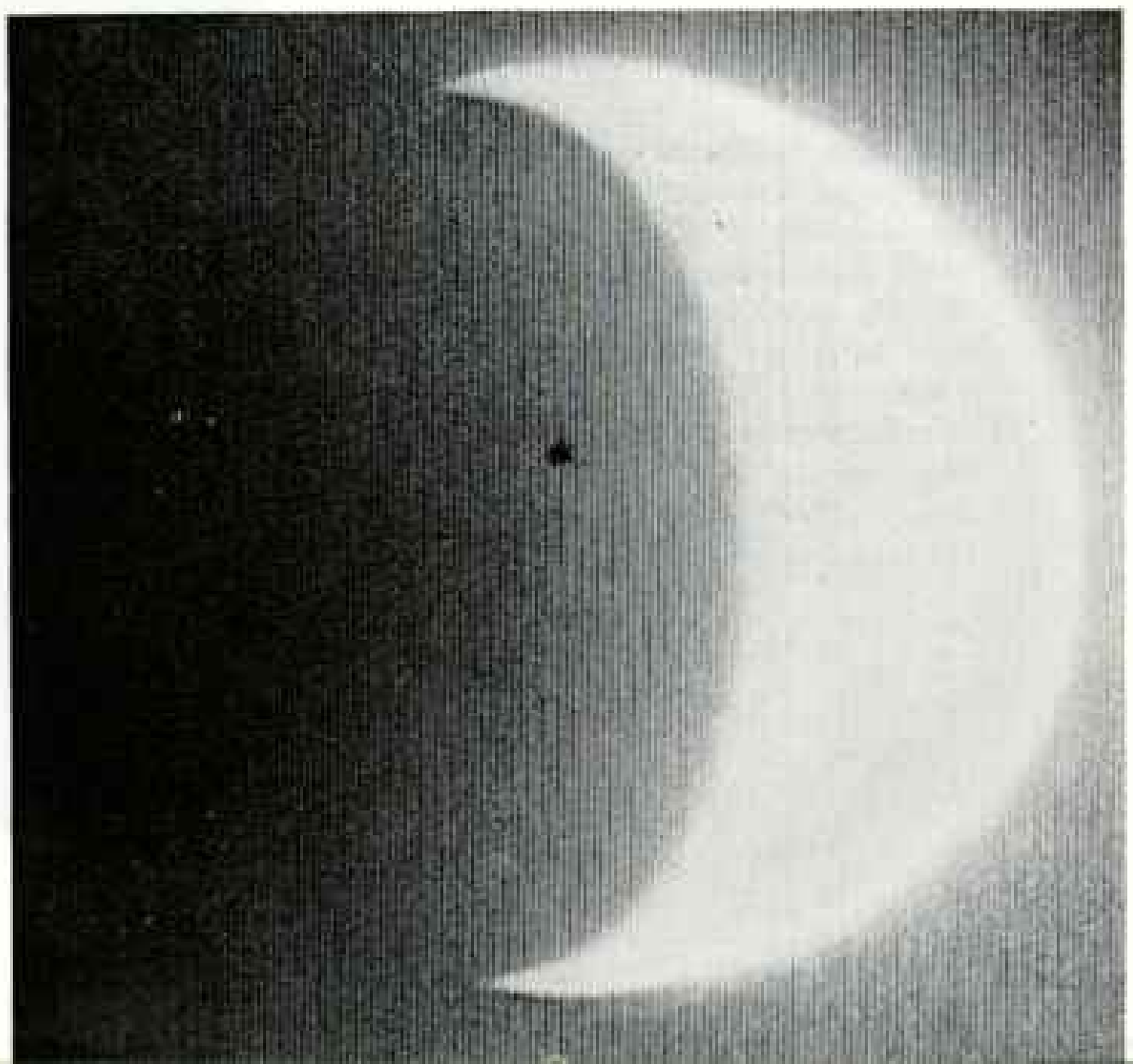
As new surface is created along ocean ridges, other areas must make room by subducting or folding. A rugged peak in the Swiss Alps (**right**), Wildhauser-Schafberg, exhibits folding caused by the collision of the African and Eurasian plates.

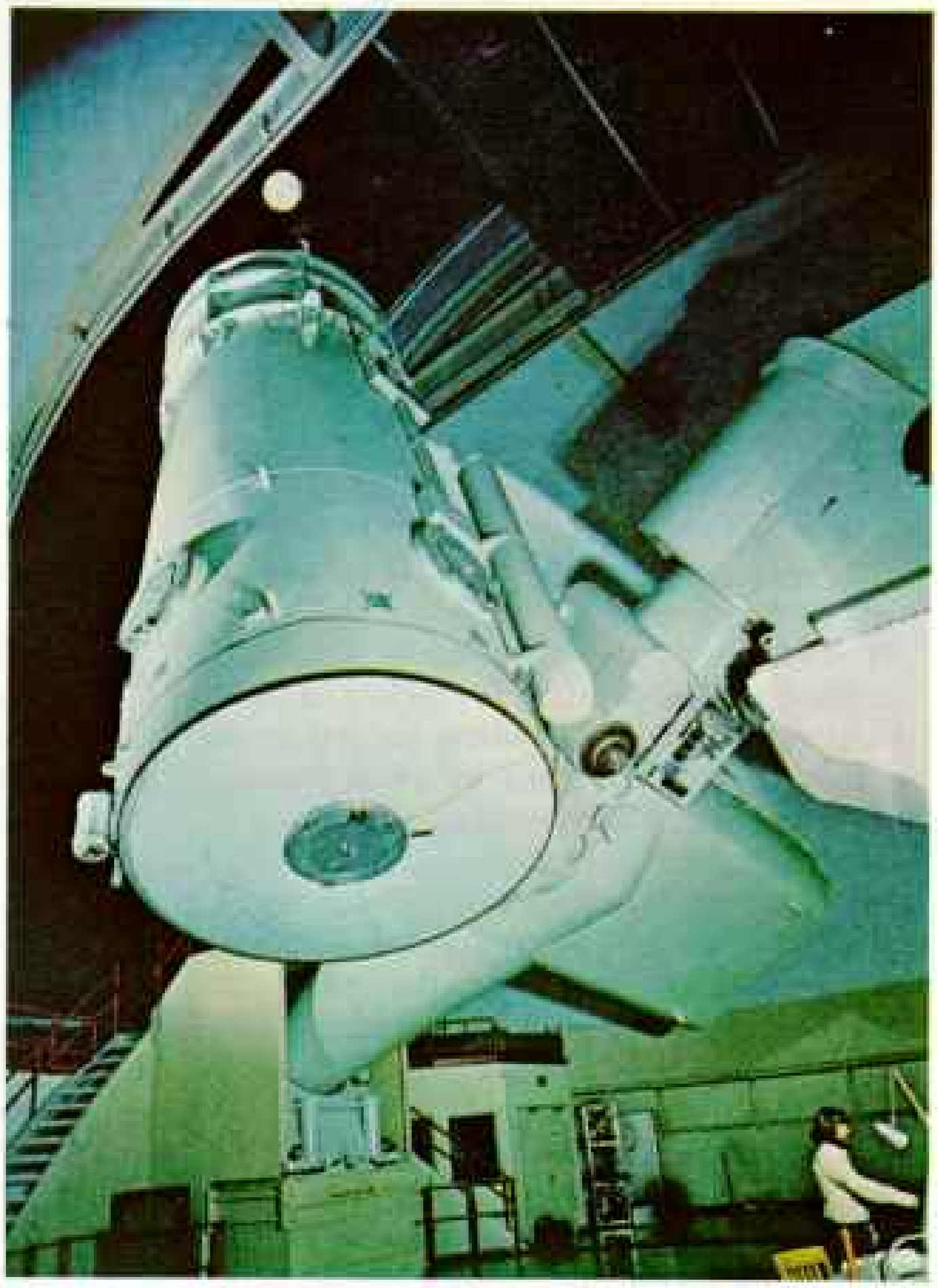
ANTHONY BOUCHER (ABOVE AND RIGHT) AND JAMES P. BLAIR (LEFT)

Rift that builds a nation: Fractures and massive subsidence trace the rift of the Mid-Atlantic Ridge across Iceland's bleak countryside (**right**). Its spreading steadily adds to the nation's size. Scientists such as Iceland's Dr. Sigurdur Thorarinsson believe that as recently as 15 million years ago Iceland rose Surtsey-like from the sea. Violent eruptions and steady upwelling of magma have built the island of today.

Yardstick of the Space Age, laser beams reflected from the moon help measure the speed and direction of earth's moving continents. By timing the light's travel time, physicists fix their exact position on earth, and thus can measure amounts of drift.

When Surveyor 7, an unmanned lunar explorer, landed on the moon in 1968, scientists on earth aimed two laser beams at it. The robot's TV eye, scanning earth's disk half lighted by the sun (**right**), picked up the lasers as faint pinpricks deep in the dark area at left. One beam shines from an observatory in Arizona, the other from California.

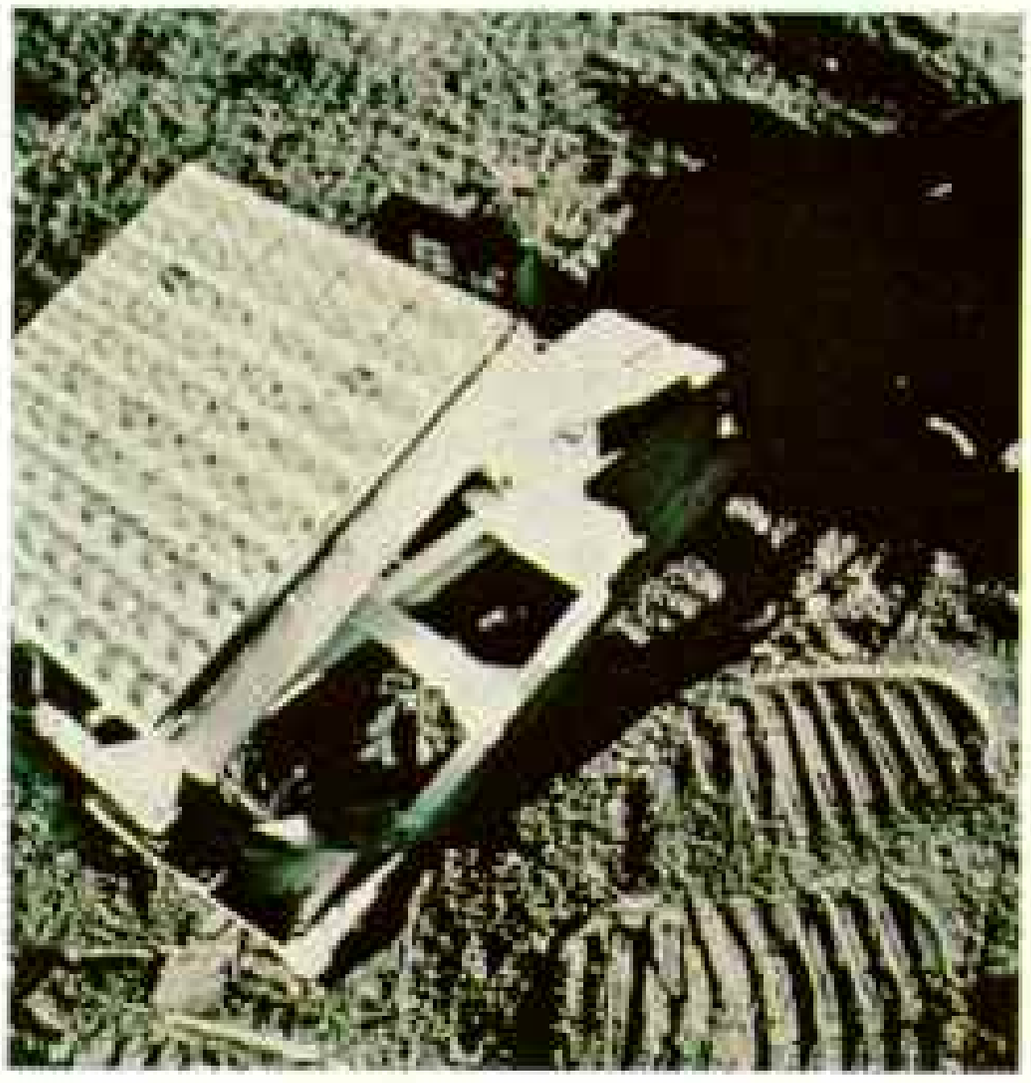




A. R. FIEBIGER (BOTH IMAGES) AND NASA

Fired point-blank, a laser beam bounces from a "corner reflector" (**above**) at McDonald Observatory in Texas. Arrays of such reflectors, designed to return light precisely to its source, traveled to the moon with the Apollo missions. Apollo 14 astronauts placed the one at right, leaving footprints in the lunar dust.

Aiming a laser whose pulse time is three billionths of a second, a McDonald telescope (**above right**) fires at an array on the moon. The rebound arrives 2½ seconds later. A computer times the interval to within a fraction of a billionth of a second to determine the observatory's precise position.



boggles the imagination. And, yet, man has initiated earthquakes. He may even have stopped an earthquake sequence."

He may indeed. A few years ago, seismic recorders began picking up numerous tremors near Denver, Colorado. The sudden activity centered on the U.S. Rocky Mountain Arsenal, where dangerous waste fluids were being disposed of by pumping them down a deep well into the earth.

Suspecting cause and effect, officials stopped the pumps. The tremors died away.

Geologists since then have gone much further in an experiment near Rangely, Colorado. Here water is injected through wells around an old oil field to force more oil out of deep rock layers. By varying the pressure, U.S. Geological Survey experts have shown that they can turn minor earthquakes on and off as if by a faucet.

Basically, unstable rock layers are being "greased." Water pressure in cracks and pores is built up to the point where natural stress in the rock releases itself by small shifts—man-made minor earthquakes.

The significance is apparent: By drilling wells into locked sections of massive faults, such as the San Andreas, it may be possible to reduce the likelihood of a catastrophic quake by deliberately setting off many smaller ones.

Dr. John H. Healy of the National Center for Earthquake Research in Menlo Park, California, admitted in Moscow that scientists and the public alike "wouldn't want us to drill a hole and begin pumping water . . . without very careful thought. But if we can demonstrate that we understand the fault system well enough to avoid triggering a dangerous earthquake, I think there is a possibility of earthquake control."

The shudders of the restless earth may thus someday be rendered harmless. They may be released in small jerks or as a steady creep, rather than in big destructive jumps. All that may be needed, in the end, is the courage to push the button to start the pumps.

By such ingenuity men may start or stop local movements of the great plates that encrust earth. And equally ingenious scientists are already trying to measure directly how much movement is taking place. To do it, they have sent mirrors to the moon.

In 1969 Neil Armstrong and Edwin (Buzz) Aldrin of Apollo 11 left behind on the Sea of Tranquillity an array of "corner reflectors" designed to fire back to its origin any light striking them (preceding pages). Similar mirrors were taken to the moon by Apollos 14 and 15 and by the Soviet Union's Lunakhod unmanned crawler, which landed on the Sea of Rains in 1970.

Since then astrophysicists in the U.S., France, the Soviet Union, and Japan have beamed high-powered lasers—light-cannons, if you will—at the mirrors. By measuring the time it takes a pulse to return, the scientists now can measure distances to the moon mirrors to within six inches. That accuracy may soon be improved to an inch.

By repeating such measurements over years —even decades—observatories on opposite sides of an ocean may be able to detect the few inches a year by which they themselves are moving apart or coming together as the continents and ocean floors drift.

AS THE OCEAN FLOOR MOVES, its leading edges—particularly in the Pacific —bend down in the great sea trenches and are swallowed back into the earth.

Why could not man dispose of his trash and garbage in the same subduction process? Two University of Washington researchers, Robert C. Bostrom and Mehmet A. Sherif, have proposed that great cities could rid themselves of their burgeoning refuse by dumping it in the deep-sea trenches.

The waste would have to be compacted, to sink and stay put. The best places, say the scientists, would be where rivers disgorge their loads of silt off the continental edges, to bury the garbage rapidly in mud while it is carried, at inches a year, into earth's interior.

Los Angeles's garbage, for example, would have to be shipped a thousand miles south to the Middle America Trench; New York's and London's, to the Puerto Rico Trench. Costs would be formidable. But, proponents argue, mineral ores and other raw materials are shipped just as far before being processed into things that wind up as trash.

Bostrom and Sherif say, "In an age in which waste material is mass-produced, only a mass-production disposal technique can be successful."

And only facetiously do other scientists point out that refuse carried down into molten regions under sea trenches might not be "geodegradable," but would come spewing back out the mouths of volcanoes. Nicaragua's Cerro Negro spitting back old washing machines from Cucamonga!

THE SEA FLOOR SPREADS, the plates move, the earth's rigid crust is created and destroyed. What unimaginably great force drives this system? What causes the globe to shudder and shift, continents to move?

Geologists with the deepest involvement in this field are the first to admit they do not know. The motive power of the new "global tectonics" is still its greatest mystery.

Many forces have been proposed, some carefully reasoned, others outright flights of fancy. Nonscientists have blamed a giant meteorite's striking the earth for setting the continents adrift; others say that growing polar ice caps unbalance the spinning planet. Earth's axis, they warn, may (again) tip in space, or its crust as a whole slide into a new position, like the dried skin of an onion.

Alfred Wegener speculated that the broken pieces of Pangaea were being driven toward the Equator by a steady *Polflucht*, or "flight from the poles," caused by earth's spin.

Arthur Holmes, Harry Hess, and others felt there must be slow-creeping but relentless convection currents in the semiplastic mantle, the hot layer of rock beneath the crust.

Tuzo Wilson likened the process to a pot of soup boiling on a stove, with patches of froth drifting hither and yon over the surface.

Other, even stranger analogies have been suggested. The ocean ridges may be nothing but scar tissue, or welts. As mantle rock wells up and combines with water, it changes in crystalline structure and expands. This swelling could create the oceanic mountain ranges, raising one edge of each crustal plate. The plate then simply slides down the slope under the pull of gravity.

Another hypothesis is that the heavy cold leading edge of the plate, sinking into hotter, less rigid mantle material, pulls the rest of the plate behind it. Its proponents liken this process to a bath towel floating on water; as one edge becomes wet and sinks, it drags the rest of the towel sideways.

Currently causing most interest is the suggestion by W. Jason Morgan of Princeton University that the plates are being driven by deep-rooted hot spots or plumes, such as the one that has broken through repeatedly to form the Hawaiian Islands.

Whatever the forces, they are beyond man's control, and perhaps his full comprehension. They are also so slow as to be almost unfelt over any man's life-span, or even that of man on earth. Remember that on our daylong time scale, our species has existed for less than one minute.

I say almost unfelt. Great earthquakes are among the most terrible and terrifying of natural events. And even the slow creep that goes on beneath our feet does make measurable changes. The Atlantic Ocean will grow wider by about your own height in your lifetime. The Pacific will shrink by perhaps the width of your house.

In the last hour of the earth-day, India has moved nearly 5,000 miles north, the United States the same distance west.

Robert Dietz and John C. Holden have postulated and mapped what will happen in the next 17 minutes—50 million years—if present rates of drift continue (map, page 6).

"Los Angeles, far north of San Francisco by then, will nearly have reached the Aleutian Islands," they say. "Ten million years more and it will either slide into the Aleutian Trench and be destroyed, or become part of a new landmass."

Central America will be gone; Atlantic and Pacific will meet in the Caribbean Sea. East Africa will have broken from the rest of the African Continent, and the Great Rift Valley will be a long water-filled gulf. The Red Sea will have widened, the Mediterranean shrunk. Australia will have moved north beyond the latitude of Singapore, and will have overrun most of Indonesia.

Such changes are all in the ungraspable future. By studying and reconstructing just how the continents once fitted together, however, geologists have already found ore and oil deposits on one side of an ocean by knowing where they were on the other side.

Scientists continue their search for the oldest rocks of earth's crust, and for clues to what may have happened not just millions but billions of years ago. In a new six-year international effort called the Geodynamics Project, headed by U. S. earthscientist Charles L. Drake of Dartmouth College, they will study the slow drift of plates and its effects in mountain building, earthquakes, and volcanoes. They will look for the driving mechanism, the "engine" that moves entire continents and creates oceans.

The search has been called the greatest jigsaw puzzle ever put together, a new game of chess played on a spherical board. It certainly fulfills the ancient Chinese maxim, embodied in the *I Ching*, that the one constant certainty in the world is change. □

California's San Andreas Fault

By THOMAS Y. CANBY

Photographs by
JAMES P. BLAIR

BOTH NATIONAL GEOGRAPHIC STAFF

Raw wound across a tortured land, the San Andreas Fault slashes the desolate Carrizo Plain 100 miles north of Los Angeles. A ranch fence banked with blown tumbleweed borders the escarpment at right.

Slicing for 700 miles (page 42), the fault system marks the boundary of two gigantic slabs of earth's crust. The eastern plate carries most of California and the rest of North America; the western bears a sliver of coastal California and the Pacific Ocean. As the Pacific plate pushes northwest in relation to the American plate, friction binds the edges. Periodically the rock breaks along the fault and shifts, unleashing earthquakes.

Such a rupture caused the disastrous San Francisco earthquake of 1906. Many scientists predict another major quake somewhere along the fault before the end of the century.

FROM FIRST LIGHT OF DAY we have occupied our strategic hilltop, overlooking a long, shadowy crease in the land that marks the San Andreas Fault. Now we deploy around a concrete-and-bronze geodetic marker, one of many that pepper this quake-prone area south of San Francisco.

Our detachment is small—four fieldmen of the United States Geological Survey, a helicopter crew, photographer Jim Blair, and myself. Our armament is a laser gun, which we now train across the San Andreas toward a reflector ten miles away. Our mission: To measure within a hundredth of an inch the amount the markers have shifted in the past year—and thus how much the State of California is being wrenched and warped by the great fracture zone that scars most of its length and part of northern Mexico.

With a sudden flash our laser beam strikes the reflector across the fault and bounces back, giving us the distance. Later a computer will scrub out atmospheric distortions detected by instruments on the copter. Ultimately our measurements will join thousands of others made along the fault to advance a goal that both the Federal and California Governments regard as urgent: that of earthquake prediction.

In the not-so-distant future, scientists believe, the seismic forecaster will join the weatherman, able to give timely warning of danger to the one American in ten who lives in earthquake country.

A dramatic understanding of *why* California is earthquake country has emerged only in the past decade. It is based on the newly accepted theories of continental drift and sea-floor spreading described in the article preceding this one. These theories depict the San Andreas Fault as the meeting place of two of the many segments of crustal rock that form the planet's surface. Pushed or pulled by titanic forces still not clearly understood, these segments—geologists call them "plates"—slowly drift. In some regions they collide, buckle, and lift up mountains. Along the San Andreas they grind past each other, scraping edge to edge. The Pacific plate carries California's coastal edge northwest in relation to the rest of the state, which rides the American plate (map, page 42).

Some scientists say the plates grind past each other at only an inch a year; others believe they gallop along at three times that speed. At an in-between rate of two inches, Los Angeles, riding the Pacific plate, would majestically draw abreast of San Francisco in only ten million years, on its way toward oblivion in the Aleutian Trench (page 6).

If the plates would slide smoothly past each other, as indeed they seem to do along part of the fault, most Californians would happily ride along. This smooth motion is what geologists know as "creep." But stupendous pressures along most of the plate boundary create friction; the edges lock.

Wrenched askew, streams jog sharply as they cross the fault, here a muted line running horizontally across the picture. As the earth shifts during successive quakes, streams hold fast to their courses across the bleak Carrizo Plain. Much of the offset visible here, about 70 feet, probably occurred during the mighty Fort Tejon quake of 1857, when the earth ruptured for 200 miles and the west side of the fault, at top, shot 30 feet past the east.

Diagnosing strain along the fault, the U. S. Geological Survey measures bending of surface rock near Hollister. Positioning a laser (**bottom**) over a geodetic marker, the team bounces the beam off a reflector at another marker ten miles across the fault (**upper**). The beam's travel time is corrected for atmospheric distortions read by instruments on the helicopter. By recording the buildup of strain, U. S. and California agencies seek ways to forecast quakes.

Where the edges are locked but the plates inexorably advance, the boundary rock bends, or strains, until finally it can strain no more. Then it snaps along the fault and shifts violently back toward equilibrium, like a bent stick breaking. This shifting rock spawns the devastating shock waves we know as an earthquake.

"It is this shaking, not the actual surface rupture of the fault, that causes most of a quake's damage," emphasizes geophysicist Clarence R. Allen of the California Institute of Technology, a leading expert on the fault. "A major quake destroys buildings ten miles away as easily as those a hundred feet from the fault; even some structures a hundred miles distant can be flattened."

IN MILLIONS OF YEARS of butting and bruising, the plates have shattered California with hundreds of fractures. The San Andreas is by far the longest and most notorious of these, and so its name brands the entire 700-mile-long fault zone. But an earthquake's sudden terror, Californians know, can erupt from the most insignificant of faults.

Like the San Fernando Fault. Few geologists knew of its existence in the San Gabriel Mountains behind Los Angeles—until it ruptured before dawn on February 9, 1971. Thrusting parts of the mountains eight feet higher, its shock waves cudgeled the sleeping San Fernando Valley for about ten seconds.

In all, 64 persons died. Hundreds more suffered severe emotional shock, brought on by the terror of shaking in the darkness. Five overpasses fell (page 44); a thousand buildings were demolished or badly damaged, including three hospitals.

Destructive as it was, the quake mercifully struck the edge of a moderately populated area, not the heart of a city. It hit before crowds flowed onto freeways and sidewalks. A dam whose waters could have killed 80,000 sagged, but miraculously held. And the shock itself registered only 6.5 on the logarithmic Richter scale. Soberingly, the 8.3 quake that destroyed San Francisco in 1906 released 350 times as much energy.

In historic times only two other monster earthquakes have jolted California. An 1857 cataclysm, with its center near Fort Tejon 75 miles north of Los Angeles, rent the surface of the earth for 200 miles as the west side of the San Andreas Fault slammed northward as much as 30 feet. An 1872 convulsion along the Owens Valley Fault brought people into the streets from San Diego in the south to Eureka in the north.

The question becomes inevitable: Is another such big one on the way?

I pass on the words of an official of the National Oceanic and Atmospheric Administration, testifying last year before a Senate hearing on seismic safety. "In the weatherman's parlance," he asserted flatly, "the chances of a major quake along the fault in the foreseeable future are 100 percent."

When and where will it strike?

Emphasizing that his opinion or any other can be "little better than guessing," Dr. Charles F. Richter, the father of the magnitude scale and now Professor Emeritus of Seismology at Caltech, has estimated that the most likely locale is the San Andreas Fault inland of Los Angeles—a repeat of the 1857 Fort Tejon shaker.

The next most likely possibility, he thinks, is a convulsion near the northern end of the fault—a rerun of 1906. Assuming movement of 2½ inches a year, two scientists at the Lamont-Doherty Geological Observatory calculate that strain in the San Francisco region already equals that of 1906, meaning another major quake could be imminent.

Other experts differ. Some, like geophysicist Robert D. Nason of NOAA's Earthquake Mechanism Laboratory, think San Francisco has perhaps another century of grace.

But the tension is there—in the people as well as in the rock. In spring of 1969, for instance, concern was evident throughout the state. A mighty quake would soon split it wide open, so the warnings went, and the west side would slide into the sea.

Inspired by a mix of soothsayers' prophecies and a doomsday novel, the scare fed on itself and abundant media attention. A minor tremor heightened the fear. Families moved out of the state. An entrepreneur considered erecting bleachers on the fault—east-side seating only.

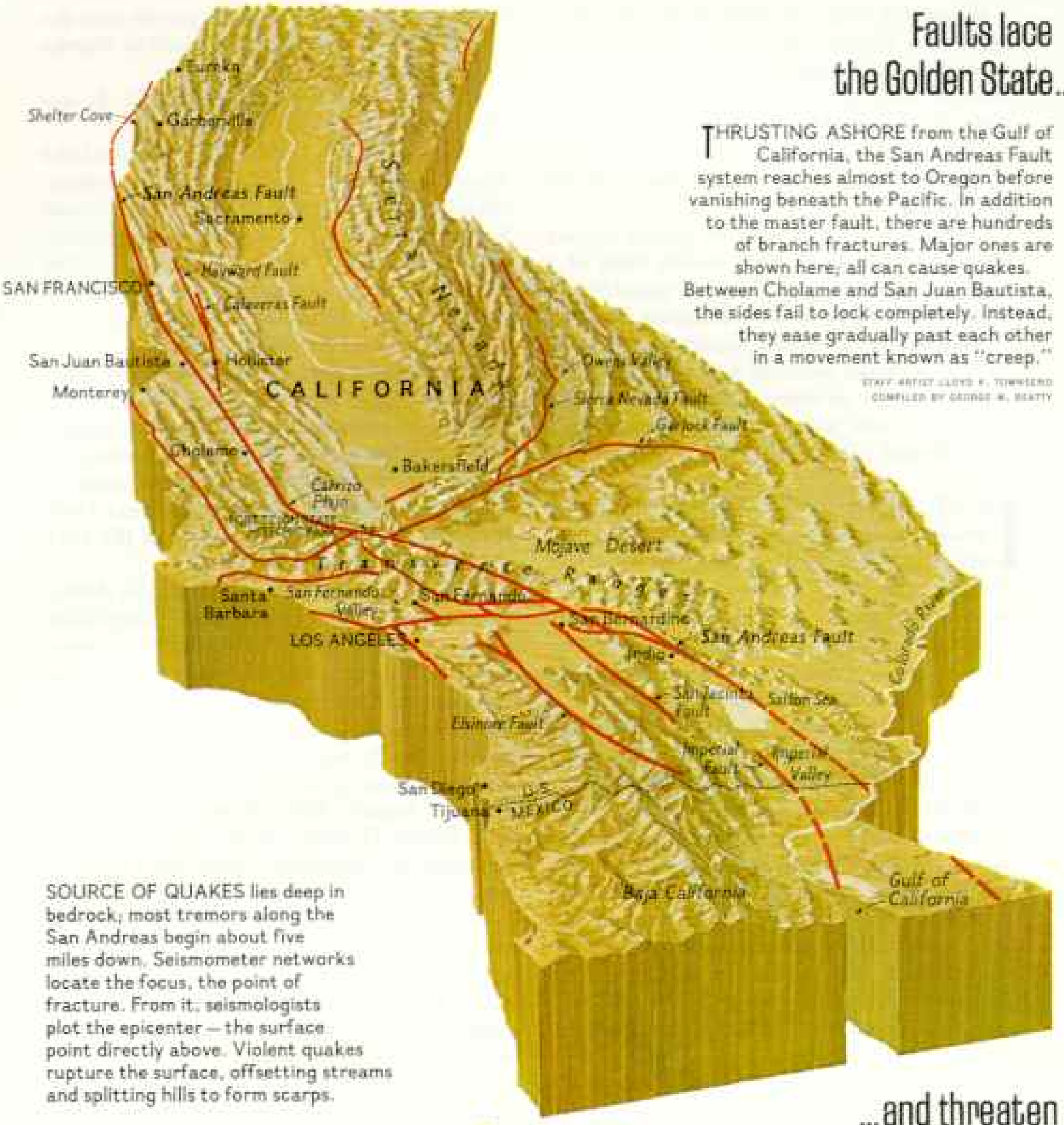
Television camera crews came from around the world; local geologists became celebrities. "I tried to point out that California *couldn't* slide into the sea," recalls NOAA's Bob Nason. "The ocean is only two miles deep, and California is at least 20 miles thick."

To no avail; April 18 was to be the day, 3:18 p.m. the time. The moment passed, California remained intact, and the trauma slid reluctantly into the sea.

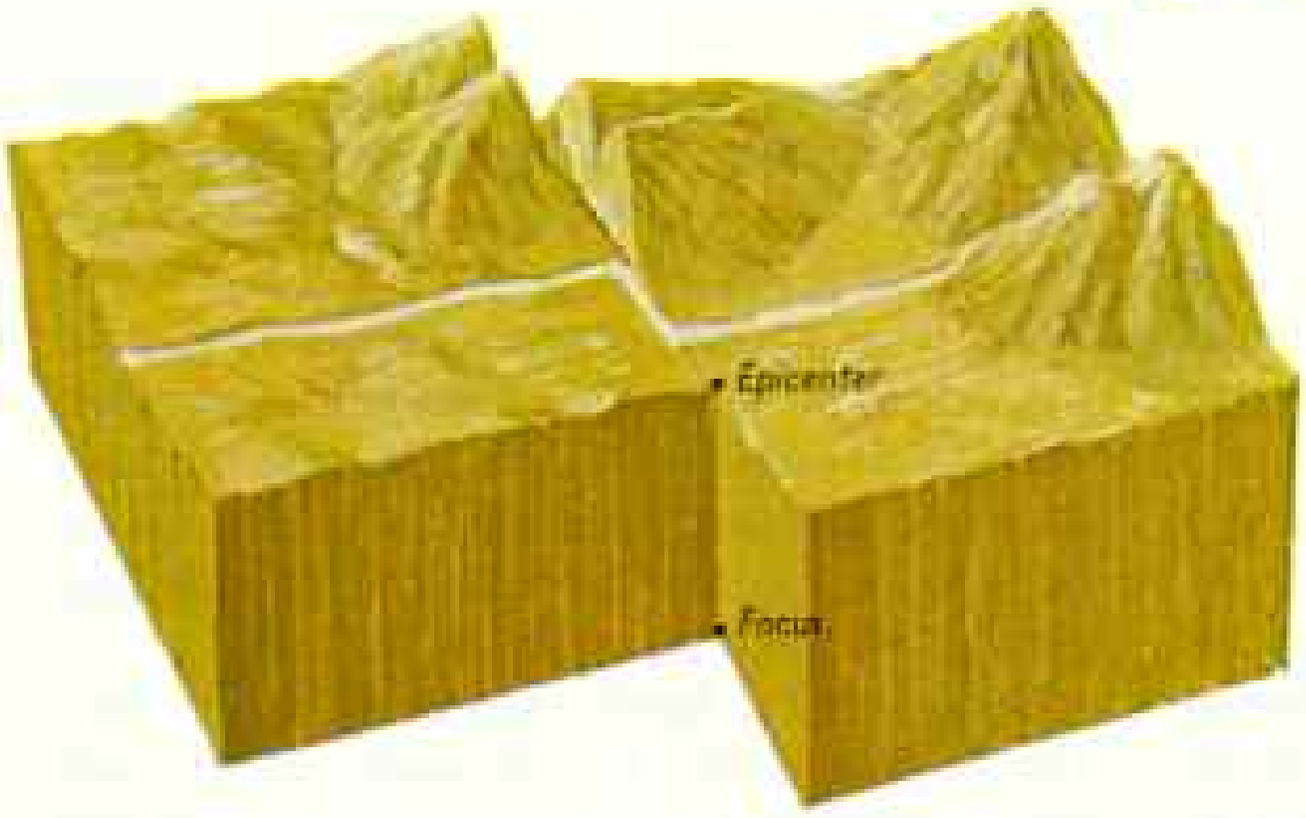
Faults lace the Golden State...

THRUSTING ASHORE from the Gulf of California, the San Andreas Fault system reaches almost to Oregon before vanishing beneath the Pacific. In addition to the master fault, there are hundreds of branch fractures. Major ones are shown here; all can cause quakes. Between Cholame and San Juan Bautista, the sides fail to lock completely. Instead, they ease gradually past each other in a movement known as "creep."

STAFF ARTIST LLOYD K. TOWNSEND
COMPILED BY GEORGE W. BEATTY



SOURCE OF QUAKES lies deep in bedrock; most tremors along the San Andreas begin about five miles down. Seismometer networks locate the focus, the point of fracture. From it, seismologists plot the epicenter — the surface point directly above. Violent quakes rupture the surface, offsetting streams and splitting hills to form scarps.



...and threaten San Francisco

Three major faults slice the San Francisco Bay region, home of 4,700,000 Californians. The San Andreas shifted 20 feet in 1906. Both the Hayward and Calaveras Faults undergo creep, possibly relieving crustal stresses. The map opposite follows a new detailed study spearheaded by the Geological Survey.

Bedrock areas best withstand shaking.

Unconsolidated soils show fair stability.

Mud and fill areas amplify shaking and in places flow like liquid when vibrated.

Unstable bedrock could produce earth slides.

Novato
HAMILTON AIR FORCE BASE
San Pablo Bay
MARE ISLAND NAVAL SHIPYARD
Vallejo
GREEN VALLEY FAULT
Grizzly Bay
SAN ANDREAS FAULT
San Anselmo
San Rafael
Stinson Beach
Mill Valley
RICHMOND-SAN RAFAEL BRIDGE
Richmond
Tiburon
Sausalito
Angel Island
San Pablo Reservoir
Briones Reservoir
Suisun Bay
Pacific Ocean
GOLDEN GATE BRIDGE
San Francisco Bay
Berkeley
UNIVERSITY OF CALIFORNIA
Pleasant Hill
BAY TUBE
SAN FRANCISCO
SAN FRANCISCO-OAKLAND BAY BRIDGE
Oakland
HAYWARD FAULT
Daly City
Alameda
METROPOLITAN OAKLAND INTERNATIONAL AIRPORT
Danville
South San Francisco
San Leandro
Pacifica
San Francisco Bay
SAN FRANCISCO INTERNATIONAL AIRPORT
San Andreas Lake
San Lorenzo
Montara
Burlingame
Hayward
San Mateo
SAN MATEO BRIDGE
CALAVERAS FAULT
Lower Crystal Springs Reservoir
Half Moon Bay
Upper Crystal Springs Reservoir
Belmont
San Carlos
Union City
PLEASANTON FAULT
SAN ANDREAS FAULT
Redwood City
Menlo Park
Newark
Fremont
Palo Alto
STANFORD UNIVERSITY
STANFORD LINEAR ACCELERATOR
San Gregorio
Portola Valley
CALAVERAS FAULT
SAN GREGORIO FAULT
Los Altos
Mountain View
Milpitas
Sunnyvale
Santa Clara
San Jose
N
STATUTE MILES
Arrows show relative motion along faults.
Dashed red lines trace faults underwater and where presumed or suspected.

TO TAKE THE MEASURE of the San Andreas system, Jim Blair and I flew it in hops, skips, and jumps from its origins in sweltering Mexican sands to its northernmost springboard into the Pacific, only a hundred miles south of Oregon. As it unfolded, we were astounded, almost shocked, by the vividness and violence of its mark upon the land.

Circling the head of the Gulf of California with Caltech seismologist Thomas C. Hanks, we looked down on one of the fault's most recent works. During the past four million years it has torn the rocky rib of Baja California from the breast of mainland Mexico, giving birth to the gulf.

Here in the south, Tom Hanks explained, the fault is splayed, taking the form of several parallel fractures. Two of these loosened a great slab of desert floor and let it slowly drop between them—the Imperial Valley.

Hot springs, symptoms of the fever afflicting this fitful region, steamed below as we skirted the Salton Sea. Ahead, a low escarpment took shape—the southernmost trace of the San Andreas Fault itself.

Where no scarps or sheared hills marked the fault, I learned to follow its path by the contrasting rock colors on each side, or by streams whose beds had been offset by earth movements across them (page 40). Often a thin line of gray marked the fracture. This was "gouge," rock ground into fine flour by the millstones of the plates.

North of Indio the fault bends abruptly west, a jog that here brings the plate edges into head-on collision. Struggling to pass, they gradually compress and thrust up the towering Transverse Ranges.

For the hundred miles between Cholame and San Juan Bautista, truly great quakes are unknown, although lesser ones abound. This is the realm of creep, where the fault's sides slide past each other at about an inch a year. South of Hollister this steady creep is slowly ripping apart an old winery building. Streets of the city itself are being offset.

Pursuing the fault north along the San Francisco peninsula, we flew over glistening San Andreas Lake, which lies within the fault trough (pages 48-9). It is for this lake and its elongated valley that the fault is named.

North of the Golden Gate the fault follows the coast, skipping at several points into the sea. At Shelter Cove only a gentle crease marks the quiet headland where it dives for the last time into the ocean.

We landed at the northern California town of Garberville. There were no cabs at the

When the earth twitched: Collapsed overpasses lie in ruin and toppled cans strew a supermarket after an earthquake along a minor fault shook the San Fernando Valley on February 9, 1971. Measuring a moderate 6.5 on the Richter scale, it left 64 persons dead and caused half a billion dollars' damage in suburban Los Angeles.

small airport, so I hitched a ride into town with 16-year-old Marshall Brisbane. I asked a question I put to Californians everywhere: Did he worry about earthquakes?

His face glowed with excitement. "I think one would be out of sight!" breathed the boy from the quiet small town.

Then his eyes climbed the towering hills around us, and the young man in him added, "I guess those ridges would split right open, wouldn't they?"

Marshall Brisbane's range of feelings, I found, embraces those of many Californians.

"Earthquakes—why worry?" ran a familiar refrain. "You can get it a lot quicker out there on the freeway." "I'll take quakes to those hurricanes they get down South," I often heard. Or, "Better than those tornadoes."

For sheer positive thinking, I admired the bartender who worked 30 stories high in San Francisco's Fairmont Hotel. "Up here," he said, "you're away from those things."

And the lady in San Bruno whose house sits directly atop the fault. "Actually," she assured me serenely, "it runs out there, over by the patio fence."

I found the pattern little different in San Fernando a year after the ordeal of 1971. "There won't be another one," declared Frank Carbonara. "I'm staying." Never mind the scars he showed me on his back, left when Sylmar Veterans Hospital collapsed and buried him alive. But his was a house divided. Mrs. Carbonara told me she feared quakes, and their two daughters wondered if people's brave talk was designed to keep up their own courage.

"Individuals obviously differ widely in feelings, from unconcern to outright fear," said psychiatrist Stephen Howard of San Fernando, who worked with shock victims of the 1971 tremor. Other experts have noted that the quake problem seems too huge, the individual too powerless, and the likelihood of harm too remote to keep quakes in the forefront of human worry.

"Even in California," states a behavioral scientist, "a damaging earthquake is a non-believable hazard."

Believable or not, scientists obviously regard the hazard as real. They swarm over the fault like Lilliputians over a colossal Gulliver.

"California is working all out against the

His world turned topsy-turvy, a bewildered boy picks up after the San Fernando quake. Striking before dawn, the tremor and its aftershocks woke people to terror, especially children. Expressing her emotional trauma with crayons (opposite), a 10-year-old girl drew "a green monster, trying to kill all the people and smash the cars."

calendar to prepare for the inevitable destructive earthquakes we *know* are coming," asserts State Geologist Wesley G. Bruer.

"If we could reliably forecast a major shock," says NOAA Administrator Robert M. White, "we could get ready. Water agencies could lower the levels of critical reservoirs. Disaster-relief forces could mobilize. Hazardous buildings could be evacuated."

BELIEVING CREEP might portend quakes, NOAA and NCER, the Geological Survey's National Center for Earthquake Research, have laced the fault with wires and rods that measure the slightest slip. I saw similar networks suturing the parallel Hayward and Calaveras Faults. ("We're stitching them so they *can't* move," quips one geologist.)

The creepmeters already have snared a clue about quakes. For two years before a 5.6 tremor shook the Almaden Cienaga winery near Hollister, spilling 11,000 gallons of wine, movement there doubled. Thus galloping creep may presage earthquakes.

Of equal interest is strain—the amount the underlying rock is bending along the five-sixths of the fault that is locked.

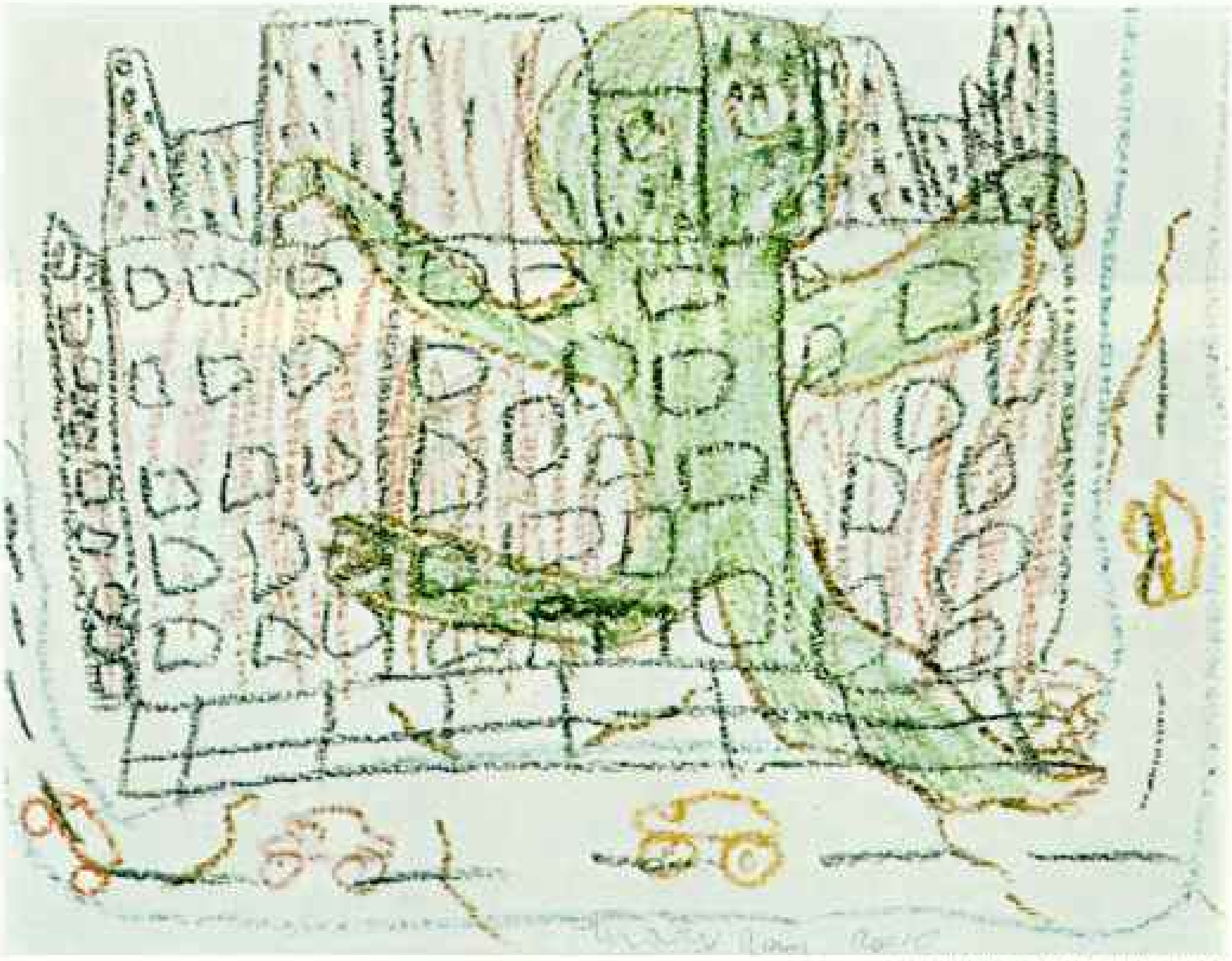
As they press the quest for quake prediction, scientists also oversee a statewide effort to minimize trouble when it strikes.

Spotted strategically along the northern fault, a dozen seismometers constantly monitor its health and telemeter their reports to the Seismographic Station of the University of California at Berkeley. In the south I saw reports from a similar network flowing into the Seismological Laboratory at Caltech.

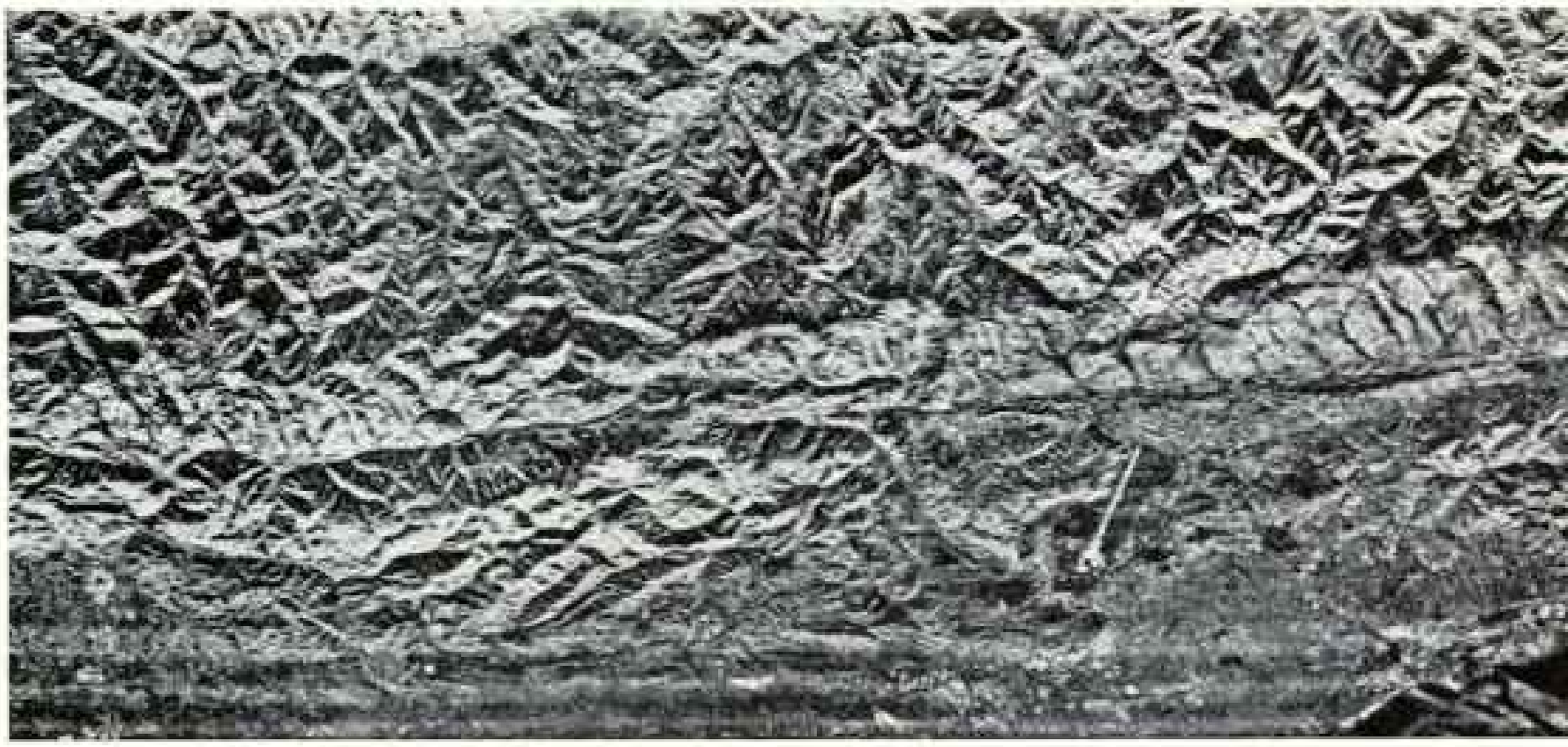
The instruments show that their patient never rests. Tremors of magnitude 2.0 or greater wrack its body at least once a day; such reports go into its bulging medical record so computers can plot the epicenters. About once a year the restless giant convulses with a 5.0 spasm or worse. This sets in motion a series of emergency operations to safeguard all Californians.

Automatic alarms at the seismographic stations notify police. Simultaneously earthquake alert panels flash and buzz at the state capital in Sacramento. At once officials dispatch crews to check the safety of dams and aqueducts, to search for potential landslides, to evacuate people if necessary.

(Continued on page 52)



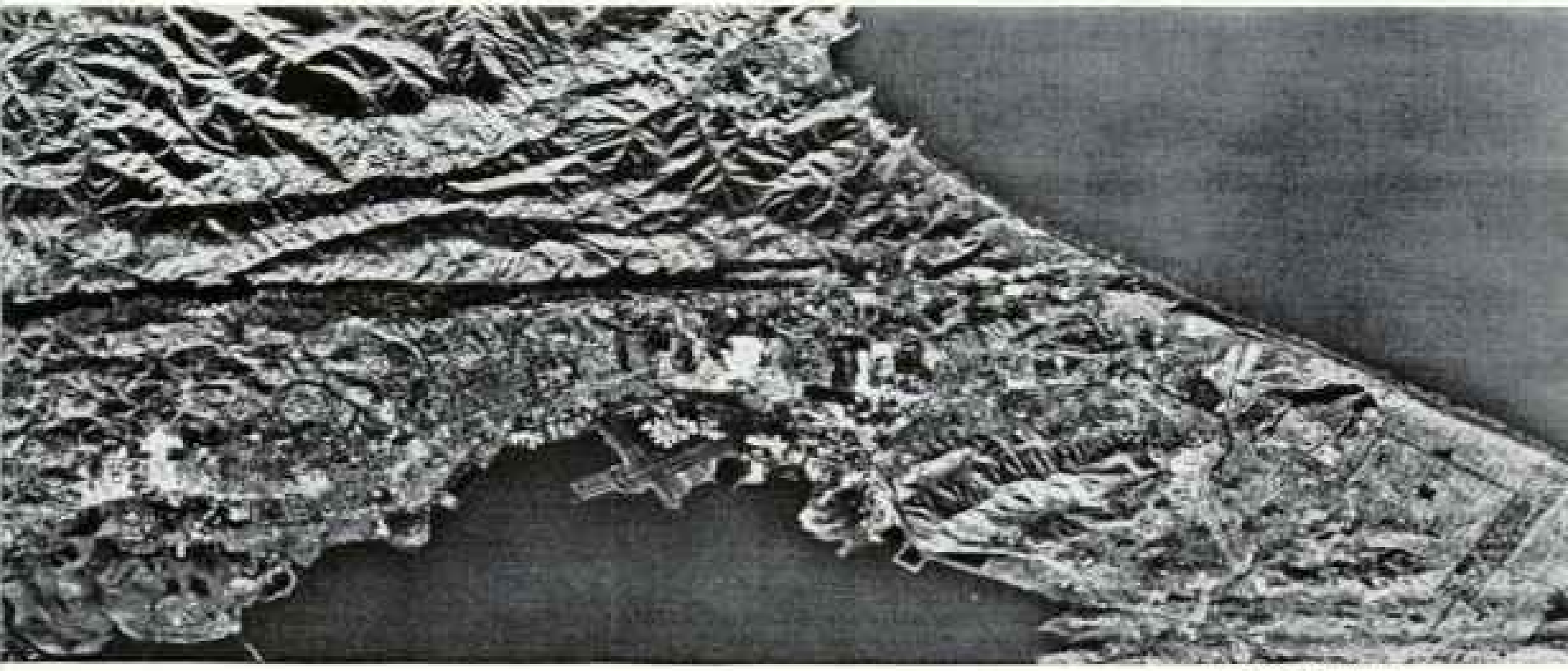
SAN FERNANDO VALLEY CHILD GUIDANCE CLINIC



Camouflaged in a cape of blue, the fault forms the bed of San Andreas Lake (**left**) in its northward procession along the San Francisco peninsula. The valley, dammed for a reservoir in 1870, gave its name to the fault zone. Between the lake's far tip and the Pacific, sections of San Bruno, Pacifica, and Daly City drape headlands wrenched and shifted violently in 1906.

Like many other Californians who dwell along the fault, a Daly City homeowner (**below**) casually dismisses any worry that a quake will strike again.

Revealed by aerial radar (**bottom**), the fault carves an ugly scar along the peninsula toward San Francisco at right. In places it splays into several strands, indicating parallel fractures. Stanford University's two-mile-long linear accelerator—an atom-smashing device—points to the fault at left. San Francisco International Airport projects like an X into the bay at bottom.



U. S. GEOLOGICAL SURVEY


DUNES
Flamingo

Making their own quake, specialists of the National Oceanic and Atmospheric Administration test a new building in Las Vegas, Nevada (**left**). By rhythmically shifting their weight from leg to leg, the two men can vibrate the 14-story structure several thousandths of an inch; sensors in the foreground record its response. Such tests in Los Angeles before and after the San Fernando tremor revealed 43 buildings with hidden damage.

A building dances as consulting engineer Henry J. Degenkolb vibrates a skyscraper model, causing all but the sixth floor to flex. A slower "quake" would shake the whole building—the motion most likely to cause collapse.

Old and new (**right**) pose a contrast in seismic safety in San Francisco. Masonry buildings that predate bracing codes show vulnerability to shaking, and their ornate cornices and parapets would easily dislodge to rain death on passersby below. Modern codes, demanding strong bracing and special installation of glass, heighten the safety of skyscrapers such as the tapering Transamerica Pyramid.

J. R. EYERMAN (LEFT AND BELOW) AND JAMES P. BLAIR

What can Californians expect when the next major quake comes?

For answers I turned to the U. S. Office of Emergency Preparedness, which with state agencies is preparing a disaster plan for the San Francisco Bay area. It takes into account that the area's 4.7 million residents live, in a sense, in double jeopardy, between the Hayward and San Andreas Faults (map, page 43).

OEP scenarios estimate the effects of a magnitude 8.3 quake, equivalent to that of 1906, striking along the San Andreas (figures for the Hayward are similar):

- SCENARIO 1: Time—2:30 a.m. Most people asleep in their homes. The area's nine dams hold. The toll: 3,000 persons killed, 11,000 hospitalized.
- SCENARIO 2: Time—2 p.m. Many people at work; streets and sidewalks busy; dams hold. OEP sees 9,500 killed, 35,000 hospitalized.
- SCENARIO 3: Time—4:30 p.m. Roads and sidewalks are crowded with rush-hour traffic; dams hold. More than 10,000 die, 40,000 hospitalized.

Add the element of failing dams, and casualties soar—to 100,000 dead or injured.

IN A SIMILAR SCENARIO for the Los Angeles area, engineering professor C. Martin Duke of UCLA considers an 8.3 shock on the San Andreas 35 miles from City Hall. Striking at 6 a.m., as did the San Fernando quake, it inflicts 3,100 deaths, 24 billion dollars' worth of damage. Let it hit in daytime, when pedestrians crowd sidewalks and traffic streams across the 100 to 200 overpasses that could fail, and it is "distressingly easy" to visualize 10,000 deaths.

The biggest worry is unsafe buildings, especially schools. Basically, this means old masonry buildings that went up before codes called for quake bracing. Perhaps forty thousand exist in the Los Angeles Basin alone; tens of thousands more stand in San Francisco and elsewhere.

As for schools, more than a quarter of a million California children still attend at least a class a day in 1,500 buildings that predate safety standards established in 1933. The San Fernando quake showed that schools built since then hold up extremely well.

Other danger areas:

- PARAPETS: These decorative little walls that jut above roof lines, along with gargoyles and other architectural ornaments, pose a frightful peril. Easily loosened by shaking, they can hurl down avalanches of masonry on pedestrians beneath. Los Angeles ranks high in parapet control. Bakersfield's problem largely vanished when a 1952 quake shook most of them off.
- DAMS: The near disaster of San Fernando's Van Norman Dam focused attention on the state's 1,100 impoundments, and led to the draining of two for safety. "Earth-filled dams properly built," asserts Safety of Dams Supervisory Engineer A. M. McClure, "will withstand the greatest earthquake."
- BRIDGES: Seven collapsed at San Fernando. "We learned a lot," concedes State Director of Bridges Arthur Elliott. He believes his engineers are successfully incorporating these lessons into the two new spans added to California's vast road network each day.
- LAND USE: As the human tide has engulfed California, people have built everywhere—on slides, on floodplains, on faults. The 77,000-seat Berkeley football stadium sits directly astraddle the Hayward Fault.

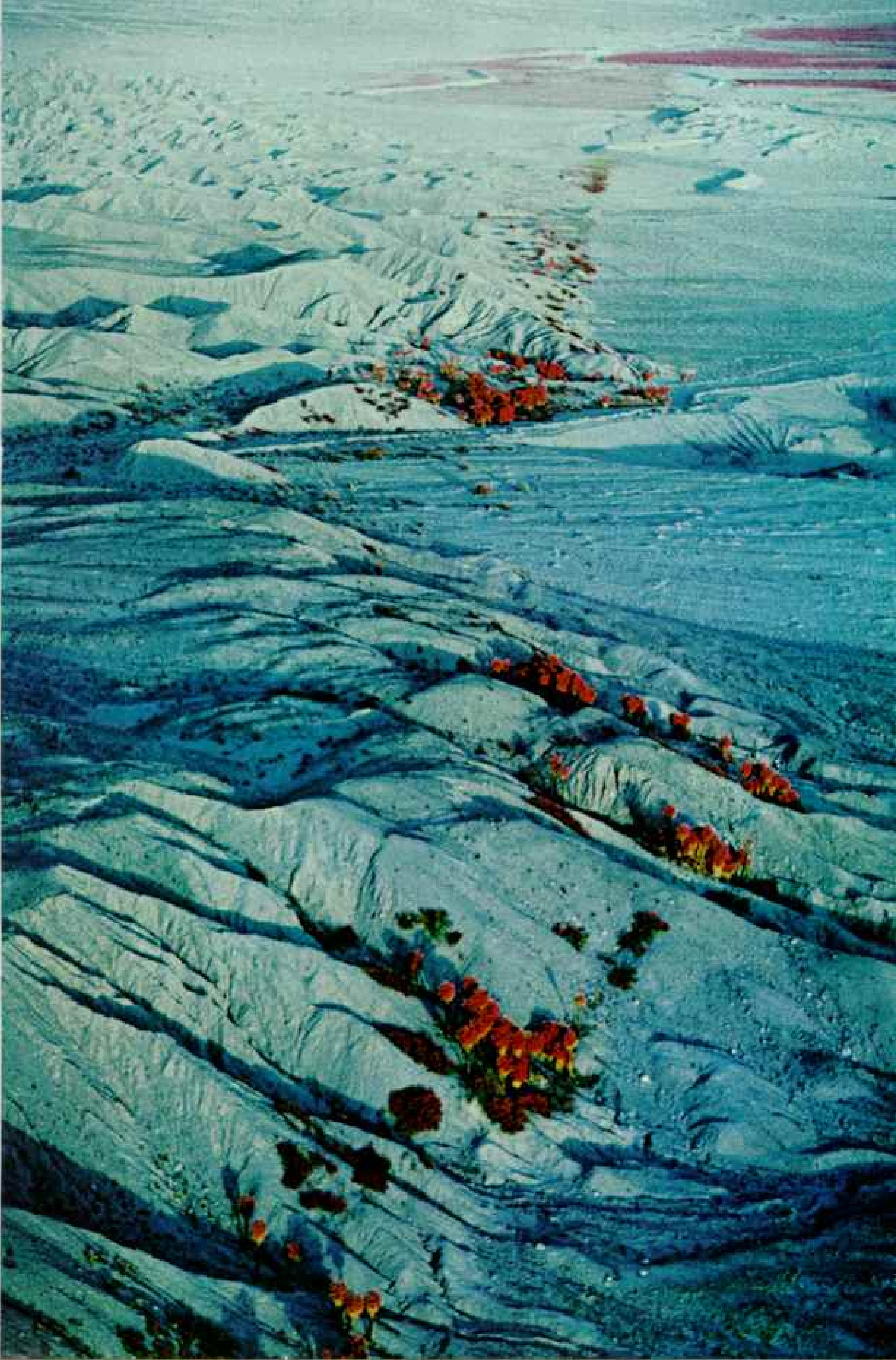
Californians still build in precarious places, but less and less. Many alarmed communities are taking a look at what they sit on.

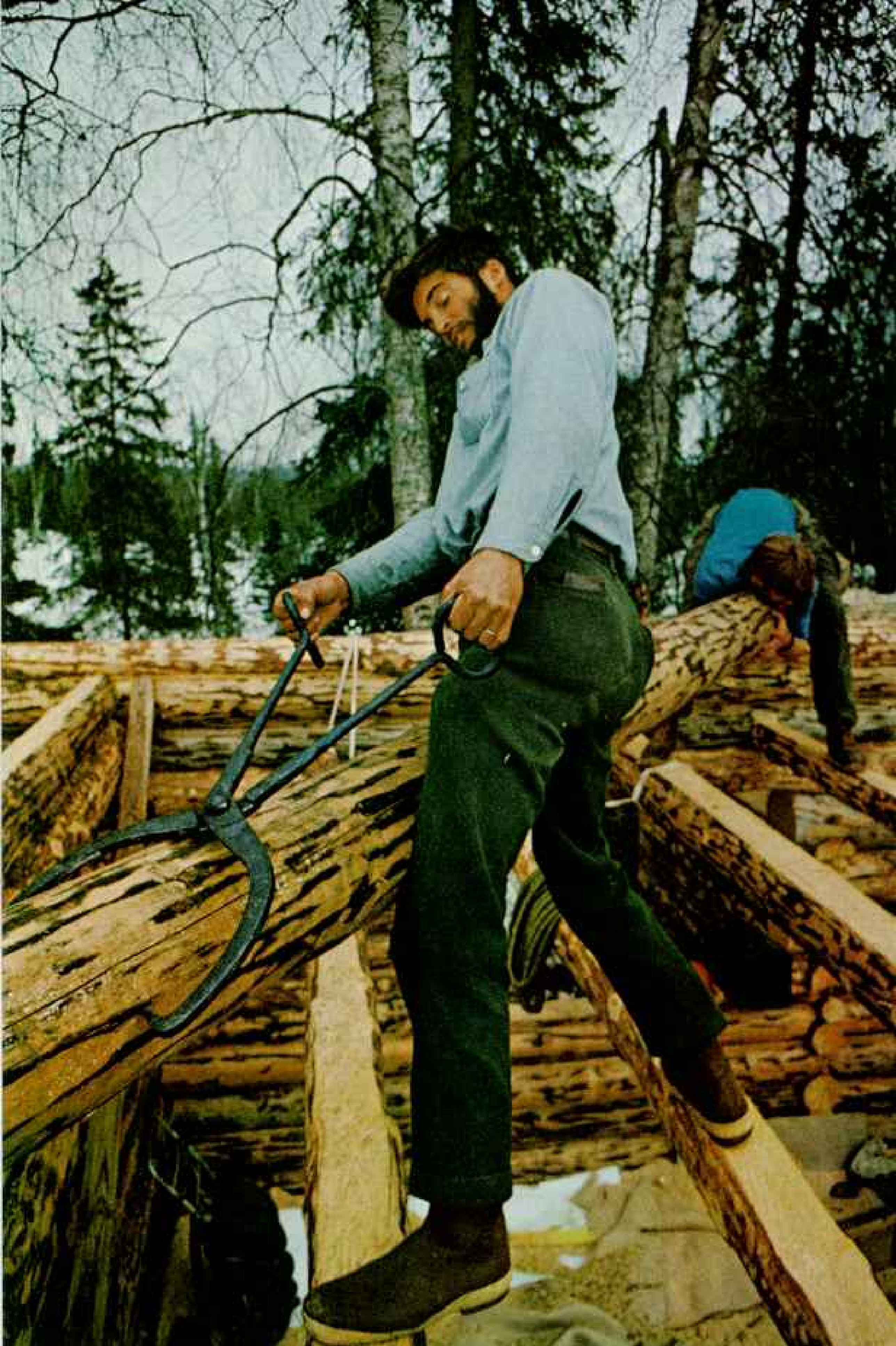
Surely a trailblazer is little Portola Valley, a eucalyptus-shaded suburb of San Francisco that the San Andreas slices like a knife.

Portolans have appropriated funds to map their slide hazards, required builders to obtain soil surveys, hired a town geologist to analyze them. They also proposed a bold moratorium on building near the fault. Fifteen minutes before council members convened to vote on the measure, a magnitude 3.0 tremor shook the town hall. The bill passed without dissent.

In a happier-than-usual way, they lived the earthquake story. Their lesson: Along with its hazard, each tremor gives a nudge toward doing something about the next one. □

Shoestring oasis of wild palms, fiery red in this infrared photograph, borders the fault north of the Imperial Valley. Movement of the plates has ground the boundary rock into a fine clay known as "gouge," which forms a subterranean dam. Groundwater trapped on the uphill side produces the striking line of vegetation—a fragile manifestation of the titanic forces constantly reshaping the restless earth.





Alaskan Family Robinson

By NANCY ROBINSON

Photographs by JOHN METZGER
and PETER ROBINSON

IT SHOULD HAVE BEEN a great evening. Pete and I had just moved into the first home we had ever built with our own hands, a tiny spruce-log cabin set on the shore of a tranquil lake deep in the Alaskan bush.

It was like being on an island in a sea of wilderness, 17 miles from the nearest train stop, eight miles from any road, and only our friends Kent and Martha Smith living nearby, in a cabin within shouting distance.

The first snows of autumn had fallen and the night was black, with clouds scudding before a frigid wind. Yet inside our cabin, warm with a roaring wood fire and sweet with the deep-sleep breathing of our 2-year-old son, we felt secure and at peace.

Then, suddenly, the cabin shook. Pete glanced toward the ceiling where our lantern hung from the ridgepole. My eyes followed his. And we both sensed the chill of fear.

The lantern was swinging!

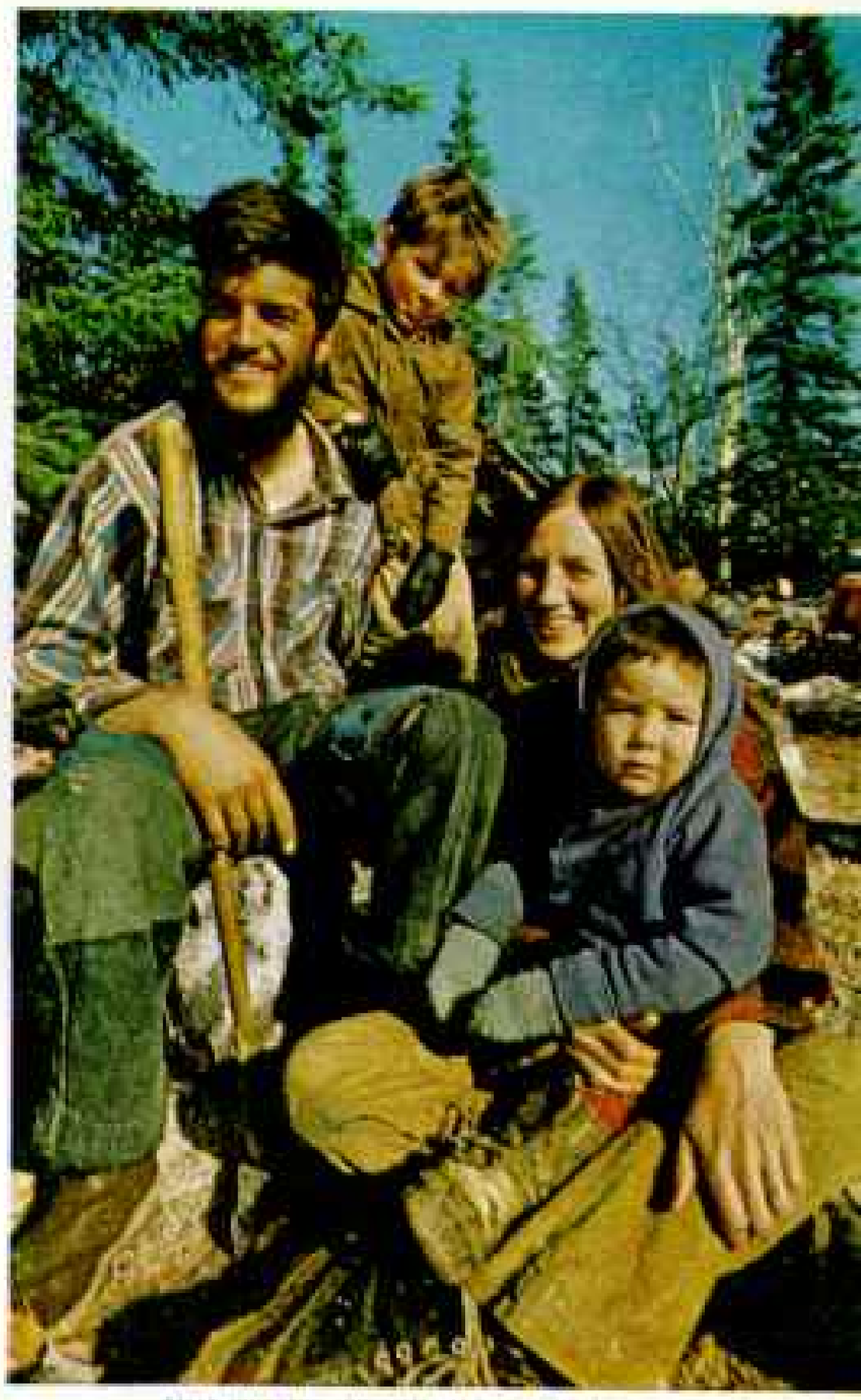
Watching, we literally held our breath, awaiting the collapse of the cabin we had raised with so much labor and so little experience. Then, after what seemed an age, the swinging slowed, stopped. Our cabin stood intact.

The next day our battery-powered radio brought us news of what had happened. The earth itself had quaked. That our cabin had been sturdy enough for such a tremor gave us needed confidence.

In the more than four years since that night in 1968, our winters in the wilderness have inspired an even greater self-confidence that we can live—and flourish—without all the customary trappings of 20th-century civilization.

Pete and I both grew up feeling good about mountains and places where there weren't many other people. He was raised near Boston, Massachusetts, and I in Denver, Colorado; we both attended Colorado State University, where we got to know one another on mountain outings.

After graduation I joined the Peace Corps, and he went climbing. When we were married, both



SALLY JOHNSTON (OPPOSITE) AND JOHN METZGER

CALL OF THE WILD *lured my husband, Pete, and me to Alaska. Now with our two sons, Harlow and Vincent, we find zest in the rugged life of the bush. Living in a log cabin we built and eating off the land, we find a new understanding of ourselves and a new strength in family ties.*

Straining at logging tongs (facing page), Pete helps our neighbor Dave Johnston raise his cabin.

SALLY JOHNSTON (ABOVE) AND ELSIE S. ROGERS

WITHOUT MACHINERY, *Pete and Dave maneuver the cabin's heavy ridgepole, which they had rolled up the logs leaning against the wall (above). Two of our college friends and their wives have settled near us in the bush. Sharing pioneer tasks, we all help each other at cabin-building time.*

The cabin we now live in (right), our second, lies across Ermine Lake from the new Anchorage-Fairbanks Highway (map). Before completion of the road, the 34-mile round trip to the railroad stop at Hurricane for mail and supplies took a day by tractor and truck or snowmobile. Now we can get there and back in an hour.

22 years old, we came to Alaska, seeking the challenge of the unexpected.

I was teaching high-school English in Talkeetna, and Pete, a biology major, was working as a weather observer when we met the Smiths. They were a young couple proposing to build a roadside lodge and cabins for guests on their 80-acre government claim. Their land, bordering a 25-acre lake they call Ermine, lay alongside the right-of-way of a highway under construction from Anchorage to Fairbanks.

After a couple of weekend visits to the Smiths' log cabin at another lake near Talkeetna, we accepted their offer to join them at Ermine Lake, help with their lodge and cabin construction, and raise a home for our family while we worked with them.

That summer—1968—Kent and Pete took jobs in Mount McKinley National Park to earn enough cash to support us for a year in the bush. It fell to Martha and me, with our children—her 4-year-old Christine and my toddler, Harlow—to fix up the log cabin already standing at Ermine Lake.

In August we went to Anchorage and bought groceries and supplies to last a couple of months. Then Martha and Chris, with half the larder, flew with bush pilot Don Sheldon to the lake; Harlow and I, with the rest of the supplies, followed on the second air trip.

I hadn't realized what I was getting into until the floatplane circled the lake before landing near where Martha and Chris, looking small and helpless, awaited us. For a fleeting instant I had the feeling I was being dumped off at the end of the world.

But there was nothing helpless about Martha. We had packed most of our supplies to shelter, 90 yards up the trail, leaving until last a 100-pound sack of cement. "That," I decided, "will have to wait for the men."

I went to the cabin, expecting Martha to follow. In ten minutes, she did—packing

that 100 pounds of cement on her back!

The following three weeks Martha and I busied ourselves with such "woman's work" as varnishing the floors and walls of the Smiths' cabin, constructing an outhouse, building a door, table, and kitchen cabinet, and installing a wood heater and stovepipe.

By the time our men arrived, we had things homey and comfortable. True, the table wobbled a little, the door didn't close smoothly, and the still-roofless outhouse leaned to the north, but we were proud of our accomplishments. Our constructions lasted long enough to get us all started with the business of living at Ermine Lake.

By the end of October the four of us had completed a second cabin, and our big happy Smith/Robinson family again became two families. We had all labored long and hard in those early months. I, for one, had calluses replacing the blisters of those first weeks. I had learned more or less how to hammer, saw, carry water buckets, operate a chain saw, and how to split firewood, using not brute strength but good aim and a knowledge of how different logs yield to the ax. In the end, there was the 12-by-18-foot cabin Pete and I were going to call home.

WE LIVE in a long, windswept valley bounded on the west by the Alaska Range, with Mount McKinley, apex of the continent, as its snowy crown (pages 74-5). From the shore of Ermine Lake we often glimpse massive McKinley, called Denali—the Tall One—by the Koyukon Indians. But if clouds veil that view, other Alaska Range peaks still gleam behind jagged and rocky ridges. Foothills of the Talkeetna Mountains wall us on the east.

Our lake, dotted in warm weather with the yellow blooms of water lilies and lively with spike-billed northern phalaropes, becomes a short-lived but fun skating rink after the first

PETER ROBINSON (LEFT) AND JOHN METZLER

CHENA NEVER LEARNS *that she makes porcupines nervous. After an encounter with one such visitor in the bright-hued thicket (left), our dog comes home bristling—and a little sheepish. Pete keeps a pair of pliers handy for pulling out quills. I like to think that Chena helps to frighten off more dangerous wildlife—the black and grizzly bears that live in our valley.*

fall freeze. Soon snows mark it with ever-changing ripples of wind drifts.

The dark, drooping evergreens that shadow the lake's swampy fringes seem as grotesque as a thousand witches in summer. But they appear graceful and soft when skirted by untracked snow in winter. They are especially lovely by moonlight just after a new snow, when each crystal catches the glow and sparkles it back to me.

The beauty of the wilderness does much to reward us for the unending hard work of mere survival. To keep warm and fuel our cookstove, we spend hours cutting and hauling sledloads and armloads of firewood.

Cooking on a wood range is a challenge, since there is no way to gauge heat output precisely. Baking needs even temperatures, and my oven gets hotter at the left rear corner. I have to remember to keep turning the cakes or loaves of bread. I discovered a pressure cooker useful in quick-cooking beans and meat stews; otherwise I would be stoking the stove all day.

Another time-occupying chore is hauling water from the lake. In winter we maintain a water hole yards out from the lakeshore, using an ice chisel to break away the frozen crust that forms each day over the opening. Experience has taught us to shovel snow on top of the skim ice as insulation to keep it from freezing too thick to break easily.

We have also learned to mark the location with stakes or spruce boughs. Several times the hole has been lost beneath drifting snow, and hacking a new one in four-foot-thick ice can take a full day.

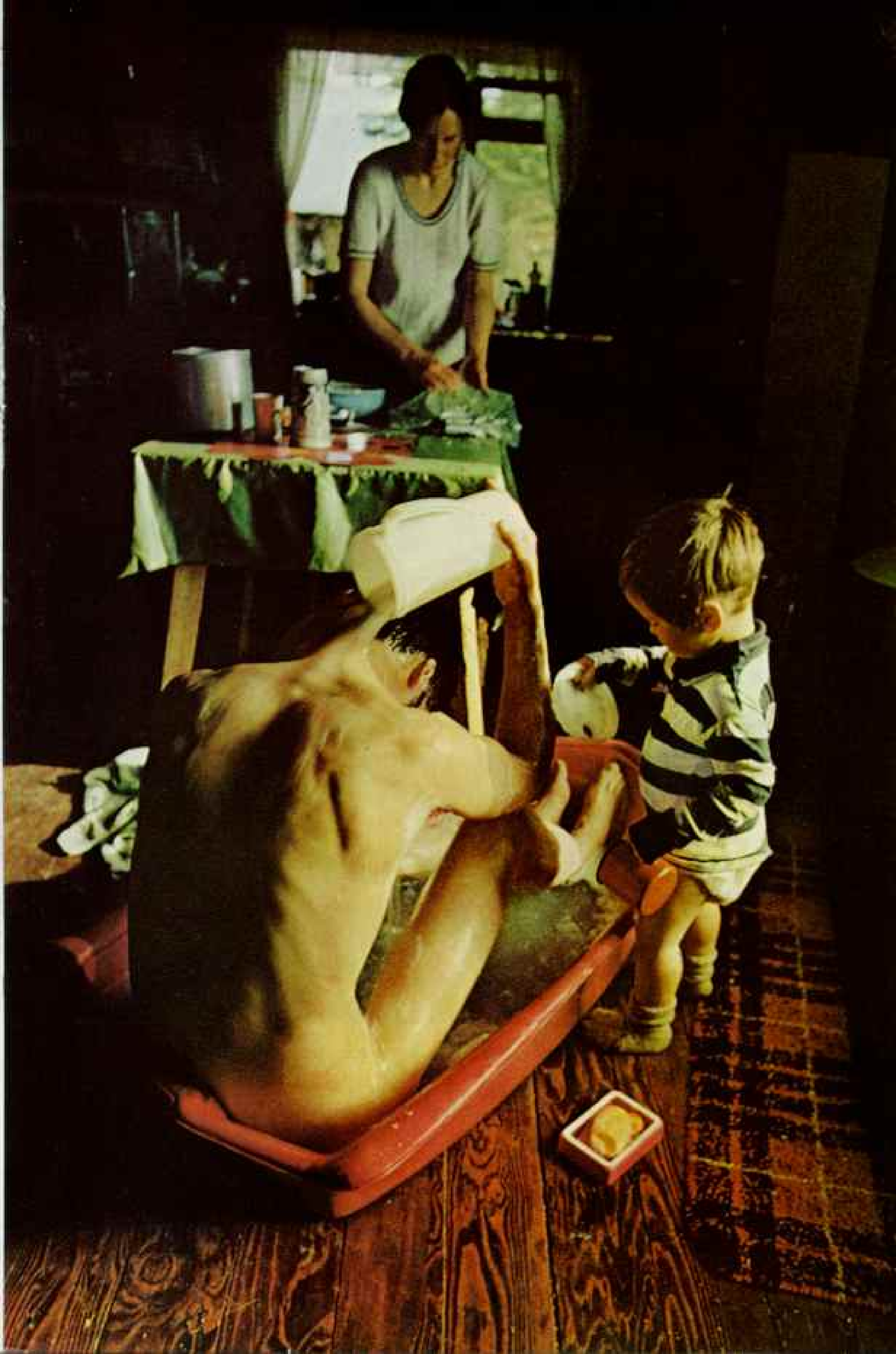
Harlow, by then 5, was playing out on the lake last winter and fell into our water hole, even though it was marked. We heard him scream and rushed out, just in time to see him scrambling from the hole. Pete let him walk back to the house by himself, cold and crying, hoping that his misery might teach him to be more careful next time. Careless dealing with nature can be fatal in this wilderness.

WITH WATER so hard to come by, doing the laundry can be sheer drudgery. In summer I find it pleasant to spend a morning at the lake scrubbing the clothes. But in winter lake water must be hauled to the cabin and dirty water must be lugged outside. We wear our clothes as long between washings as decently possible, and I do the dishes only once a day, often

BOTH BY JOHN BETTAQUE

ALL THE WATER *we use at home must be drawn by hand from Ermine Lake. Pete fills a five-gallon can from a hole in the ice. By using the same hole each time, we have to chisel away only an icy crust. Mount McKinley, highest peak on the continent, dominates the skyline.*

BATHING IN A PLASTIC BOAT. *Pete gets splashing help from Vin. None of us enjoy carrying the water from lake to house, so we use as little as possible, letting one tubful serve the whole family.*

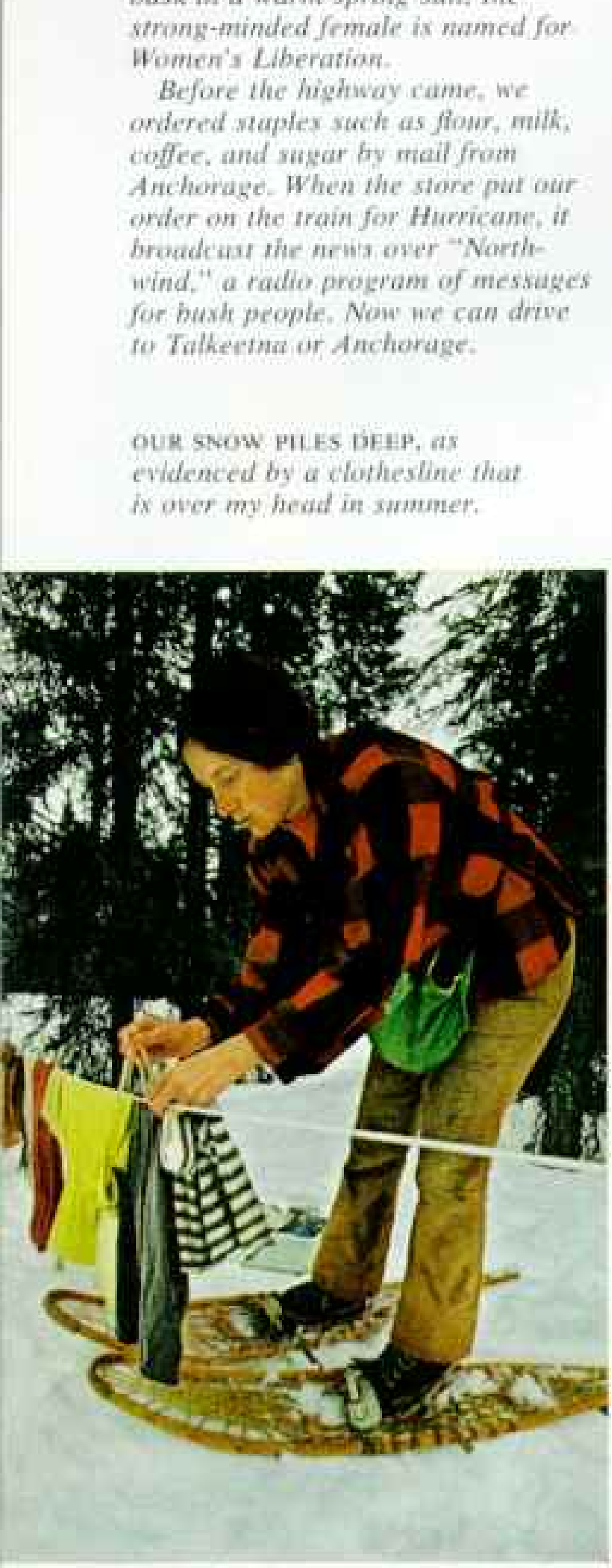


FAR FROM GROCERY STORES, *I make all our bread, turning out three loaves every five days. I love it when the baking smells fill the cabin. Chena's pups, Buddy and Lib, bask in a warm spring sun; the strong-minded female is named for Women's Liberation.*

Before the highway came, we ordered staples such as flour, milk, coffee, and sugar by mail from Anchorage. When the store put our order on the train for Hurricane, it broadcast the news over "Northwind," a radio program of messages for bush people. Now we can drive to Talkeetna or Anchorage.

OUR SNOW PILES DEEP, *as evidenced by a clothesline that is over my head in summer.*

PETER ROBINSON (ABOVE) AND JOHN NETTLES



MOOSE-MEAT STEAK *comes off a leg stored in our natural deepfreeze, the woodshed. Pete kills one moose each fall. What we don't eat in winter, I preserve.*

VIN WALES *beside the plastic trash can that we store water in. At times like these, no matter how busy I am, I interrupt my chores to console distraught sons who have only their parents to rely on for companionship.*

saving rinse water for mopping the floor.

Sometimes my chores make me wish I had gone to barber school and butcher school. Although I now cut hair and meat adequately, both skills have been learned by the trial-and-error method.

The first moose-slaughtering experience was especially memorable. Pete shot the animal during the November moose season and fetched me to help with the butchering. My job was to hold up the legs while Pete did the cutting. There was about a foot of snow and the temperature was hitting zero.

About three hours later the job was done, and we snowshoed home pulling our sledload of meat and discussing the unforgettable odor of moose entrails. I quickly learned not to be squeamish about a bloody moose carcass, and now carving the quarters into steaks, roasts, and stew meat comes easily.

To supply our family, we need one good-size moose each year. Cold weather lets us store meat in our natural freezer—the woodshed. I preserve leftovers for summer.

In winter moose move out of the hills into low-lying swamps and woods. When we lived in Talkeetna, I saw as many as 30 wintering right in town. One turned up on the street where we lived and challenged Pete, who was out walking with Harlow. The face-off ended when I brought our truck up and frightened the moose away.

You never can tell what a moose will do, though, when a vehicle is involved. They'll run, all right, but if pointed in your direction they might run into you, as happened to Pete

JOHN METZGER (ABOVE) AND PETER ROBINSON

NEW NEIGHBORS, *Betty Menard and her infant daughter come to call. Betty, an Eskimo who became a computer programmer and enthusiastic mountain climber, met our Colorado State University friend George Menard at a mountaineering club. Here we study books on plants, winning Harlow's attention. This winter I am teaching him with a correspondence course.*

STILL A TODDLER. *Vin tries skis for the first time. As did Harlow, he will probably learn quickly, and in a year or two the family can go ski touring together, a favorite sport. Harlow "records" the scene with a toy camera made for him by photographer John Metzger.*

last winter. He was driving at night on an icy section of the newly completed Anchorage-Fairbanks Highway when a moose jumped out in front of the car.

"It was like slow motion," Pete told me later. "I saw it coming closer and closer and there was nothing I could do, rolling on ice. So I just lay down on the seat and boom! The windshield popped out with glass all over the place, and I had moose hair in my face."

The moose bounced up and ran, little harmed. But Pete nearly froze, driving in below-zero weather without a windshield.

Other wildlife is more elusive. We see fresh wolf tracks around the lake two or three times a winter, and occasionally hear a distant howl. Ermine, brown weasels in their white winter phase, come around and gnaw on our moose meat. We also have martens, foxes, and wolverines.

Winter is a lonely time, especially in the coldest spells. But when all seems lifeless except the wind on the lake, we find the birds still with us. The gray jays—regular clowns—puff up their feathers to keep out the chill, dropping down to steal one more piece of food from the dogs' pans. Other faithful friends are the little boreal chickadees.

At times, when it's cold and dark and the wind is howling, we'll stoke the fire and put a favorite record—Beethoven, Brubeck, Jelly Roll Morton—on the battery-powered player. And, of course, we read a lot.

To get a fresh supply of books, magazines, mail, or groceries in those first years, we had to make the 17-mile, partly cross-country trip

to Hurricane, a railroad section-house stop. At Hurricane, we would mail our grocery order to Anchorage. When it was ready, the store would broadcast the news over "Northwind," a daily radio program of personal messages for people living in the bush. The best way for others to pass on information to us, "Northwind" is also splendid entertainment. Typical of the messages we hear was the one that said, "Don't give grandma any more Sal Hepatica. The medicine the doctor sent her is also a laxative."

We tuned in every night and when we heard, "Groceries for the Robinsons leave tomorrow on the Peddler"—that's the slow freight—we got ready to head for Hurricane.

BEFORE the new highway was completed, the round trip took as long as eight hours by tractor and pickup. When snow piled deep, we towed a sled with our snowmobile. Even so, two hills on the return trip proved troublesome. Many times we had to unhitch the sled and pull it up by hand.

Occasionally our machines break down and must be repaired. One winter our snowmobile engine needed parts and its frame mountings required professional welding. We decided the whole family would accompany the snowmobile frame to Talkeetna, via Hurricane.

We left under calm, clear skies, but in 15-below-zero cold. The plan was for me to ski in front of our two dogs, Chena and Buck, who would pull the sled with the two children bundled inside a sleeping bag. A toboggan loaded with the snowmobile frame was hooked on behind the dogsled. Pete would ski behind and help the dogs.

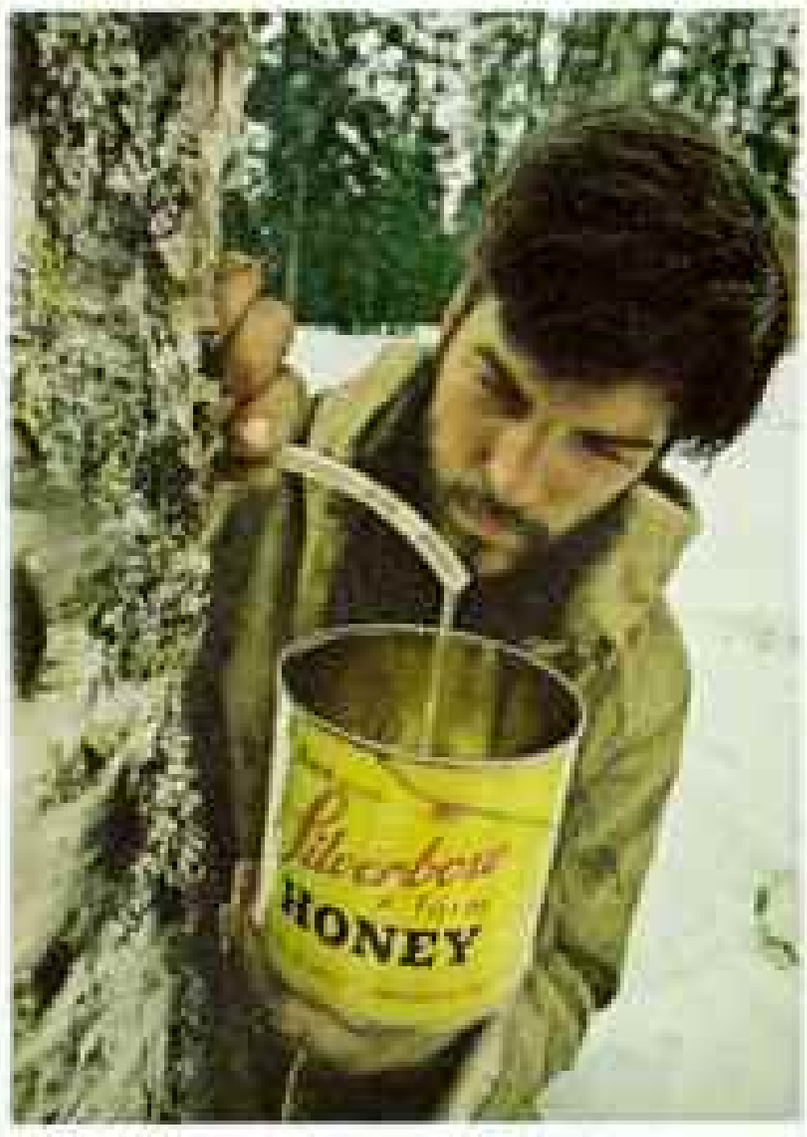
Immediately we found the combined load too heavy for the animals, so we abandoned the snowmobile frame and left anyway, to buy the engine parts. We moved along steadily to shake the chill, stopping only for a lunch

THE WINTER WAY TO TRAVEL *is on skis and snowshoes. Dave and Sally Johnston, here hiking for fun, use their own backs and those of their dogs—Tiklik and Katiktok—to pack in supplies to their cabin, two miles from the nearest road. Sally, a New Zealand nurse, met Dave—another Colorado State friend—when he passed through her country returning from an Antarctic fossil hunt. Year-old Gina goes everywhere strapped to mother's back.*

PETER ROBINSON

"BERRY FEVER" *is the summer-fall seizure that sends me out picking the wonderful variety of wild fruits: blueberries (left), raspberries, cranberries, currants, and the watermelon berries that serve as thirst quenchers on the trail.*

Birch syrup is another favorite, but we must tap about 80 gallons of sap (below) to produce a gallon. We enjoyed but a pint last year.



PETER ROBINSON (ABOVE) AND JOHN METZLER

VIN NAPS PAPOOSE-STYLE *and Harlow explores while I forage for edibles near our cabin (above). We have a great sense of oneness with nature here; she gives of her bounty freely and we accept in good conscience, knowing we have not disturbed the environment. An overgrown tangle of bushes, grasses, weeds, and trees, the land looks just the way we want it—natural, untouched. "I'm so proud," Pete commented one spring day, "of the way the yard is coming along."*

We can always find wild greens, such as cow parsnip (left), only a few minutes' walk from the salad bowl.

break. It was just long enough to swallow the frozen sandwiches and for me to breast-feed 5-month-old Vin, undoubtedly the chilliest meal he or I ever endured.

The trip to our rail connection at Hurricane took five hours. After a visit with friends there, we boarded the train for Talkeetna.

Two miles out of Hurricane, the whistle blew and the train slowed to a stop. There was George Menard, our college friend and a new neighbor. He had snowshoed 15 miles, pulling our snowmobile frame on the toboggan. After loading it in the baggage car, he handed us a letter to mail, then turned around and snowshoed home.

George said he didn't have much else to do and was glad to help out. That's the way it is in the bush. Everyone pitches in. The mutual isolation and common interests of the families who choose to live this simple life seem to tighten the bonds of friendship.

Snow cover lasts from October until May or even early June. But I like to think of winter in terms of the amount of daylight. In that case, it gets really wintry only by mid-November, and by mid-March it is light enough to be spring. Then our spirits pick up and we take off for cross-country skiing.

We like to follow animal tracks, just to see where they go, or ski to nearby landmarks to see how they look in the snow.

The going gets rough at spring breakup, when snow and ice are melting and everything is wet and soggy and muddy. Then we don rubber boots, which we will wear when outdoors until freeze-up in fall.

One's senses become more acute living in the bush. When things begin to thaw in spring, nature's aromas and colors nearly overpower us. Fiddlehead ferns—when young as delicious

JOHN BET

OLD FRIENDS AND NEW, *parents and kids—we all meet for a happy Thanksgiving reunion at the barely completed cabin of other young friends in the bush, Kathy and Rick Ernst. A makeshift table holds the feast contributed by all, and we dine on the floor. Since most of us have to take summer jobs in towns to make ends meet, we treasure such get-togethers with fellow wilderness lovers.*

as asparagus—push up in the melted spots at the bases of trees. And the new green of birches and alders is intoxicating.

Summer, with the snow gone and long hours of light each day, brings a frenzy of activity. Pete has spent many long hours building cabins with Kent Smith. The men felled the white spruce trees with chain saws, and we women helped peel bark off the logs.

In the summer of 1969 we completed the roadside lodge for food service, a washhouse, and two lakeside cabins for future tourists, all of logs.

The summer vegetation around the lake is surprisingly lush: ferns and waist-high grass, brilliant fuchsia-colored fireweed, alder trees, mixed stands of birch and spruce, fields of Alaska cotton grass, and berry bushes of every description. I've made countless jars of jams and jellies, juices and syrups.

Being outdoors all summer, we must fight off that scourge of Alaska, the mosquito. Curiously, at our lake the insects aren't as bad as in nearby localities. We have friends living only 25 miles south of us who have to wear head nets to get around outdoors, and who just automatically "dope up" with insect repellent whenever they set out from the house. We have bad days, though, usually just before a storm.

ANOTHER SUMMER HAZARD is a potential encounter with a black or grizzly bear. Pete tells apprehensive visitors that "bears are only looking for food and probably won't bother you." The word *probably* wasn't too reassuring to my teen-age sister, Jeanie, who spent a summer with us.

Pete, the boys, and I were away with the dogs; Jeanie stayed behind, reading in front of the cabin.

"All of a sudden," she recalls, "I looked up and saw this huge black bear coming toward me from the woodshed. You can believe I moved fast!"

In her haste to scurry into the cabin, she failed to close the entryway door. The bear followed her. Jeanie took refuge in the cabin's sleeping loft and listened to her visitor knocking about in the front hall.

Summoning her nerve, she leaned out the upstairs side window and whistled, hoping the bear would be curious and go outside to see where the sound came from. Perhaps that did the trick, for after a period of silence Jeanie looked out the window again and saw the bear digging about in our compost pile.

She took advantage of the animal's preoccupation to run for our boat *Blueberry* and row across the lake to the Smiths' cabin. By the time Kent returned with a gun to frighten the bear away, it was nowhere to be seen.

We think the bear was the same 300-pounder that once pawed a hole in a plastic window at the Smiths'. Pete says the bear was just curious, that we're in his home range and should leave him alone.

WINTER is the only season we can be sure of being in our wilderness home, since to make ends meet Pete must seek jobs elsewhere for a part of each year. We wish it were otherwise, but being self-sufficient is impossible—unless one chooses to live like the early Eskimo or Indian.

We must either be satisfied with a diet of meat, greens, berries, fish, and game birds, or we must earn money for such extras as flour, cereals, sugar, and milk. We could spend much time sewing clothing of animal hides or do as we do—buy our clothing from the Salvation Army thrift store in Anchorage, which saves time for reading and other self-enriching projects. So we compromise, and go wherever Pete finds work.

He has held such varied jobs as weather observer, park caretaker, and hunting guide. He once worked for a lumber company in Fairbanks, and more recently he was employed as a cabin builder in Palmer. None of the jobs would be satisfying to Pete as a life-work, but all have been invaluable experiences. We have found just $3,000 a year sufficient, barring expensive illnesses.

Last spring Pete and five friends, including photographer John Metzger, made a two-week ski tour near towering Mount McKinley, traveling up Ruth Glacier and down Buckskin Glacier. They returned thrilled with the scenery and the comradeship of mountaineering, and eager to explore the area further.

Now we feel a ski-tour business is one possible and agreeable answer to our money problems. Pete would like to build cabins, spaced a day of ski touring apart, where he could stock food, sleeping bags, and firewood. And this business could be operated from our present location at Ermine Lake.

As for the future, we do, of course, want to make some improvements in our lives. One major project already has been to build a larger, five-room cabin for our growing family.

It is small by city standards, but to us it seems a mansion after three years in our one-room home. Pete worked on the building all one winter, somehow managing carpentry in below-zero weather. He often had to shovel new-fallen and wind-drifted snow out of the roofless structure in order to begin putting up new rounds of logs.

We'd like to improve the cabin further by the addition of a root cellar, and a well to pump water to an indoor sink. Pete is also building a wind-powered generator from junk parts. If it's successful, we hope to heat and light the house with electricity. Also being considered are a greenhouse and an icehouse; we will insulate the ice with sawdust left from our cabin building.

Then there is the sauna, already under construction back in the woods by a creek. The sauna, instead of the plastic boat in the living room, will give us our baths.

GENERALLY SPEAKING, our life-style is simple, involving a minimal dependence on the benefits of civilization. But, when Vin, then 15 months old, was near death with pneumonia and meningitis last winter, we had to seek civilized medical care.

The symptoms appeared with frightening suddenness, transforming usually loud and good-natured Vin into an unresponsive, feverish phantom. That was one time we felt relieved to have the new road nearby; the heavy snow that day would have made landing a plane to evacuate Vin impossible. He recovered completely after massive doses of antibiotics and 26 days of hospital care.

Learning to cope with the basics of life has given us a sense of direction and substance, and we hope our way of life will also teach our sons self-sufficiency and common sense. The boys will have an added benefit of seeing how their father spends most of his days, a rarity in the rapid pace of life in the 1970's. Sadly, though, they miss the companionship of other children. We can only hope the gain compensates for the lack.

We have to keep in mind schooling for the children. The nearest school at present is 55 miles away, too far to send a small child for a long day. The state offers correspondence courses with teachers assigned to receive homework and exams. Harlow is now enjoying kindergarten this way. It is obvious that he misses out on social contact and such educational tools as films, so we try to provide those kinds of learning experiences whenever we visit Anchorage.

WE DO NOT FEEL we are socially isolated. We get together frequently throughout the year with close friends in our valley. In 1971 we decided to establish a tradition of gathering all of our young bush friends for Thanksgiving at someone's cabin. That year we all went to the cabin of Rick and Kathy Ernst. He's a Peace Corps veteran and she holds a master's degree in chemistry from the University of Alaska.

Skis, snowshoes, a dogsled, and a snowmobile outside the Ernst cabin revealed how guests had traveled from the road two miles away. Since the cabin was barely completed, the spirit of the whole Thanksgiving dinner was make-do.

We improvised plates with cardboard and aluminum foil, and put boards over sections of upended logs for a table. Kathy and I manned the cooking station, producing on her wood stove two roast turkeys and a roast goose. When the meal was ready, we all served ourselves, ate cross-legged on the floor, and were indeed glad to be together (page 70).

The warm, cheery atmosphere lingered on into the night as we made the most of this rare moment of comradeship as a group. Then we guests shared the wonderful experience of making our way under a full moon in view of Mount McKinley back those two miles to our waiting trucks.

The next day at Ermine Lake, 55 people gathered for another festival—the wedding of George Menard and Betty Ivanoff. George, a past Peace Corps volunteer in Nepal, and Betty, a computer programmer for an oil company, had met in Anchorage at a mountaineering club meeting. Shortly after that Betty became the first Eskimo woman to climb Mount McKinley.

Guests on snowshoes began arriving early

PEEPHOLE ON A FROSTY WORLD, *our window frames Harlow, Pete, and Vin. They look out onto a spectacular view of Mount McKinley (following pages). In that snowy fastness, Pete wants to build overnight cabins and set up ski tours for visitors. Thus we hope to earn the money necessary for year-round living in the wild.*

JOHN METZGER (ABOVE) AND PETER ROBINSON

IN THE WONDROUS REALM *of Mount McKinley, Pete (above) and a party of our friends (right) seek the future. We don't like to think of Alaska as a "last frontier" but as a "new frontier." It's a place where we find the adventure of discovery—the discovery of who we really are and what the unexploited earth can give.*

for the outdoor wedding to tramp down a clearing beside the lake. With the temperature hovering at five below zero and the north wind gusting, the Reverend Dick Madden kept the simple ceremony brief—reading by the light of a lantern as the Alaskan dusk closed in around us.

Betty, smiling in the fur parka made by her Eskimo mother, warmed our hearts; we kept the rest of ourselves warm by huddling close.

The pronouncement that they were husband and wife was responded to by a kiss on George and Betty's part, the thumping applause of mittens, and a few hoots on our part.

Finally, in moonlight so bright we could see the mountain peaks, we all trudged back across frozen Ermine Lake to Kent and Martha Smith's lodge. There we witnessed the christening of tiny Gina, the baby daughter of Dave and Sally Johnston.

When it was all over, we asked Mr. Madden to comment on his day's work.

"Of all the tasks a minister is called on to perform," the clergyman said, "none please me more than weddings and christenings. It is an honor and a joy to do both the same day. And I must say," he added with a smile, "today I've seen the coldest wedding and the warmest hearts!" □

High, Wild World of the Vicuña

ARTICLE AND PHOTOGRAPHS BY
WILLIAM L. FRANKLIN

SINCE FROZEN DAWN we had huddled in a thatched observation shack on the rolling grasslands of the altiplano, two and a half miles above the sea in Peru's Andes. I had come 5,000 miles to observe the behavior of the vicuña, that most beautiful and graceful member of the camel family, and I had not been disappointed. For hours a family group had browsed near us. Now, in the bright spring afternoon, they acted out before me the seemingly cruel rite upon which the survival of their kind depends.

There were seven in the group: one male, his harem of five, all pregnant, and a lovely female that was almost a year old. No other young were there. As I watched I found out why. The young female was being expelled from the family. Despite pathetic gestures of supplication, in which she bent her knees and arched her long neck in total submissiveness, both parents were rejecting her. Suddenly the male attacked her violently, driving her away from the others.

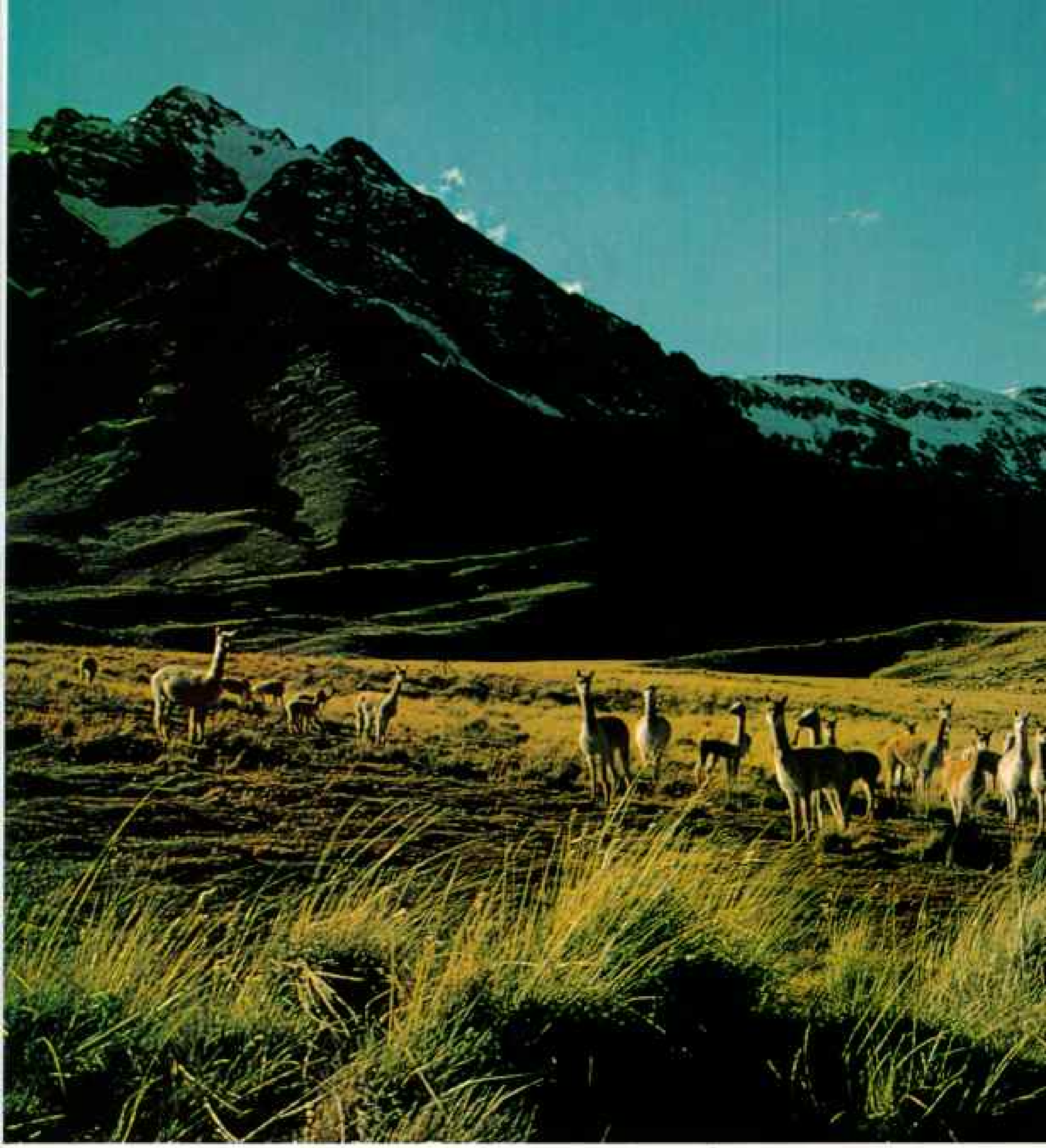
She ran to a hilltop, stopped to look back at her family, now placidly grazing, then turned and walked away. I followed her until night began its slow ascent of the mountains. She did not look back again. She never returned.

Thus the last of the previous year's young was exiled, to find refuge in the clan of another male. When the females of her family group dropped their *crias*, or babies, there would be food enough for all in the carefully defined territory ruled by the young female's sire.

Too cold and dry for crops, these high plains today support sheep and two domesticated cousins of the camel: the cargo-carrying llamas and the wool-bearing alpacas. This land has always been the natural habitat of their wild relatives, the llamalike guanaco and the dainty white-bibbed, fleet-footed vicuña. The camel family evolved on the grasslands of North America millions of years ago and migrated to Asia and South America. Only two species exist outside the New World: the two-humped Bactrian camel of central Asia and the familiar one-humped camel of North Africa and southwest Asia.

The animals we were watching formed part of a herd that inhabits the Pampa Galeras National Vicuña Reserve and adjacent rangelands. Peru established the 15,000-acre reserve in 1966 in an attempt to save these animals, once abundant in the central Andes and now an endangered species.

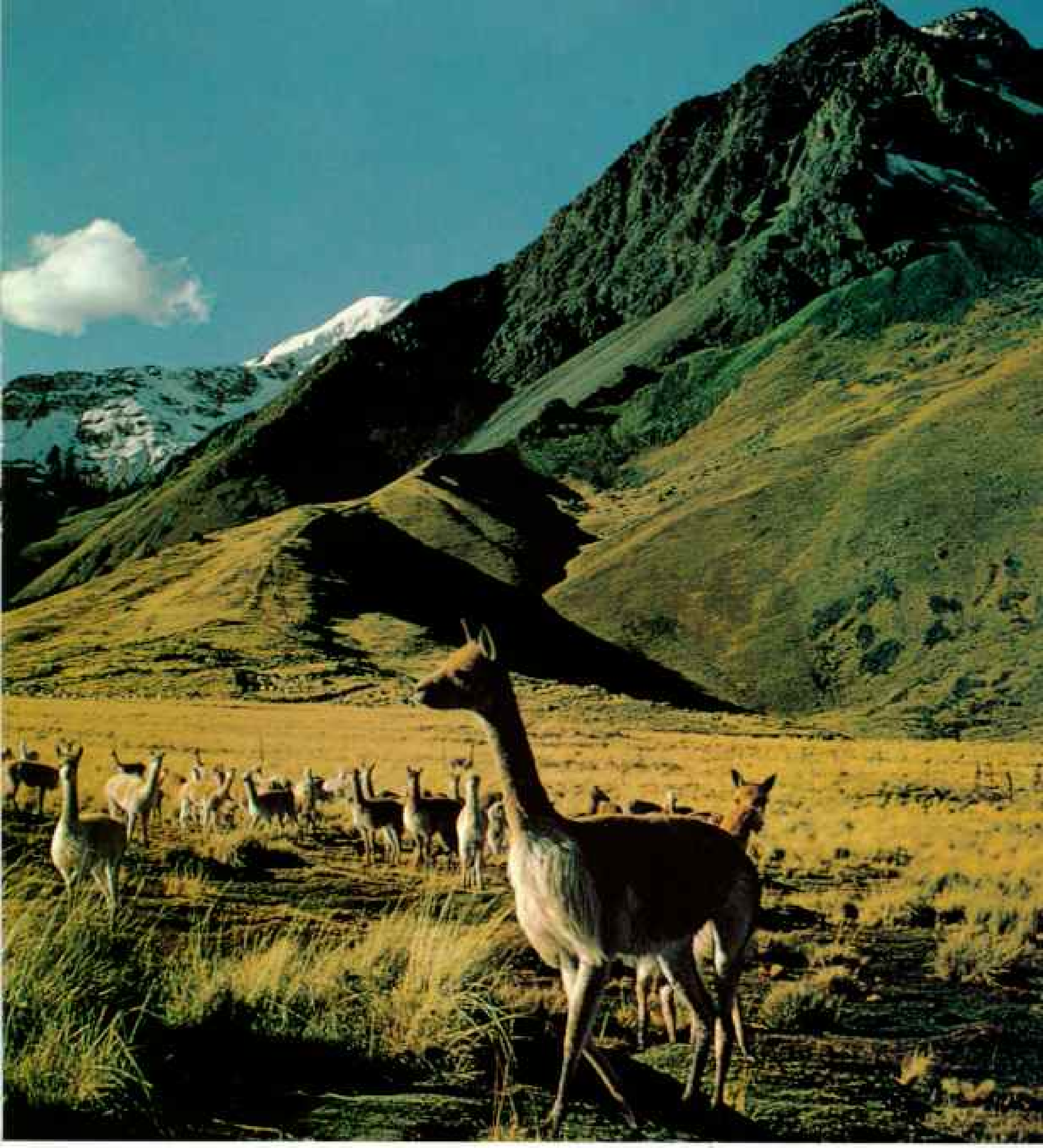
Graceful Andean, a vicuña shows its golden fleece at sunset. In its cloud-scraping abode this little cousin of the camel has few enemies: the fox, puma, dog, and man—the deadliest. Mankind's lust for its silky wool has reduced the vicuña population—which once may have exceeded a million—to no more than 15,000. Happily, new preserves and laws promise to halt the gentle creature's slide toward oblivion.



Early accounts indicate that vicuñas numbered more than a million prior to the Spanish conquest. The Europeans slaughtered them by tens of thousands. In 1825 Simón Bolívar, South America's great liberator, declared vicuña hunting illegal in Peru. But the ban could not be enforced. The killing continued; the animals' wool brought a high price.

Today there are only 10,000 to 15,000 vicuñas. Most of these are in Peru. Some 6,500 roam the Pampa Galeras region. That herd, protected by armed wardens, is growing. The vicuña seems to have been pulled back from the brink of extinction.

I went to Peru in 1968 to begin a three-year study of the vicuña. My adviser on the project was Dr. Allen W. Stokes of Utah State University, and my sponsors were the Conservation Foundation, the World Wildlife Fund, the Peruvian Ministry of Agriculture, and Utah State University. My research would serve the Peruvian Government in



further planning for the conservation and management of this imperiled species.

In the three-room prefabricated headquarters at the Pampa Galeras Reserve our day began at 4:30 a.m. We lit lanterns, and the smell of kerosene permeated the place as Primus stoves were pumped up to heat water from the rushing stream at our door. Feliciano Mendoza, my assistant and close friend, went out in the icy dawn to warm the engine of my much-used jeep with a teakettle

Neck and ears erect, wary vicuñas graze the *puna,* a high, arid land between timberline and snow line. In the wild, mature males stake out large territories for their families. At Peru's National Cameloid Center, these animals have lost such territoriality. Some have interbred with the closely related domestic alpacas to produce paco-vicuñas, which grow much longer wool than the vicuñas', and nearly as fine. Slow growth limits shearing to about once every two years.

Downy captive, a baby vicuña, or *cria*, accepts primping by Señora Emma Salinas de Paredes. Fearing the vicuña's decline, her late husband, Don Francisco Paredes, began raising vicuñas at Cala Cala, the family ranch, some 50 years ago. Vicuñas rely on speed for escape, and even a minutes-old cria can outrun a man. Hunters once took a high toll of the young for their pelts, prized for softness. The author's wife and daughter examine a bedspread that cost the lives of 156 crias (**right**).

Old rites for the newborn: Indian shepherds of the high country still observe the traditional ceremony of regularly smearing an infant with vicuña bone marrow "so he will run like the vicuña" (**above**). To ensure healthy offspring, pregnant women also massage the valued grease on their abdomens, especially as the day of birth draws near. Generally, Indians do not kill vicuñas, but gather marrow from leg bones of those that have died naturally (**below**).

of hot water so it could be coaxed into life.

Always we raced the sun. To record the full span of the vicuña's daily activities, we had to reach our chosen outlook post before daylight. Vicuñas are commuters, in a sense: They bed down and graze in separate areas. I wanted to observe them rising from sleep near the ridgetops and moving down to the valley floors to feed until late in the day, when they returned to their high resting places.

Each morning I parked my jeep beside a peripheral road (no roads exist in the reserve itself) and hiked to one of our four observation huts. Scattered clusters of vicuñas, each group averaging six to eight females and young under command of a single territorial male, grazed the grassy slopes. Long-necked, quick-footed, curious, and alert, they are delightful animals to live among and watch.

Watching was my main occupation, and I enjoyed my lonely vigils under the vast Andean sky. I recorded the details of vicuña life—the daily movements that center on eating, the seasonal mating and giving birth. Most important, I studied the fascinating social organization of this species, which depends so strikingly on the dominance of the group's only adult male.

One clear, cool February morning—summer, south of the Equator—I sat perched on a knoll at the Achupilla hut. Feliciano and I were silent, feeling the serenity of the day. Puffy clouds drifted across a deep-blue sky. The dry *ichu* grasses rustled in the pampa wind. Occasionally I heard the *puco-puco* trill of a distant bird.

The blue sky did not deceive us. Summer is the rainy season. By noon the clouds would blot out the sun. I was never without rain gear and carried "magic" amulets to protect me against lightning.

In the Andes lightning is a major peril. It seems to ignore the general rule of hitting only the high spots, and spares neither man nor beast. On the reserve during the summers of 1970 and '71 we found 20 vicuñas killed by lightning. In separate strikes, fatal bolts hit 7 cows, 18 sheep, 11 llamas, and a shepherdess. Incidentally, if you get hit by lightning and live to tell about it, a sip of vicuña blood supposedly will restore you to full health.

My field lunch of raw carrots, alpaca jerky, and salty goat cheese was nearly finished when Feliciano and I were jolted by a brilliant flash and a mighty clap of thunder. We soon discovered that the roof had been ripped off the Fortaleza observation post across the valley. Later, on the way home, we found the ground churned up around the Fortaleza hut as if by a hundred gophers.

Back at headquarters we received a hero's welcome. Our friends there had thought we

Tail raised to signal hostility, a male patriarch pursues bachelors that dared intrude into his well-defined home territory. Racing at perhaps thirty miles an hour, he drives

were at Fortaleza, and one of the game guards on patrol had heard a shepherd exclaim, after the lightning struck: *"¡Ya se fué el gringo!*—There went the gringo!"

Regardless of the danger, we were eager to get out among the animals during these rainy months. Summer awakens the pampa, brightening the drab landscape with green grass. And it is the season for vicuña birth and breeding. Some eleven months after mating, the female drops her single cria, only a few weeks before she mates again.

The hour of birth, I learned, is critical. A cria born during the afternoon rains gets soaked, then chilled by the cold of night. It will usually die. But behavioral adaptation protects the population. Nearly all the births we observed occurred between eight and ten-thirty in the morning.

Newborn Animals Ready to Scamper

The highland Indians take it as a portent of good fortune to witness the birth of a vicuña. The female gives birth standing up and often goes right on feeding. I was lucky enough to capture and tag a few newly dropped crias, but it was never easy. One March morning, scanning the rangeland with binoculars, I saw that a female vicuña was giving birth three-quarters of a mile away. I dropped my notebook and ran. When I reached the scene, the mother and her still-staggering infant took to their heels and left me stumbling far behind. In a race, I was no match even for a minutes-old vicuña, especially at 13,000 feet.

But even more interesting than the vicuña's life cycle is its structured society. After only a few days in the field I began to grasp its basic principle. The territorial male controls the group with firm discipline. He has to, because vicuñas are among the very few hoofed animals in the world that occupy and actively defend a year-round territory.

Each family, in effect, was socially isolated. Vital activities such as feeding, sleeping, mating, and birth took place virtually free from interference by outside animals.

It was the male who chose the living area and established the boundaries and size of his territory. It was he who decided whether an adult female attempting to join his family would be accepted. And if a resident female tried to leave the group, it was the male who let her go or compelled her to remain.

Since territorial males and their mates took over the choicest feeding areas, what, I wondered, became of the excess males? To find out, I followed a bachelor band as it lazed along on the fringes of the family feeding areas. Excluded from territorial zones, these all-male groups, usually 15 to 25 strong, confined themselves to less desirable land.

the interlopers from among his clan of as many as eight females and their crias. He rules the family, determining its membership and leading daily movements.

Furry family of New World camels includes the domestic llama, far left, whose large size makes it an Andean beast of burden. Next in line, a recently shorn domestic alpaca provides plentiful wool. Then come its kin, the hybrid paco-vicuña and the wild vicuña, whose fleece has sold for $25 a pound, five times that of cashmere. The wild guanaco is the only other South American relative.

Democracy speaks: A centuries-old system of town forums brings hatted Peruvian shepherds to exchange views with conservationists explaining the Pampa Galeras National Vicuña Reserve (**left**). This 15,000-acre haven helps shield 6,500 vicuñas from poachers and the competition of domestic grazers. It absorbed the rangelands of several herders, who moved their sheep to other areas.

The vicuñas' remarkable way of marking and defending their private preserves seals their boundaries almost as effectively as a fence. Adjoining territories fit the vicuña families together as a great social mosaic spreading across the pampa. Sometimes creek beds or washes serve as dividing lines. But over most of the region, natural landmarks are lacking. So the vicuñas stake out their domains—plots of 20 to 75 acres—in a way that keeps both family members and intruders constantly oriented. They defecate and urinate on established dung piles scattered throughout their home territories. The male of each group makes these markings to let other animals know that this is his domain.

Many other species of animals mark off their territory by rubbing scent glands on plants or ground, or by their distinctively scented urine and defecation, for the purpose of keeping outsiders out. With the vicuñas I observed, the excrement piles were serving also to keep the insiders in. Each pile, with its familiar scent, signaled to the residents of a given area that they were on their own turf.

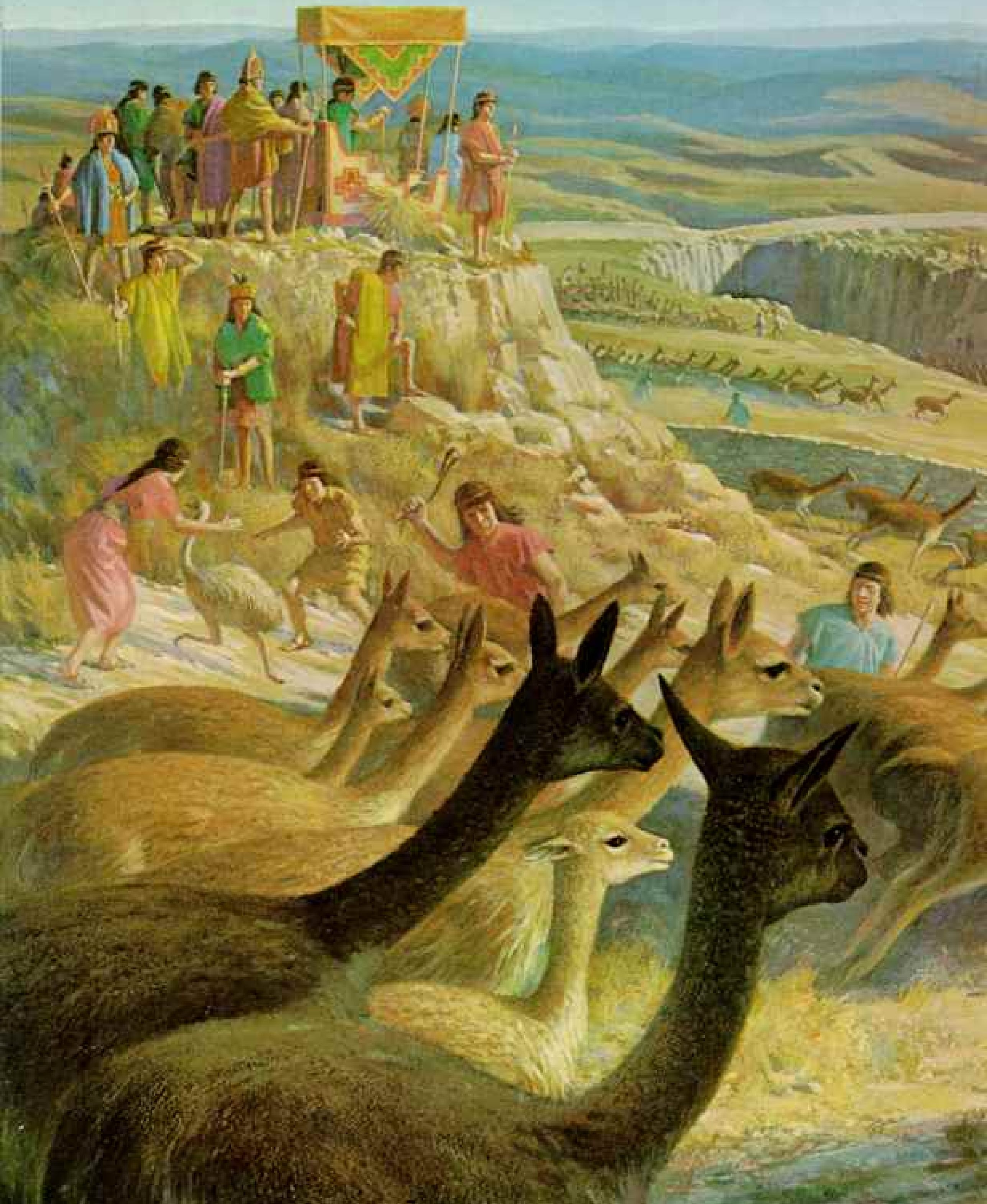
Trespassers Get a Violent Reception

The dung piles alone do not serve to keep members of other groups off the family land. If the resident group is away, perhaps to drink at a distant stream, others do not hesitate to invade their territory.

I remember watching one afternoon as the young of a male we called Head Honcho romped about in a playful game of chase. Honcho grazed nonchalantly, slightly apart from his family. Some disturbance brought his head erect, ears perked forward, front legs drawn together.

Frozen in stillness, his white bib waving in the breeze, he glared toward a vicuña group grazing some 200 yards away. Three or four of the neighbor females negligently moved into his domain. Honcho trotted toward them, then broke into a loping run, his long neck nearly horizontal, his eyes dead ahead.

Suddenly Honcho drew up at a large dung pile near his own border. In almost ritual fashion he smelled it, kneaded it with his front feet, made a quarter turn, positioned, and marked the spot. Glancing back at his own brood to make sure no other male threatened them, he turned and charged into the trespassers, sounding a high-pitched screech, chasing the frightened females in erratic circles, forcing them into frantic retreat.



Under the watchful gaze of their ruler, Indians of the Inca nation sweep across an Andean plain of five centuries ago in a gigantic *chaco*—the royal hunt. Thousands of beaters form an ever-shrinking noose, driving all wildlife within a hundred square miles toward a vast stone-walled

PAINTING BY STAFF ARTIST NED M. SEIDLER

corral. Counters record the variety and number of animals taken. In the distant box canyon, hunters kill the weak and the old for food, but spare most vicuñas, which they shear and release unhurt. The prized fleece is spun and woven into a royal cloth, forbidden to commoners on pain of death.

Despite the evident dominance of the male, experienced females exerted some control of the group. Honcho's eldest mate was one such, an unlovely one-eyed creature, but wiser than the rest. During the dry season, it was she who initiated brief daily excursions out of the home territory in search of water.

Sadly, not long before my study ended, when her newest cria was seven months old, we found One Eye dead at the bottom of a wash. Both her forelegs were broken. I speculated that a neighboring male vicuña had chased her into unfamiliar terrain and a fatal fall. Two weeks later, her cria mysteriously disappeared from the family group.

Most crias leave the group by being rejected, like the young female I'd seen early in my study. Since then, I'd observed the same brutal expulsion enforced on each of the young in turn. The males were exiled at about eight months of age, the females near the end of their first year.

But it was not only the young that were rejected. The territorial male, unlike those of many hoofed species, often turns away females that try to join him. Thus he controls not only much of the behavior of his group, but also its size. In this ungenerous land, where pasture is never more than barely sufficient, it is essential that the population of a permanent, well-defined grazing area be limited to the number of animals it can support. And that, through long genetic selection, is exactly what the behavior of the male promotes. If he drives away his young and rebuffs new mates, it is to help guarantee the survival of his group. That is the way of his world.

Man Prized Vicuñas Before Inca Times

For millenniums the world of the vicuñas and that of Andean Indians have been closely interlocked. Man's covetous quest for vicuña wool, one of the world's finest, has given the animals a special standing in the Andean economy since pre-Inca times. In the Sumbay caves of southern Peru there are ancient wall paintings that show hunting scenes in which vicuñas and guanacos were the main victims. The hunters of that preagricultural society knew the value of vicuña meat and wool.

Hunters of a later time, though still before the Incas, built traps for the animals here in my own study region. Game guard Saturno Torres Blanco showed me two forms never before described. From a hilltop he pointed out a stone structure in the valley below.

"Look," he said, "the stone wall forms a V,

Cast out at the age of one, a female flees from her kicking, biting father. His mates placidly watch the abrupt send-off, which regulates clan size and thus guards against overgrazing. Expelled females join other families to mate and give birth; young males may roam in bachelor

into which the animals were chased. Notice that there are breaks in the wall. Do you see what lies behind these breaks? Pits! The running animals would fall into them, and *snap!* Their forelegs would break.

"That is a kill trap. But up there is a live trap, a walled enclosure in which vicuñas were caught and sheared, then released."

The Incas some five centuries ago organized great hunts in which thousands of the animals were captured by a great ring of hunters (painting, pages 86-7). The surplus males and old or inferior animals were killed. The rest were shorn and set free to graze unmolested for four years, until their wool and their numbers had been replenished.

Conservation was the rule then, a rule strictly enforced: None but those of royal birth might wear the precious wool. Violators were executed. The Spaniards changed all that, and slaughter continued until recent times. But the people of the altiplano retained their fondness and respect for the animals. To this day most resent poachers who occasionally invade the region to kill vicuñas—something they rarely do themselves.

Yet the Indians prize parts of the animals, and credit them with magic properties. When Feliciano and I one afternoon encountered two highland sheepherders chin to chin in noisy dispute over the body of a newborn cría, I began to learn how intimately the vicuña is involved with Andean custom and folklore.

My understanding of the local Quechua dialect is sketchy, so Feliciano interpreted the loud diatribes.

"They each claim the carcass," he said.

"There isn't enough meat or skin to be worth that much rage," I told him.

"Of course not!" said Feliciano. "But it is the stomach they want."

Fleetness Stirs Yearning of Indians

My companion explained that the local people use the baby vicuña stomach for curdling milk to make cheese. They regard the flavor of such cheese as especially delectable and of a superior freshness. The handsome bib of white hair that hangs down from the vicuña's lower neck and chest is favored for making the sack that carries the narcotic coca leaves the Indians habitually chew. And inhaling the smoke from bib hairs, they think, will ward off illness.

"*¡Para que corra como la vicuña!*—May he run like the vicuña!"—is the mountain people's ardent wish. To bestow the animal's speed and endurance on their children, the

bands for several years, then establish their own territories and find mates.

Dawn-to-dusk vicuña vigils for more than three years occupied the ecologist-author, right, with "Puppy" as his constant companion. Here Peruvian game guard Saturno Torres Blanco lends assistance.

parents bathe and rub an infant's entire body with warm grease extracted from the marrow of the vicuña's long leg bones (page 81). An expectant mother, with the same aim, rubs her abdomen with the marrow grease.

Before leaving the Andes, I found evidence in centers of civilization that the vicuña's future is brightening. In La Paz, Bolivia, where skins were once sold in great quantities, there remains only a sparse selection of vicuña rugs, sweaters, and bedcovers. These had gone on the market before new laws banning sales became effective, and before foreign countries, notably the United States and Britain, had prohibited import of any vicuña products.

The goods were beautiful, but I found them repellent. I couldn't imagine sleeping soundly under the bedspread I saw that was made from the head skins of 136 crias (page 81). Vicuña wool looks best on vicuñas.

Rancher's Project Wins National Acclaim

Apart from the reduction in poaching activities, there are current attempts to bring the vicuña into the economy as the protected wool producers they were in Inca times. Perhaps the most notable experiment is at the Cala Cala vicuña hacienda in the tall-grass Peruvian highlands north of Lake Titicaca near the Bolivian frontier.* Its owner, the late Don Francisco Paredes, was a man of vision.

Alarmed at the decline in numbers of the once-numerous vicuñas on his sheep and cattle ranch, Señor Paredes determined to try to raise them in captivity. He began with 20 vicuñas in a stone corral. Fifty years later he had about 500, and a presidential award for distinguished service to his country.

Seeking to increase wool production and create a new national product, Don Francisco tried crossbreeding vicuñas with alpacas. The vicuña's biennial wool yield is only 1/4 to 1/2 pound, while the alpaca's is four to six pounds. The paco-vicuña combined the fine quality of vicuña wool and the more abundant, longer fibers of alpaca wool. Research on paco-vicuña breeding continues at the National Camelоid Center, between Lake Titicaca and Cuzco (map, page 77).†

Señor Paredes died shortly before my arrival in Peru, but I was privileged to watch the unforgettable vicuña roundups at Cala Cala as a guest of Señora Emma Salinas de Paredes (page 80). The small corral her husband had built had been replaced by a 5,000-acre enclosure ringed by smaller paddocks. Captive, but not domesticated, the vicuñas were free to roam.

Herd of Hundreds Thunders Into Corral

To witness the annual roundup at Cala Cala was to relive the Inca past in a wild pageant of racing animals, whirling dust, cracking whips, and shouting herders.

Indians had gathered from miles around, the women in round felt hats and multi-layered long skirts, the men in loose-fitting pants of heavy wool. Tire-tread sandals protected weathered feet.

The vicuñas flowed down the hillsides, pressed on by the converging human chain. Whistles and yells blended with the drum of hoofs. Dust blurred vision and clogged nostrils. Then, as the last of some 500 animals thundered down the narrowing corridor into the holding corral, the gates were closed and tallying and sorting began.

Later, after a feast of roast lamb, potatoes, and cheese, the Indians kept the night alive with dancing and music that throbbed through the hacienda grounds until dawn. To them, this annual *chaco* is the happiest of times. They love the vicuña and the link with the past that the great roundup offers.

These people, who live in such harmony with their harsh environment, have long resisted change. They hold to many customs and traditions of Inca times. And they, like the vicuña, have been victimized by civilization. Perhaps that is why they care so deeply for this wild highland creature, which they venerate as a legacy from their great forebears.

If civilized man can learn to see the vicuña through Indian eyes, that legacy will be preserved forever. □

*See pages 78-79, 114-115, and 119 of Mary and Laurance Rockefeller's report on South American park developments, "Parks, Plans, and People," in the January 1967 NATIONAL GEOGRAPHIC.

†"Titicaca, Abode of the Sun," by Luis Marden, appeared in the February 1971 GEOGRAPHIC, and "The Five Worlds of Peru," by Kenneth F. Weaver, was published in the February 1964 issue.

Walled in by stones and men, Cala Cala's vicuñas and paco-vicuñas funnel into a corral to be counted and sorted. Both this annual roundup and the all-night fiesta that follows recall Inca tradition. They also demonstrate the Indians' bond to an animal that man now seeks to preserve, after centuries of indifference to its survival.

A SCIENTIST VISITS SOME OF THE WORLD'S OLDEST PEOPLE

"Every Day Is a Gift When You Are Over 100"

By ALEXANDER LEAF, M.D.

Photographs by JOHN LAUNOIS

BLACK STAR

IN THE LITTLE VILLAGE of Kutol, in the foothills of the Caucasus Mountains of the southern U.S.S.R., lives a sprightly lady named Khfaf Lasuria. She is small—not five feet tall—white-haired, and full of humor. I visited her one spring morning and found her in her garden, surrounded by children, pigs, and chickens. I was greeted in warm Georgian fashion, and we toasted each other first with vodka and then with wine as we talked.

She talked about her life, the present and the past, about things she remembered. She had a lot to tell because her memory was good—and she was more than 130 years old.

She told me about her first marriage at age 16; her husband died during an epidemic some twenty years later, and she married again when she was about 50. A son lives in the stone house next to hers. He is 82 years old.

She remembered as a recent event the big snowfall in 1910. "My son was already an adult then, and I was about 70. The snow was more than two meters deep, and I helped him shovel it from the roof."

The present? She was just back from a visit to relatives in a distant village. She simply got on the bus alone and went visiting. She had worked on the local collective farm since it was formed some 40 years ago, retiring only in 1970; in the 1940's, when she was already more than 100 years old, she had held the record as the farm's fastest tea-leaf picker.

As she sat talking, she smoked cigarettes, inhaling each puff. She had started smoking in 1910, and has consumed about a pack a day for 62 years.

As a physician and teacher in a large general hospital, I see many of the medical misfortunes that befall the elderly, and have grown interested in how a healthy, vigorous old age can be attained. Today more than twenty million Americans are age 65 and older—nearly 10 percent of our population. Yet our understanding of aging is minimal, especially in explaining the factors that produce a Khfaf Lasuria in one instance and wasting senility and sickness in another.

Villages Where Time Moves Kindly

There are places in the world where people are alleged to live much longer and remain more vigorous in old age than in most modern societies. During the past two years, taking advantage of a sabbatical and of support from the National Geographic Society, I have visited the best known of these regions, all relatively remote and mountainous: the Andean village of Vilcabamba in Ecuador, the land of Hunza in the Karakoram Range in Pakistani-controlled Kashmir, and Abkhazia in the Georgian Soviet Socialist Republic in the southern Soviet Union (map, page 96)—where I met Khfaf Lasuria, oldest of the many centenarians I interviewed. Other research groups in the three areas generously gave me access to their information, some representing years of study.

Serene at the summit of a long life, Khfaf Lasuria—more than 130 years old—watches the world from the porch of her home in the Soviet Union's Abkhazia, an autonomous republic in the Georgian S.S.R. She was nudged into retirement from her job as a tea picker two years earlier. Still active around the house, Mrs. Lasuria enjoys a little vodka before breakfast and a daily pack of cigarettes.

Guiding a favorite mount through the tea plantation where he labored most of his life, 100-year-old Temur Tarba (**above**) displays the superb horsemanship characteristic of Abkhazians. Among the medals he wears is the prized "Hero of Labor" award.

Bracing dip holds the key to longevity, believes Markhti Tarkil, who has taken a daily swim winter and summer during most of his 104 years (**right**). To get to the chill stream from his home in Duripshi, Abkhazia, he has to scramble down a steep half-mile-long trail.

"I was amazed at such exertion by a man over a hundred," says author Alexander Leaf, "but wherever I went, the level of physical activity among such old people was high."

Testing a centenarian's reflexes, Dr. Alexander Leaf pursues a lifelong quest to fathom the mysteries of the elderly. He is Chief of Medical Services at Massachusetts General Hospital and a professor at Harvard University Medical School, both in Boston. To gather material for this article, Dr. Leaf traveled to three areas of the world where people are known to live to extreme ages: Vilcabamba in Ecuador, the Caucasus, and Hunza.

FERTILE GARDEN of tobacco, tea, and citrus, Abkhazia lies in the wettest region of the Soviet Union.

CLIFFSIDE REALM of Hunza, once a princely state, today is part of Pakistani-controlled Kashmir.

RUGGED ANDEAN TERRAIN and a nearly impassable road keep Ecuador's tiny Vilcabamba isolated.

BASTIONS OF LONGEVITY, Vilcabamba, Abkhazia, and Hunza contain unusually high numbers of elderly, vigorous people—a phenomenon that excites the curiosity of gerontologists.

A primary question plagues all who take to the field to study longevity: How can you be sure of the ages of those who claim to be centenarians? There is no way to "date" a living human being.

In Vilcabamba the community was Catholic, and church baptismal records confirmed some of the ages claimed there. Some could also be supported by the number of generations of offspring, and by testimony from friends and relatives of similar age. A census taken in 1971 showed that Vilcabamba, with a population of only 819, had nine individuals above the age of 100. In the United States, by comparison, the figure is about three centenarians per 100,000 population.

Memories Constitute Hunza's Records

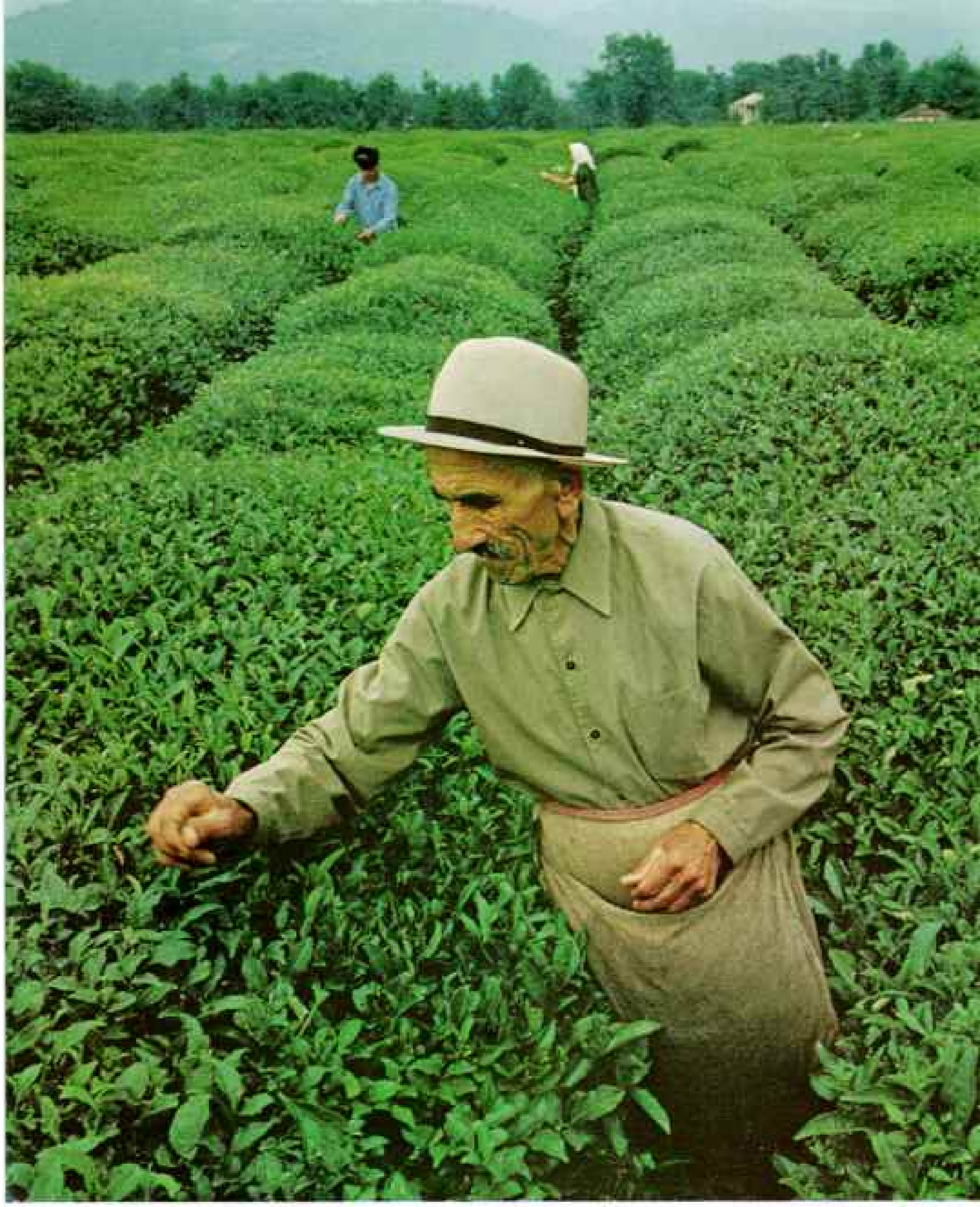
In Hunza (population 40,000) the dating problem was particularly difficult. Hunzukuts live in high valleys near the China and Afghanistan borders, so remote that their language, Burushaski, bears no relationship to any other language on earth. There is no written form, so no records exist. In some instances, however, the Mir (ruler) of Hunza could, from personal knowledge of his state's history, verify ages.

In short, I was not able to confirm exact ages in Hunza. Yet I had the definite impression of an unusual number of very vigorous old folk clambering over the steep slopes that make up this mountainous land. It was the fitness of many of the elderly rather than their extreme ages that impressed me.

The largest number of people above 100 years old, and the best documented, exists in the Caucasus. The documentation is due in large part to the work of Professor G. E. Pitzkhelauri, head of the gerontological center in Tbilisi, Georgia, who told me of the methods he uses to validate ages.

First, documents of dates of birth hold highest

Wearing his 102 years lightly, Tandel Tchopia of Abkhazia dances nimbly as his neighbors clap.



Still a working man, 98-year-old Tikhed Gunba gathers tea leaves near Duripshi. Gunba, whose father lived to 125, doesn't smoke, but reports a fondness for wine. His resting blood pressure was a creditable 104/72. "He has a lot of mileage left," Dr. Leaf says.

credence. Church baptismal and birth records are the main source, but other documents are also useful. These include passports, papers such as letters, and sometimes writings or even carvings on doors and walls that recorded a birth in the family.

Second, age at marriage (usually well remembered), time until birth of children, and the present ages of these offspring, which can usually be more easily verified.

Third, memories of outstanding events, such as war service, changes in the czarist

regimes, the Russian Revolution, the Russo-Turkish War, or outstanding local events—a drought or a heavy snow like the one Khfaf Lasuria remembered.

How reliable are the results obtained from the last two approaches? Professor Pitzkhelauri replied that 704 centenarians whose ages were known from birth records were also tested by questions. The results showed that nearly 95 percent of those tested by the questionnaire gave the correct age, and for the remainder it was within 5 percent of the correct age, and not more than ten years off the mark in any instance.

There is no baptismal record for Khfaf Lasuria. So as I talked to her, I kept doing mental arithmetic. I have said that she is more than 130; I should have said "at least." According to her account, her father lived to be 100 and her mother 101 or 102. She had seven sisters and three brothers, and is the only survivor. Her son, who was born when she was 52, is now 82 (arithmetic: 82 + 52 = 134). She was married the second time at age 50, at the time of the Turkish war—which ended 94 years ago in 1878 (50 + 94 = 144). When she was 20, her first husband almost left home to fight in the Crimean War of 1853-56 (118 + 20 = 138). She started smoking in 1910 when her younger brother died at age 60; he was some ten years younger than she (60 + 10 + 62 = 132). Her second husband, who was two years younger than she, died 28 to 30 years ago, when he was more than 100 (100 + 29 + 2 = 131).

My interview was conducted in such a way that it would have been difficult for each of these assessments to come out in such fair agreement unless a common thread of reality linked them. Mrs. Lasuria believes she is 141 years old; thus I would accept some age between 131 and 141.

Nip of Vodka Starts Each Day

Surprisingly robust for her age, Mrs. Lasuria told me that she drinks a small glass of vodka each morning before breakfast and has a glass of wine before her noon meal.

She ended our talk with a toast: "I want to drink to women all over the world . . . for them not to work too hard, and to be happy in their families."

In contrast to the isolated valleys of Vilcabamba and of Hunza, the Caucasus region covers a large area, including the Soviet republics of Georgia, Azerbaijan, and Armenia. The population is spread from the Black and Caspian seacoasts to mountain villages 3,000 to 4,500 feet above sea level.

A 1970 census placed the number of centenarians for the entire Caucasus region at 4,500 to 5,000. Of these, 1,844 live in Georgia, or 39 per 100,000 of population; 2,500 live in Azerbaijan, or 63 per 100,000.

Shirali Mislimov, acclaimed as the world's oldest living person at an alleged age of 167 years, resides in Azerbaijan, in the small village of Barzavu on the Iranian border. That

Taking a break from moderation, Georgians honor their elderly at a banquet of chicken, mutton, beef, goat cheese, bread, tomatoes, cucumbers, green onions, garlic, spicy sauces, and wine. Such feasts occur infrequently, however. Aged Georgians consume around 1,800 calories a day, 600 less than the U. S. National Academy of Sciences recommends for males over 55. In a Soviet study, the plasma cholesterol level of centenarians averaged less than half the accepted normal amount for Americans aged 50 to 60.

In the autumn of their long love, Karum Utiashvili, 95, clasps his 80-year-old wife, Keke (**above**), in an affectionate embrace ratified by the smiles of relatives and friends. Get married and extend your life, concludes Soviet gerontologist Dr. G. E. Pitzkhelauri after studying 15,000 elderly persons. He found, with few exceptions, that only the married reach advanced age.

area of the Soviet Union lies near the border and is closed to outsiders. Neither I nor any other Westerner that I know of has been granted permission to interview the man. His fragile health, Soviet officials say, prevents him from leaving his home village for interviews elsewhere.

Much of my research was done in a region within Georgia called Abkhazia. The peoples here are a mixture. The census identifies ten ethnic groups in a total population of almost half a million.

The old people are found in agrarian settings; many of the men have worked as hunters and shepherds as well as farmers. The standard of living is much higher than that of Vilcabamba or Hunza.

Since we are composed of what we eat and drink, I was particularly interested in dietary habits in my three study areas.

In 1968 a nutritional study published by the U. S. National Academy of Sciences made these recommendations for diet among people above age 55: For males, 2,400 calories, including 65 grams of protein; for females, 1,700 calories, with 55 grams of protein (28 grams equal an ounce).

In the United States, though, nearly everyone consumes more. A U. S. Department of Agriculture study lists average daily intake for Americans of all ages at 3,300 calories, with 100 grams of protein, 157 grams of fat, and 380 grams of carbohydrate.

Scant Diet Promotes Long Life?

By contrast, I found the diets of Vilcabamba and Hunza strikingly similar to each other—and substantially lower than the U. S. recommendations. In a survey of 55 adult males in Hunza, Pakistani nutritionist Dr. S. Maqsood Ali found an average caloric intake of 1,923, with 50 grams of protein, 36 grams of fat, and 354 grams of carbohydrate. Furthermore, meat and dairy products constitute only 1½ percent of the total. The absence of pastureland makes animal husbandry nearly impossible, and the few livestock are usually killed for food during the festival season in winter. Fats of animal origin are scarce; instead, oil obtained from apricot seeds is generally used for all culinary purposes.

Dr. Guillermo Vela of Quito found a strikingly low caloric consumption also among the elderly of Vilcabamba. The average daily diet provided 1,200 calories. The daily protein intake was 35 to 38 grams, and of fat only 12 to 19 grams; 200 to 260 grams of carbohydrate completed the diet. Protein and fat again were largely of vegetable origin, with only some 12 grams of protein daily from animal sources. Needless to say, one sees no obesity among the elderly in either Vilcabamba or Hunza; neither were there signs of undernutrition.

The weight of current medical opinion would concur that a diet such as described for Hunza and Vilcabamba would delay development of atherosclerosis—that is, fatty deterioration of arteries of the heart.

Georgians Muddle the Myth

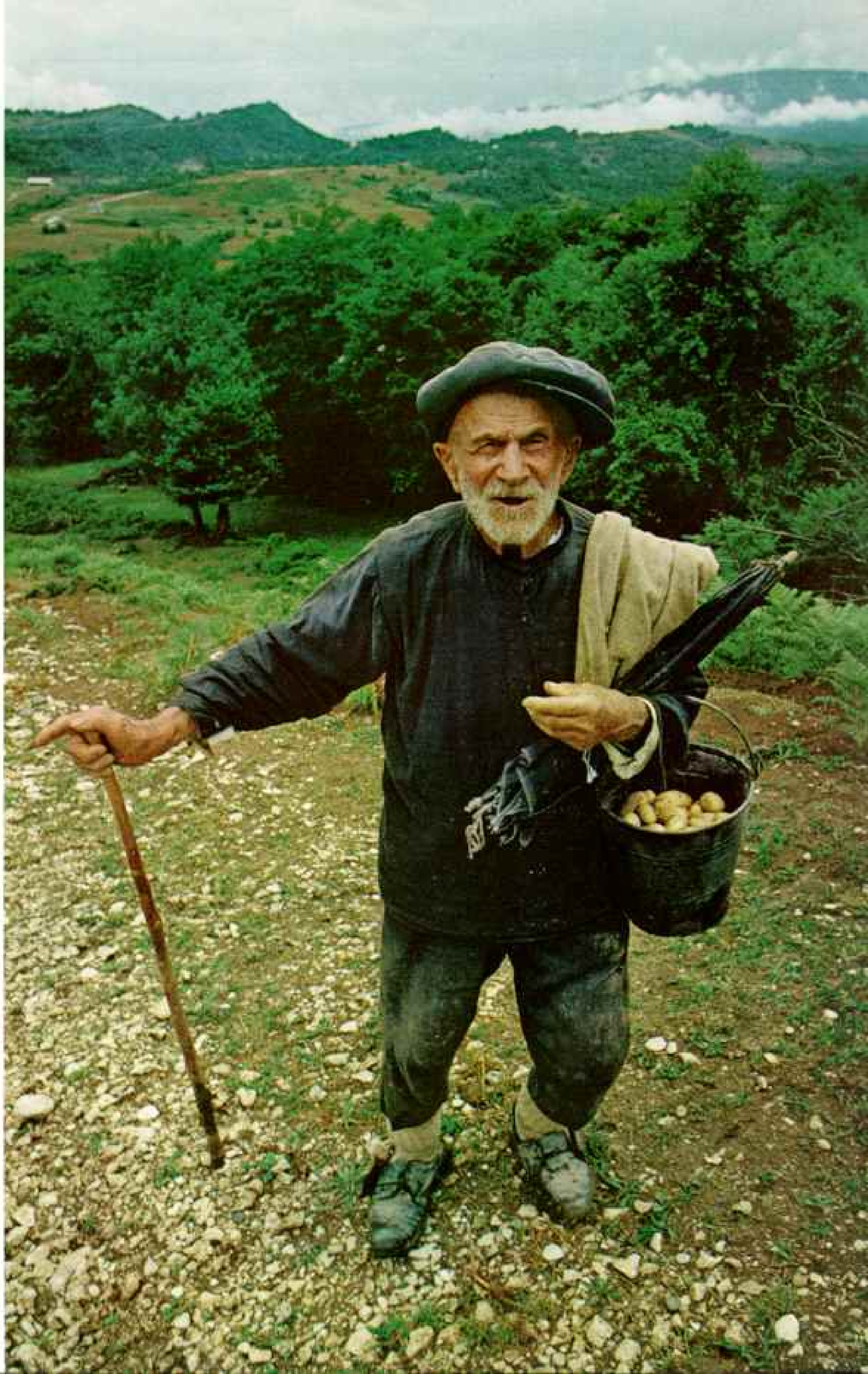
My confidence in the importance to health and longevity of a low-animal-fat, low-cholesterol, low-caloric diet was somewhat shaken, however, by eating habits in the Caucasus. There Dr. Pitzkhelauri and a colleague, Dr. Deli Dzhorbenadze, have studied the dietary habits of 1,000 persons above the age of 80, including more than 100 centenarians. The old people consume 1,700 to 1,900 calories daily, considerably more than do most people of such advanced age.

Sixty percent ate a mixed diet of milk, vegetables, meats, and fruits. Seventy percent of the calories were of vegetable origin and the remainder from meat and dairy products. Seventy to 90 grams of protein were included in the diets. Milk was a main source of protein; sour milk and cheese were widely used at all meals in all seasons. Georgian cheeses are low in fat content, however, so that the daily fat intake was only 40 to 60 grams.

Bread provides the major source of carbohydrate. In central Georgia, marvelous flat, pointed loaves—two feet long and curled upward at one end—are baked in an outside oven and stacked, still crisp and warm, on the table. In the west we also saw *abusta*, a boiled, unflavored cornmeal-mush patty. Dipped into a variety of sauces spiced with sharp red pepper, it is eaten with the fingers.

(Continued on page 108)

Indefatigable at age 117, Gabriel Chapnian carries a pail of newly harvested potatoes home for lunch up an Abkhazian hill that exhausted the author. The lifelong farmer continues to work half a day in the fields. His prescription for longevity: "Active physical work, and a moderate interest in alcohol and the ladies."



R. HENRIQUES, TASS FROM SOVFOTO

Oldest living person? If Shirali Mislimov was born in 1805, as Soviet gerontologists maintain, he is now in his 168th year. The old man, here listening to a transistor radio, lives in the village of Barzavu in Azerbaijan, west of the Caspian Sea. Authorities have permitted no Western journalists or medical men to interview him, and they judge him too frail to travel. Even so, he still rides horseback and tends an orchard he tells of planting in the 1870's. Mislimov says that he married his 120-year-old wife 102 years ago.

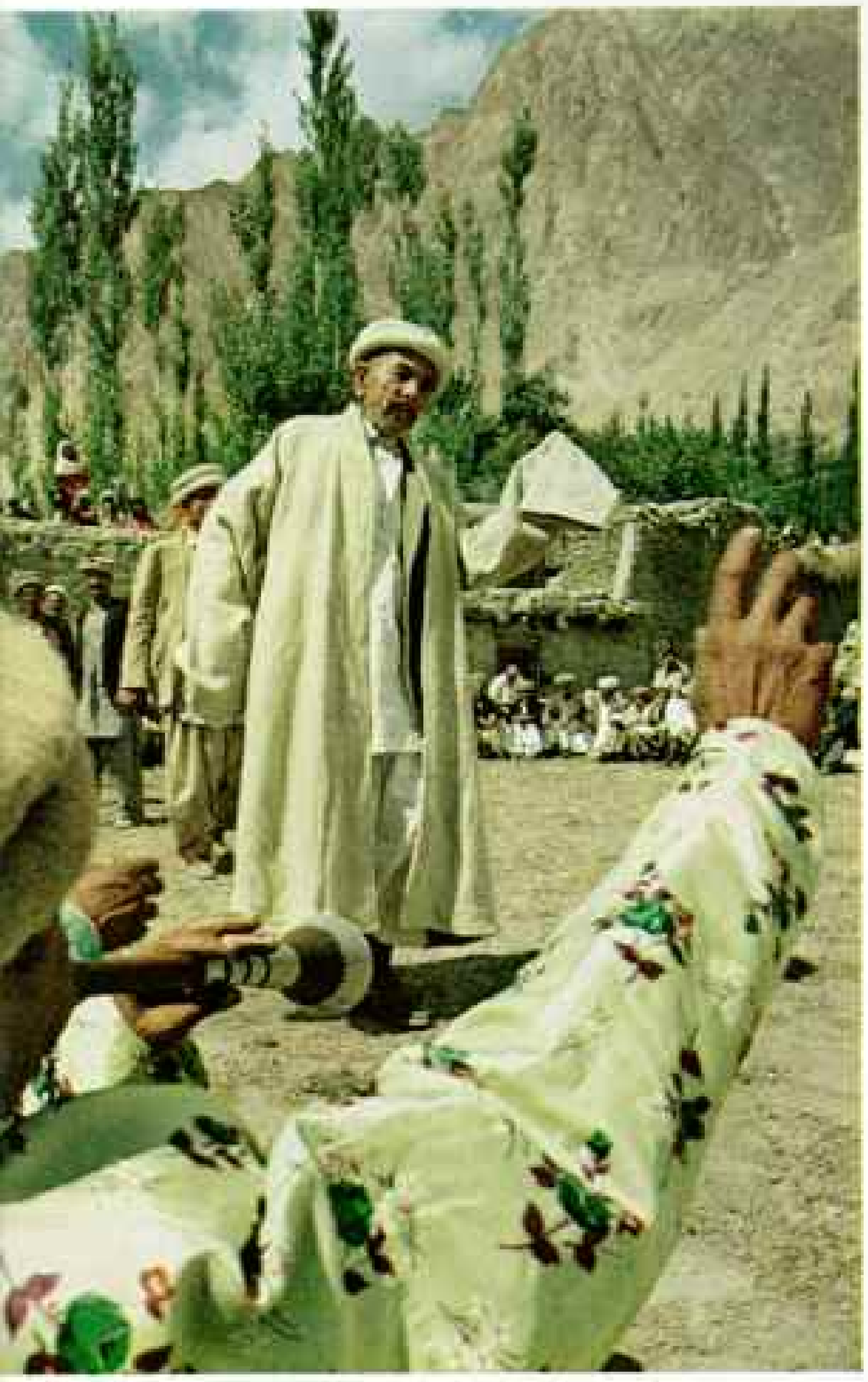
"If I get any closer, I'll have to kiss her," joked Abkhazian Seliac Butba (**left**), sitting beside his wife, Marusia. Butba said he was 120, his wife 109. After interviews, Dr. Leaf estimated their ages at 113 and 101.

Cordial friends, Michael Mchedleschvili, 95, and Georgi Gvelykashvili, 87 (**right**), sample homemade Georgian wine in the cellar of Georgi's house. Each of the sunken ceramic vats holds 40 gallons.

Piping away the time, 108-year-old Magul Surmeneliani of Abkhazia recalls his lonely days as a shepherd, when music was his best company. He now lives with his daughter,

takes daily walks, and mildly complains that his children won't let him do anything. "I never had a single enemy," he told Dr. Leaf. "I read no books and have no worries."

Revered as the oldest Hunzukut, Tulah Beg, flanked by his sons (**facing page**), claims to be 110. Dr. Leaf regards this as approximate, since no written records exist in Hunza. "It is the fitness of many of the elderly rather than their ages that impresses me," he says. Photographer Launois was also impressed when Beg's sons, both in their sixties, shouldered heavy cases of his photo gear and bounded over the forbidding terrain "like agile mountain goats."



Stately dancer, 99-year-old Kabul Hayat keeps time to the reedy wail of an oboelike instrument during wedding festivities for the crown prince of Hunza. Inhabitants of the tiny mountain land esteem their aged; elderly Hunzukuts counsel the mir, or head of state, daily on matters great and small.

Breakfast generally consists of cheese, bread, tea, and sometimes honey. The usual beverage is sour milk with cold water added. Every household has its vineyard and makes its own wine, which is quite dry and drunk fresh. The old people consume two to three glasses daily with their meals.

When I visited the centenarians in their homes, I was invariably invited to stay for food and drink. Within minutes the women of the household would have a table buried under its load of bread, cucumbers, onions, tomatoes, garlic, cheese, roasted and boiled chicken, sauces and spices, boiled mutton, goat's meat, and beef. Fresh fruits and occasionally pastry or a platter of chocolate candies completed the setting.

Feasting Fosters Camaraderie

Toasts would then be drunk, starting with homemade grape "vodka" or a Georgian brandy, the first a real firewater and the latter the boast of the Georgians. Then the drink changed to the local wine, and the toasting settled down to a steady pace throughout the meal—which would continue for three to five hours.

Every person and every honorable and friendly sentiment provided subject for the toasts. The tumblers were promptly refilled as the old people, ourselves, our driver, our parents, our children, peace, friendship, and understanding were separately toasted.

One respected member was elected president of the table by acclaim—"empty your glass if you approve his election," we were told. He then served as toastmaster. I watched with awe as, after proposing a series of toasts, the toastmaster might accumulate five tumblers of wine, which he would then down ostentatiously in rapid succession.

These festivities hardly seemed consistent with the moderate habits I had been told the old people practiced. However, I noted that the centenarians often would forgo the vodka, and their wineglasses were smaller than those of the others. Also, of course, such feasts were not a daily event, nor had food always been so plentiful.

I was often told by the old people that "things are much better now." One Armenian in Abkhazia explained: "In Turkey, and when we first came here, we had only beans and other vegetables to eat, but now we have meat and wine every day." It is well documented in animal experiments that a low-calorie diet

during early life will extend the total life-span. Thus dietary habits of early life may be as pertinent to long life as exercising moderation in middle and old age.

In Vilcabamba and Hunza the old people were generally quite slim, but in Georgia one occasionally saw an overweight centenarian, a phenomenon I would not have thought possible. I visited Quada Jonashian, an obese 110-year-old Armenian, on a farm near Gulripshi. He told me, "If one is healthy, it is obligatory to drink one liter [34 ounces] of wine daily, and on holidays and at weddings 17 to 20 tumblers are common."

Sonia Kvedzenia of Atara is 107 and very fat. When I asked how long she had been overweight, she laughed and said:

"I became fat when I stopped having children. For 60 years I have been fat as a barrel and all my children are like me. My mother was fatter, stronger, and warmer than I!" I learned that her mother had died only recently—and had been the oldest person in that region at the time. These, of course, are the exceptions, but nevertheless striking to this physician who was taught and has taught that obesity is an unmitigated health disaster.

Workaday Vigor Vital to Health

Whether slim or not, the old people of all three cultures share a great deal of physical activity. The traditional farming and household practices demand heavy work, and male and female are all involved from early childhood to terminal days. Superimposed on the usual labor involved in farming is the mountainous terrain. Simply traversing the hills on foot during the day's activities sustains a high degree of cardiovascular fitness as well as general muscular tone.

Dr. David Kakiashvili, a Georgian cardiologist who has been studying gerontology for the past 12 years, is convinced that exercise is a major factor in longevity. He has tested the hearts and lungs of these old people, using modern investigative techniques, and he finds that they have all kinds of cardiovascular diseases.

He asked, "Why do people in the small mountain villages tolerate myocardial infarction [heart attack] much better than their urbanized relatives?" Getting no response from me, he continued, "The constant physical activity required of them improves cardiopulmonary function so that the oxygen supply to the heart muscle is much superior to that

Binding hay for animal fodder, 95-year-old Akbar Khan makes use of a niche of level land on a steep Hunza hillside. "It seemed no slope was less than 30 degrees," Dr. Leaf reports. "Just getting through the affairs of the day conditions the hearts of the Hunzukuts."

in city dwellers." Thus, though the old people did have heart attacks, they apparently were "silent"—not felt by the victims.

The importance of physical activity—or lack of it—to the occurrence of myocardial infarction has long been suspected by the medical profession, and was given support by a classic study among British postal workers. Those doing desk jobs suffered a higher incidence of and mortality from heart attacks than did their more active colleagues employed in mail delivery.

During my last few days in Abkhazia, I heard that one old man from the village of Khopi was, as usual, spending the summer months with his herd of goats in the high alpine pastures—altitude 5,000 to 6,000 feet. Since I was told he was more than 100 years

old, I decided to visit him there, and to learn firsthand the physical exertion involved in his daily activities.

With three companions I set out at dawn for the six-hour hike up the mountain. The trail was muddy, slippery, and so steep that we were often climbing rather than hiking; two of our party, in fact, gave up and headed back downhill.

At times I felt like following them, but finally, about one o'clock, we came out of the woods onto a high grassy slope and found Kosta Kashig, who claimed to be 106 years old. He lived with two men and a boy as companions in a lean-to built of wood saplings with a sheet of plastic for the roof and goatskins covering the floor. Their outdoor kitchen consisted of an iron caldron suspended from a pole over an open fire. In it they cooked abusta, which they stirred with a large wooden spoon and ate with red peppers off a board; their diet also included cheese (which they make), and soured goat's milk.

Since one of the dropouts on the way up the mountain had been my interpreter, interrogation of Kosta was difficult, but I think he probably is 90 rather than 106. Whichever is correct, to be able to spend four months of the year bounding over the hillside from dawn till dusk in pursuit of his agile goats seemed incredible enough.

My own elation over getting up to the pasturelands was quelled when I was informed that the old man made the same trek in just half the time it had taken me.

Science Probes Genes for Answers

Most students of longevity are convinced of the importance of genetic factors. It has long been noted that very old individuals had parents who lived to be very old. This was strikingly brought out when I talked to the centenarians. Almost all had at least one parent or sibling who had lived for more than 100 years.

There is no known gene for longevity; there is only the absence of "bad" genes—those that increase the risk of fatal disease. Thus in a small, interrelated community like Vilcabamba it seemed possible that a few individuals lacking such genes might have been the progenitors of an isolated pocket of centenarians. The mountainous setting might have kept this genetic strain pure—and prevented the introduction of "bad" genes.

In Hunza one is dealing with a much larger population and territory. Again, however, the isolation has been extreme. Although the state of Nagir lies immediately adjacent to Hunza, there is virtually no intermarriage between the two peoples.

A careful study of the health and longevity of people in Nagir and comparison with the Hunzukuts would be invaluable. Since environmental influences would seem to be nearly identical, any significant differences might safely be attributed to genetic factors. Unfortunately, I did not have the time, the facilities, or permission to conduct such studies in Nagir. I was told repeatedly in Hunza, however, that the people of Nagir were not so long-lived as the Hunzukuts.

Driving through Nagir after leaving Hunza, I encountered only two 80-year-old men—and they and others repeated all that I had heard about the superior health and longevity of the Hunzukuts.

Interest in Opposite Sex Persists

In the Caucasus area, however, any notion of a pure genetic strain is promptly banished by the fact that one sees centenarians from so many different ethnic groups. I saw Georgians, Azerbaijanis, Russians, Georgian Jews, and Armenians all more than 100. Yet here, too, despite the diversity of ancestry, I found that most of the old people were born of long-lived parents.

An active interest in the opposite sex is popularly regarded as the *sine qua non* of vigor and vitality. Although the ovaries of women do age and stop functioning at the menopause, usually in the late forties or early fifties, this has little effect on libido. In the male, too, aging is associated with a gradual decrease in the number of cells in the reproductive organs.

Still, sexual potency in the male may persist to advanced old age. In the United States, Herman Brotman of the Department of Health, Education and Welfare states that each year in America there are some 35,000 marriages of persons above age 64, and that "sex as well as companionship and economy are given as the reasons."

Miguel Carpio, age 123, the oldest citizen of Vilcabamba, smokes and drinks, and his daughter says that he still likes to flirt with the girls. According to her, "he was quite a ladies' man in his younger days." Says he, "I can't see them too well anymore, but by feeling, I can tell if they are women or not."

Then he laughs, happy at the reaction of his audience.

In the Caucasus I asked the old people to what age they thought youth extends. Gabriel Chapnian of Gulripshi, age 117, gave a typical response, "Youth normally extends up to the age of 80. I was still young then." The youngest age cited was 60.

Quada Jonashian, aged 110, also of Gulripshi, was embarrassed at the question, since I was accompanied by a woman doctor from the regional health center. He thought "youth" meant engaging in sexual activity and admitted that he had considered himself a youth until "a dozen years ago."

Professor Pitzkhelauri has collected some figures relating marital status to longevity. He found from studies of 15,000 persons older than 80 that, with rare exceptions, only married people attain extreme age. Many elderly couples had been married 70, 80, or even 100 years. He concludes that marriage and a regular, prolonged sex life are very important to longevity.

Women who have many children tend to live longer. His figures showed that among the centenarians only 2.5 percent of marriages were childless, whereas 44 percent of the women had four to six children, 23 percent had only two or three children, 19 percent had seven to nine children and 5 percent had ten to fifteen. Several women had more than twenty children!

The importance of a happy marriage was emphasized by a 100-year-old Azerbaijani who had married his seventh wife only three years before. "My first six wives were all wonderful women," he reported, "but this present

Hands that toil and spin: Micaela Quezada, 102, gathers strands of sheep wool in front of her adobe house in Ecuador's Vilcabamba, a mountain village where 16.4 percent of the inhabitants are above the age of 60, in contrast to 4.6 percent for the rest of rural Ecuador. Señorita Quezada had a sister who died at 107 and 12 brothers who lived past 90. A baptismal record (**below**) verifies her own age. She does not drink or smoke, but smilingly confides that "I have to have my five cups of coffee each day."

wife is an angry woman, and I have aged at least ten years since marrying her. If a man has a good and kind wife, he can easily live 100 years."

A striking feature common to all three cultures is the high social status of the aged. Each of the very elderly persons I saw lived with family and close relatives—often an extensive household—and occupied a central and privileged position within this group. The sense of family continuity is strong.

There is also a sense of usefulness. Even those well over 100 for the most part continue to perform essential duties and contribute to the economy of the community. These duties included weeding in the fields, feeding the poultry, tending flocks, picking tea, washing the laundry, cleaning house, or caring for grandchildren, all on a regular daily basis.

In addition, the aged are esteemed for the wisdom that is thought to derive from long experience, and their word in the family group is generally law.

In Hunza this last point was evident even in the way the state is governed. The mir holds court daily at 10 a.m. with a council of elders. The council is comprised of some twenty wise old men of the state. They sit in a circle on carpets spread at the foot of the mir's wooden throne and listen to disputes among citizens and to other domestic problems. After a lively discussion (often marked by three or four elders talking simultaneously) with the mir presiding, a consensus is reached, and the mir announces his government's decision.

In none of the three communities is there any forced retirement age, and the elderly

are not shelved, as occurs in most of our industrialized societies. Khfaf Lasuria, the former tea picker, had retired only two years before I met her. When I asked Seliac Butba, age 121, if he was helping in the construction of a new house springing up next to his own, he responded, "Of course, they can't do without me."

Temur Tarba, a vigorous horse-riding member of the collective farm at Duripshi, had celebrated his hundredth birthday just three weeks before my visit. He showed from his bearing and happy manner that he felt he had "arrived." A few years earlier he had been designated a "Hero of Labor"; he was awarded this high Soviet honor for his cultivation of corn.

He smoked a good deal while I talked to him, but he did not inhale. He devotes the mornings to picking tea and cultivating his garden. "It is best to be a youth," Temur states, "but I have good health, feel well, have wonderful children, and I enjoy myself greatly now." He paused a moment in thought, and then added, "Every day is a gift when you are over a hundred."

Death Stalks the No Longer Useful

To sum up: Of the 15,000 persons above the age of 80 whom Professor Pitzkhelauri has studied, more than 70 percent continue to be very active and more than 60 percent are still working. They die quickly once they lose useful roles in the community.

Many of the centenarians emphasized the importance of being independent and free to do the things they enjoyed and wanted to do, and of maintaining a placid state of mind free from worry or emotional strain.

"Now everywhere people don't live so long because they don't live a free life," commented Sonia Kvedzenia of Atara, age 109. "They worry more and don't do what they want." Gabriel Chapnian, 117, of Gulripshi expressed a similar thought when told that few Americans attain his age. His response: "Hmm . . . too literate!"

Expectation of longevity may also be important. In America the traditional life-span is three score and ten years. But when we asked the young people of Abkhazia how long they expected to live, they generally said, "To a hundred." Dr. Georgi Kaprashvili of Gulripshi confirmed that the public has the notion that the normal life-span of man is 100 years. For exaggeration when proposing toasts, they may say 300 years, but everyone expects to be 100. Are we in the United States perhaps a mortality-ridden society, programming our lives to a shorter existence?

Scientists Gather to Compare Notes

After my weeks in the Caucasus seeing the old people, I went to a scientific meeting in the city of Kiev in the Ukraine: the 9th International Congress of Gerontology. Students of gerontology from 41 countries were there—scientists, social workers, physicians, and other professionals interested in the understanding and care of the elderly. In all, they presented 553 reports during the week of meetings.

I came away with a feeling that very little that was said there bore much relation to the old people I had just seen. Yet there are many interesting studies in progress on the nature of the aging process and the problems of the elderly in society.

Basic questions about longevity are being raised and studied.

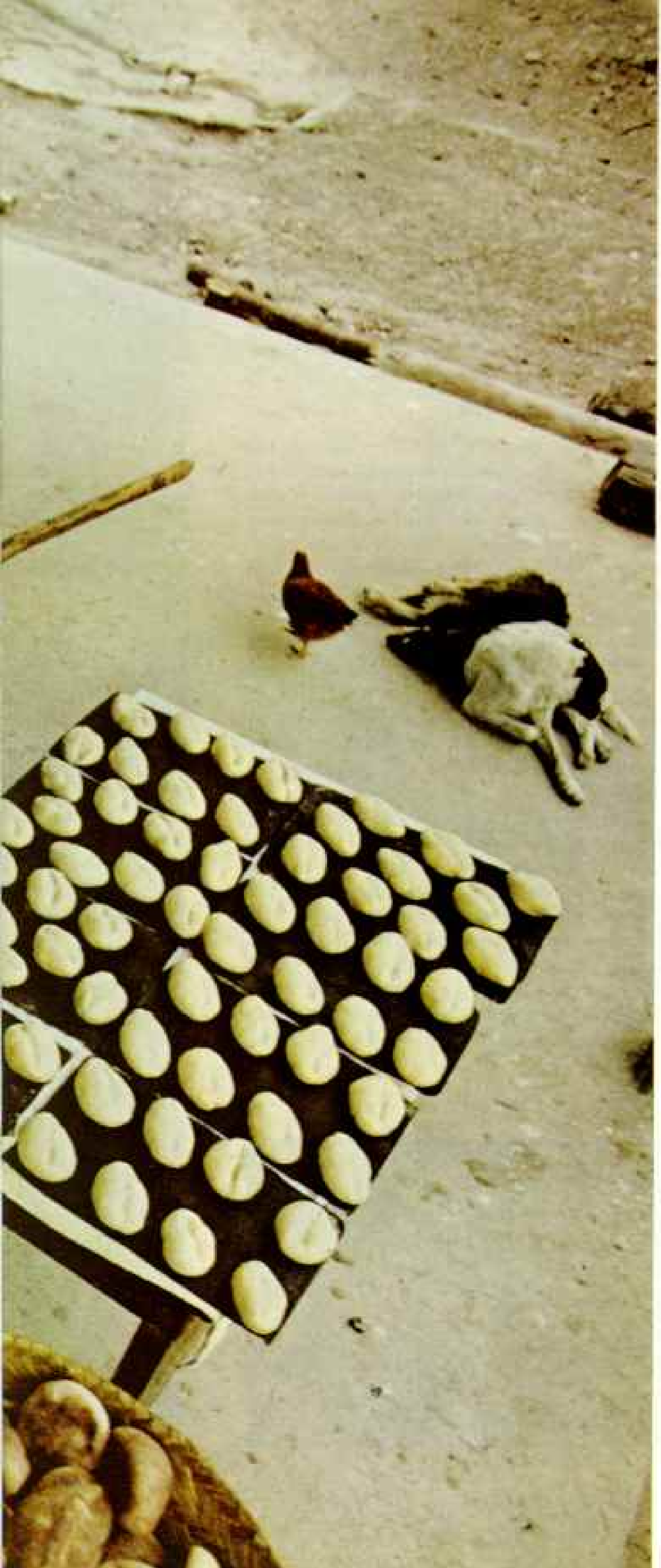
Is the aging process programmed initially into the genetic material of every cell? Or do, say, atmospheric or other noxious environmental factors damage the chromatin in the cell nucleus throughout life, so that eventually the genetic message gets so scrambled the cells no longer function normally?

Normal connective-tissue cells from human embryos, when transplanted and grown in tissue culture, have been found to divide some 50 times before they die. If the natural cell division is stopped at any point by freezing and then started again by thawing, the cells will complete only the remainder of the 50 divisions and no more. This makes it seem likely that the limit of 50 divisions was programmed into the nuclear material of the original parent cell.

The relatively early senescence of the ovaries in women, which occurs at the menopause—often long before other cells and organs begin to fail—suggests that the ovary is

"Oh, to be 108 again!" One of Vilcabamba's patriarchs at 123, Miguel Carpio sits for a haircut. Once a hunter who roamed steep Andean hills, Carpio retired from that arduous pursuit 50 years ago and took up farming. "I would not like to be young again," he said, "but if I could take 15 years from my age—wonderful!"

PELUQUERIA
Y REPARO
CALZADO



Spilling fresh-baked loaves into a basket, Hermelinda León, 95, labors at her job in a Vilcabamba bakery. She works here a day or two each week to earn a little money.

Active in her garden from first light till dusk on other days, she cultivates bananas and beans, ingredients for *repe*—a soup laced with white cheese, salt, and lard. Señora León does not own a clock, has never seen television, and scoffs at reports of men on the moon.

Unlike the Abkhazians and the Hunzukuts, most aged Vilcabambans find little joy at the peak of their long lives, which they regard as only a tedious circle of drudgery broken by religious ceremonies and an occasional fiesta. "Life has been hard," Señora León said. "I would not want to live it again."

responding to its own self-contained aging program. Is some critical organ of the body programmed as the pacemaker that sets the tempo of aging?

While investigations and speculations seek an answer to this fundamental question, other scientists have noted that macromolecules—the very large molecules of proteins and nucleic acids—themselves undergo a process of aging. Collagen, the main protein of connective tissue, constitutes approximately 30 percent of all human protein. As we grow older, it undergoes a continuous spontaneous chemical change—"cross-linking"—that increases its rigidity and reduces its solubility. Such a stiffening of this important structural component of our bodies could in turn lead to rigidity of blood vessels, increased resistance to blood flow, reduced delivery of blood to nourish tissues through such hardened arteries. As a final consequence it could cause loss of cells and of function—the essence of aging.

New Theories of Aging Emerge

A new area in aging research appears to be opening up from studies of the so-called "immune system" of the body. This system provides antibodies against bacteria or foreign substances introduced into our bodies. It also maintains a surveillance function that recognizes and destroys abnormal or foreign cells. When these functions of the immune system diminish—as occurs with age—the antibodies formed may attack normal body cells and destroy them or reduce their function, possibly hastening the aging process.

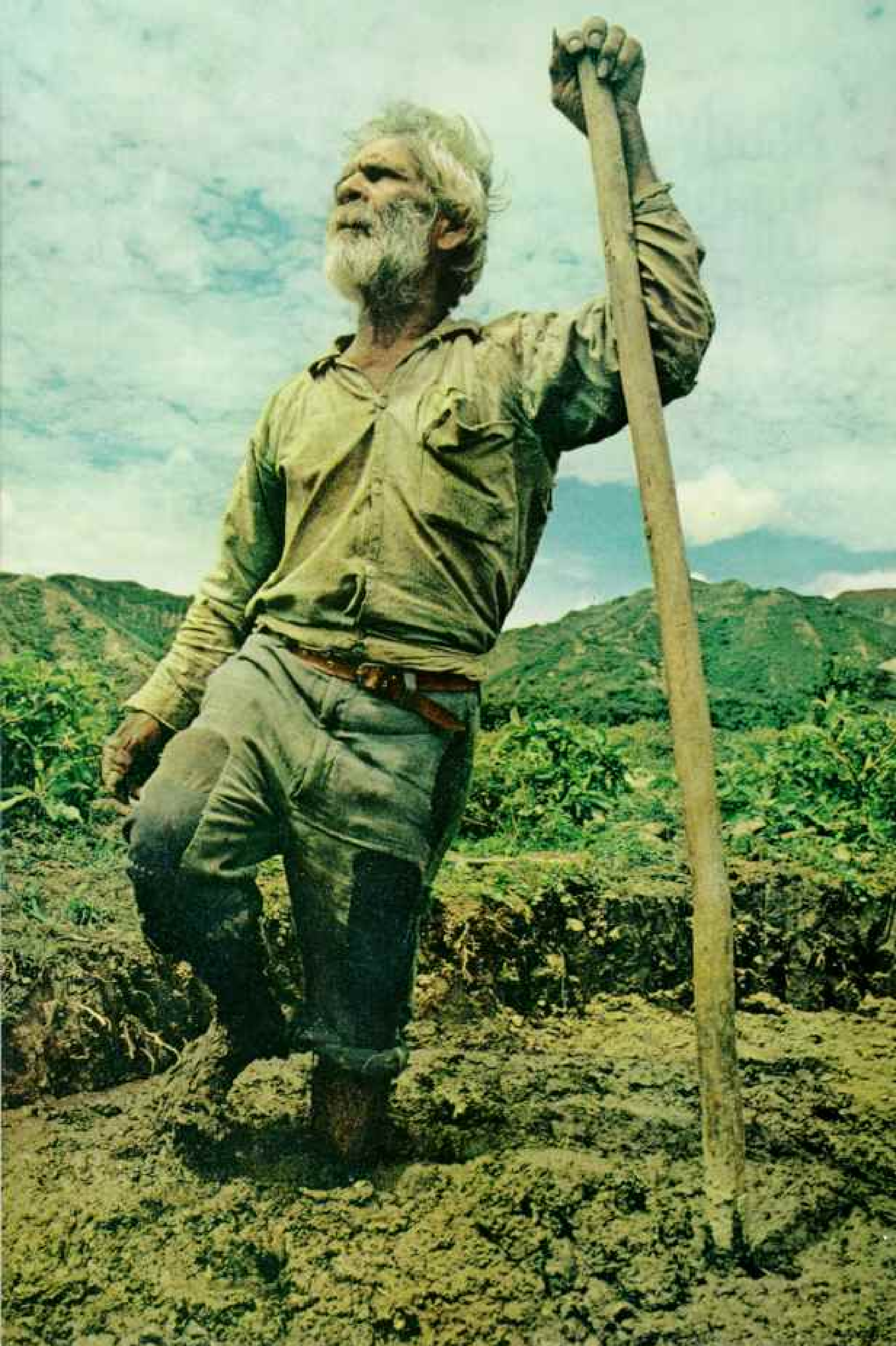
Some researchers think rejuvenation of the immune system may be possible. However, the hope that some medicine will be discovered that will prevent aging seems very distant to me, certainly until the nature of this fundamental process is understood.

It is encouraging that more support for research is becoming available in several countries. In the United States, establishment of a National Institute on Aging seems imminent; it would give recognition to the importance of this field and impetus to further research.

As I listened to the learned papers and discussions at the Gerontology Congress, I often caught myself daydreaming about Abkhazia. I thought of the response of Kristina Azuba, age 110 years, when I asked her why she had lived in such good health for so long. "I can't explain in scientific terms," she said, "but there just seems to be something special in the life here." Her statement is a fair summary of my present understanding of the problem.

Or I would wonder about Markhti Tarkil, who walks half a mile downhill to his daily bath in the river and then climbs uphill again. Surely any day a man can do this he must be too fit to die. The next day he repeats this physical activity and so on, day after day while the years roll by, and at 104 Tarkil is still much too fit to die! □

Sturdy as his staff, José María Roa, 87, slogs through the Ecuadorean ooze from which he makes adobe. Forty years at the task have deformed his feet but increased the ability of his heart to fuel his body with oxygen. Sedentary urbanites can do likewise, says Dr. Leaf, by a sustained regimen of running, swimming, or cycling. The doctor, aged 52, took up jogging when he returned home.



Studying Wildlife by Satellite

By FRANK CRAIGHEAD, Jr., Ph.D.
and JOHN CRAIGHEAD, Ph.D.
Photographs by the authors

WHILE MEN WALK on the moon, taking giant strides for mankind, wildlife biologists like ourselves reap benefits for animal research in an unusual spin-off of the space program.

For years scientists have relied on direct observation to unlock the secrets of animal migration, orientation, and timing. In recent decades radio and radar have joined our list of observation aids. We have fitted radio-transmitter collars on grizzly bears and elk and tracked the animals for months. Ornithologists can follow a single migrating bird with a giant radar antenna.

But these instruments have limited ranges —about 100 miles—and many mysteries remain: How do polar bears find their way in the Arctic? By what internal compasses do sea turtles navigate 1,400 miles of open water to lay their eggs? What regulator allows bears

to sleep for six months? How can these great carnivores live off body fat and, without defecating or urinating, manage accumulations of wastes that would be deadly to man?

Far-thinking space scientists want the answers, too. As Dr. David Elliott of the National Aeronautics and Space Council maintains, "The complex systems that animals use to navigate over great distances and to orient themselves are marvels of microminiaturization and reliability that we would like to duplicate, electronically or mechanically."

To probe these marvels, the National Aeronautics and Space Administration has made available a new research tool—the weather satellite Nimbus. During 13 world-girdling orbits each day, Nimbus can "see" every spot on the earth's surface from 700 miles. Aided by funds from NASA and the National Geographic Society, we recently used Nimbus to monitor animals equipped with transmitters.

As a first step, we had earlier tracked a black bear to his den, instrumented him, and kept tab on his temperature by ground radio (**below**). While his radio collar beeped, we shivered beside a campfire, converting the sounds into readings to obtain a 24-hour temperature pattern for a bear in winter sleep.

For the satellite test we selected a free-roaming elk and another sleeping bear. With our colleagues, Dr. Helmut K. Buechner of the Smithsonian Institution and Joel R. Varney of the University of Montana, we fitted the elk with a radio collar that "talked" to Nimbus for 30 days. We learned that the satellite located the animal to within five miles. Simultaneously, we showed the usefulness of the overhead watchdog in such localized studies as monitoring the temperatures in a bear's den for 32 days (**following pages**).

Felled by a tranquilizer, a tagged black bear at Yellowstone National Park (**left**) is equipped with a radio-transmitter collar and temperature probe by wildlife biologist Frank Craighead (**above,** left). Improvement of such ground-monitoring techniques and equipment led to the first satellite experiment.

Ears up, a black bear peers from his well-concealed den (**left**), awakened by the approach of researchers. Karen Craighead films the action. With the bear tranquilized by a drug injection, Vince Yannone and Jay Sumner check his respiration (**lower left**). John Craighead (**below,** left), after protecting the animal with a tarpaulin, will insert a rectal probe that transmits body temperature to a recorder. Then the researchers slide the bear into his den, where they have placed light and air-temperature sensors.

From these sensors, wires lead up to a ledge (**lower right**), where electronics engineer Joel R. Varney checks a 25-pound radio package that transmits data to the Nimbus satellite (drawings, **right**).

The bear's temperature drops only a few degrees, though the den remains close to freezing. These tests are but a beginning; the future will no doubt bring wider uses of Space Age technology to wildlife and ecological research. Even now, NASA has developed transmitter packages weighing less than ten pounds that could be adapted to tracking whales, polar bears, and marine turtles.

COLLECTING INFORMATION. Nimbus passes 700 miles above the Yellowstone bear den twice a day. It signals the electronics package to transmit data gathered by the sensors. For a free-roaming elk, the research team used an instrumented collar consisting of a miniaturized antenna and a transmitter-receiver.

RELAYING DATA. Nimbus transmits its signals to a ground station at Fairbanks, Alaska. The satellite then receives a fresh set of instructions for its next orbit. Nimbus can carry equipment capable of monitoring more than a hundred weather buoys, balloons, migrating animals—or bear dens.

DAVID WILTGEN

END PRODUCT. After processing at Goddard Space Flight Center in Maryland, data from Fairbanks emerges as a computer printout. From Goddard, team member Charles Cote sends the information to the Craigheads. Adapting space technology to earth's problems, NASA is now surveying scientists' needs in order to develop more advanced observation systems. □

Ethiopia's Artful Weavers

By JUDITH OLMSTEAD

Photographs by
JAMES A. SUGAR

ALWAYS, IN THAT COUNTRY, there is song. Throughout my two years among southwestern Ethiopia's Dorze people, virtually no day passed without a succession of lovely melodies.

I remember taking long walks in mornings vibrant with the singing of young herders echoing from hilltop to hilltop as they roamed the heights with their goats and sheep and cows. At harvest time song filled the air while reapers advanced in ranks like skirmish lines through fields of barley. And at dusk the girls and women who had risen before dawn to cut wood in the lowlands made their way homeward, their heavy burdens lightened by a melody.

This Dorze affinity for music had played a large part in drawing me to their homeland as part of my work toward a doctorate in anthropology. One aspect of my project was to study rural-urban migration in a developing economy. For this the Dorze provided excellent subjects because their traditional

Pensive in the midst of activity, a Dorze girl glances across the motion-blurred market in Bodo District. Her people—a close-knit minority of 20,000 in a land of 25,000,000—form a bright thread in the human fabric of Ethiopia.

House moving, Dorze-style. Chanting in rich-throated unison, villagers prepare to lift a neighbor's home and carry it to a new site. Despite a blow-away look, such thatch-and-bamboo huts may last half a century.

Thousands dot the cramped Dorze homeland overlooking the Great Rift Valley (map, **right**). Before being swept into the Ethiopian Empire in the 1890's, the Dorze were farmers, though they did some trading and also

JUDITH GILMSTEAD

earned a reputation as fierce warriors. Today, adapting their ancient tribal craft to the ways of 20th-century commerce, they profit in peace as Ethiopia's finest weavers.

Ethiopia's Artful Weavers

skills as weavers encouraged such mobility. I could have concentrated on any of several other ethnic groups that travel to and from Addis Ababa, Ethiopia's capital, in search of livelihoods, but the Dorze preoccupation with music—matching a lifetime interest of my own—prompted the final choice. Their land, in Gemu Gofa Province, overlooks the Great Rift Valley from heights of 8,000 to 10,000 feet. Its beauty—high and rugged with clear, crisp air—clinched my decision.

Reply in Dorze Astounds Travelers

I set out for the Dorze highlands after a month of studying the tribal language in Addis Ababa. The final leg of the journey, a 13-mile drive from the provincial capital of Arba Minch, found me jammed with 11 others into a Toyota Land Cruiser "taxi." Climbing the rutted, muddy road, it slithered and skidded around an endless succession of hairpin curves. I clutched the door, praying that we wouldn't veer over the edge and plunge down the sheer mountainside.

As we bounced along, a passenger in front addressed me over his shoulder. He used Amharic, the official language of Ethiopia. I replied in Dorze, "*Amarinya erike, guts Dorze kala yottais*—I don't understand Amharic, but I speak a little Dorze."

My words startled two Dorze men seated by me. What kind of foreigner would learn a local language and not the national one? I explained that I would be spending two years with their people. They nodded politely but incredulously.

Reaching the Dorze District of Bodo, where I planned to make my home, we stopped at the marketplace, an open area surrounded

Her agony a public event, a grief-beset widow screams and flails her arms amid a throng of mourners at her husband's funeral (**upper left**). She wears the gun belt and trousers of the dead spouse, as if refusing to part with him. Four times, overcome by emotion, she fainted into the cradling arms of friends (**left**), but revived each time to continue the 4½-hour ceremony. Crouching men (**above**) clap and chant, while they rest from the strenuous dancing around the funeral ground. Thus they signify intense grief for the dead man, a village leader who died in life's prime.

by some sixty of the drab rectangular houses common to Ethiopian towns (pages 136-7). Constructed of eucalyptus and bamboo poles, plastered with mud, and roofed with corrugated metal sheeting, they represent the pinnacle of sophistication in local eyes. I moved into one of these temporarily and puzzled my Dorze neighbors when I told them I would prefer to live in one of their traditional dwellings. Unique to this area, such houses are literally woven from bamboo.

Once settled, I scouted for suitable land. Soon I found a marvelous hilltop site overlooking the marketplace. The owner agreed to let me build there, as long as the house, which might last fifty years, became his property upon my departure. The bargain was struck. For advice, I turned to one of my first Dorze friends, Ketemma Kafe, a merchant. "You need a reliable builder, of course," he said. "The best is Dengo."

But even the best builder inspires a healthy skepticism in the Dorze soul. Prodded by my new friends, I led Dengo to the police station where we signed our contract; one clause in it provided for his imprisonment if the house remained uncompleted by a certain date. I had occasion to be grateful for that harsh but necessary condition.

Dengo and his apprentice, Zage, members of a neighboring tribe, began work in early July. For three days they cut bamboo in a nearby grove. They split the stems and planted tall stakes three feet into the ground in a 24-foot-diameter circle. Then they began to weave long strands of bamboo on these uprights, creating a structure resembling an inverted basket.

I asked Dengo—whose skill was equaled only by his impatience—to be sure to leave room for windows.

"Windows!" he exploded derisively. "I can't make windows! If I cut out holes, the rain will enter."

For the Dorze, the light from a single door suffices, but I would have countless notebooks to study and transcribe. "Surely you can find a way," I pleaded. And the ingenious Dengo did, by weaving four projecting "noses" over the holes, like the ones that protect the doorways of Dorze houses (below). Thus did he keep out the rain while allowing light to enter.

While Dengo was building my house, I wandered over the hilly landscape, exploring my adopted community and its way of life. The Dorze occupy an area of only 15 heavily settled square miles. Among these people some crafts are purely hereditary, I found, and carry a social stigma. Potters and tanners, for instance, live in separate communities, are considered inferior, and must seek mates within their own numbers. So too must the descendants of slaves.

Ritual Governs Expression of Grief

Early in my stay I discovered that Dorze funerals were not simple private affairs, but important public occasions attended by everyone. Nonetheless, I felt uneasy about going to funerals until Abesha Alemu, a young friend, taught me the required ritual.

"When you stand before a relative of the dead person," he instructed, "you hit your chest with your fists and cry '*Tana weda*—kill me,' meaning you would give your life for that of the dead. You also pull some hair from your head, although if you're not related to the deceased, you only pretend to do so."

This, however, represents only the basic expression of mourning. Dorze men show deeper sorrow by falling sideways, their bodies stretched out on the dirt, muscles tense and rigid. Frequently I saw young boys practicing this social skill so they could perform convincingly as adults.

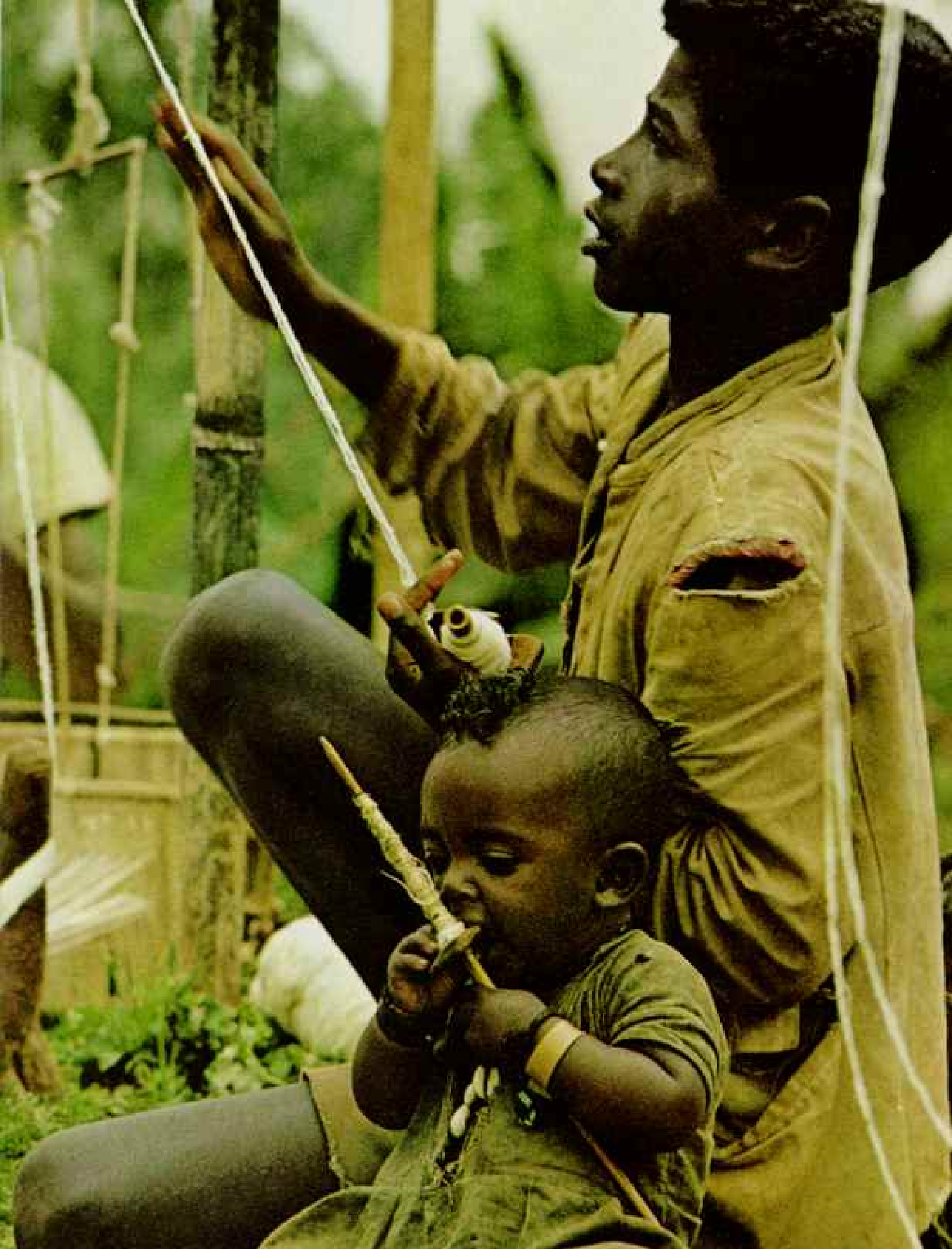
For the Dorze the zenith of the year comes in late September with the celebration of Maskal. This Ethiopian festival commemorates a tradition that St. Helena, the mother of Constantine the Great, discovered the True Cross in the Holy Land in the fourth century. Fragments of the Cross were said to have been brought to Ethiopia ten centuries later.

Since Maskal coincides with the end of the gloomy rainy season and falls approximately two weeks after the Ethiopian New Year, festivities extend over several weeks.

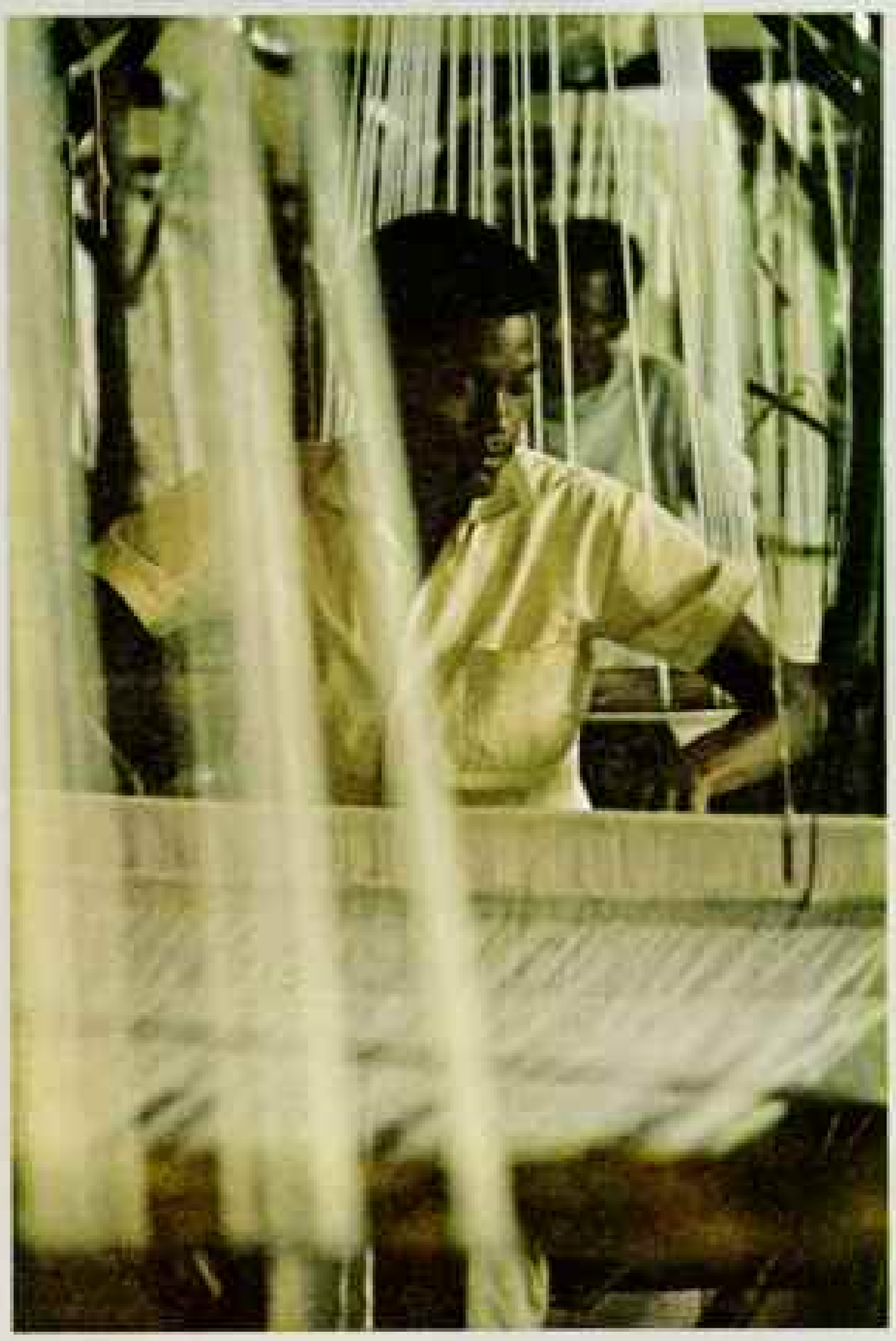
The unmarried girls heralded this season of joy; each evening they gathered in the public meadow to sing and dance with stylized, stiff-legged jumps. Their songs told of goats and leopards, jewelry and clothes. Often the lyrics heaped praise on their own district while mocking others. One evening

Prolific potters turn out wares to sell at market. Rounded pots for carrying liquids must be waterproofed with a cow-dung paste. Large platters serve as baking dishes for *injera*, a sour, pancakelike bread.

Taboo is his science: Keso Alate, interpreter of Dorze law and lore, is known far and wide for his soothsaying powers. Here he "reads" the entrails of a lamb to predict a client's future.



Dorze boys live with the loom from their earliest years.



Shuttles weave prosperity at a textile factory run by Dorze entrepreneurs in Addis Ababa, Ethiopia's capital. Here, some 300 miles from their homeland, Dorze craftsmen turn out the finely woven cotton cloth, often edged with bright trimming (**right**), used by Ethiopians for their *shammas*, the national dress. Some of the transplanted weavers earn enough to set up second households in the city—with extra sets of wives and children. Yet enough profits filter back to Dorze country to sustain those left behind and to hire members of neighboring tribes to till Dorze lands.

the girls of Amara District brushed the grass with imaginary brooms, singing, "The women of Laka sweep the house all day." Then, patting their hair before make-believe mirrors, they concluded, "But the Amara women make themselves beautiful all day!"

From all over southern Ethiopia, Dorze poured into their homeland for the traditional celebration. On Maskal day itself, they attired themselves in ostrich feathers, leopard skins, lion manes, and vivid textiles for the ceremonial dances.

I played a small role in one celebration. All the new brides, shy girls in their teens, walked in procession through the Bodo marketplace. Each wore over her hair, like a white cap, a glob of butter, traditional for the occasion (page 141). Reassuring women relatives walked beside the girls. Afterward, older women transferred the butter from the girls' heads to the heads of the female relatives.

One woman beckoned me, a lump of butter cupped in her palm. "Come closer," she invited. When I did, she smilingly plopped the lump on my head.

"Now," she proclaimed, "you're a member of our clan."

For me, it was a proud moment.

Hungry Housebuilder Proceeds Slowly

By October—thanks largely to police pressure upon Dengo the builder—my house was finished. I learned that Dengo's inattention to his work stemmed largely from my failure to fulfill a local custom. The Dorze believe that well-fed builders erect better houses; during the period of construction, they ply the craftsmen with delicacies. Unfamiliar with Dorze cuisine and unable to prepare his favorite dish, *oisa kats*—ground roasted barley cooked in spiced milk and thickened with butter—I had incurred Dengo's displeasure.

Still, he did complete the house. To celebrate, I invited about 150 leading Dorze citizens to come and bless my new dwelling and attend a feast.

On the day preceding the event, I bought a big white bull at the market and tethered it outside my door. Early the next morning the owner of the land on which my house was built slaughtered the animal in the Old Testament fashion favored by Ethiopian Orthodox Christians—he threw it to the ground and slit its throat. Then he and a group of helpers dressed the carcass. Women arrived carrying clay pots of wheat beer on their backs and left decorated gourds to serve it in. A taxi had transported 50 loaves of bakery bread—a luxury to the Dorze—from Chencha, some eight miles away.

Shortly after noon the guests began to arrive. They blessed me and the house with short phrases.

"Let the house bring you good fortune!"

"Bear sons!"

I replied with a word common to both our languages, "Amen."

My guests ate the meat raw and relaxed on the broad green ensete leaves that I'd spread on the grass. Then I delivered a short speech I had prepared in the Dorze language:

"I thank all of you for coming to bless my new house. A few months ago I arrived as a stranger; now I have many friends."

The feast won me a new name: Asho Miziraino—the one who fed us meat.

Ensete—a Plant of Many Uses

By now the fields of the Dorze were green with barley, soon to turn golden in the October sun. Barley and ensete comprise the staple diet of the Gemu highlands.

Ensete ventricosum, domesticated only in southern Ethiopia, is a remarkably versatile plant whose appearance has given it the nickname "false banana." Its underground tuberlike stem resembles a potato in texture and, to some extent, in taste. Huge leaves up to 15 feet tall rise from the base. The thick overlapping leafstalks, cut into small pieces and boiled, recall cooked celery. Juice from the mature stalks provides a tapiocalike pudding, and the fibers are twisted into rope or woven into sacks.

But agriculture no longer interests most Dorze men. Until the turn of the century they were primarily farmers, fighting petty wars now and then to settle a dispute or to capture slaves. They also knew something of weaving and trading. Then their land was merged into the Ethiopian Empire. As imperial troops made travel safe, many of the Dorze forsook their fields to concentrate on weaving and trade. Now, for the most part, they hire men of neighboring tribes to work their lands, employing themselves more profitably at their looms.

In Dorze country, on any sunny day, you can see weavers at work in the public meadows. Many Dorze weavers, however, now live in Addis Ababa and other large towns, where

they wholesale their cloth to merchants. The system has served the Dorze weavers well, for they have become the major producers of the *shamma*, the fine white cotton cloth used to make the Ethiopian national dress. Because the men spend so much time away from their homeland, many of them maintain two households, one in the city and the other in the highlands, each with a wife and perhaps children.

In Addis Ababa, Bahiru Mekuria, the bright, enthusiastic head of an *iddir*, or self-help association, told me how Dorze in the capital band together to invest in business enterprises. Five men leased an abandoned building in Addis, for example, and hired other Dorze men to operate 19 looms. The weavers turned out high-quality shammas and sold them on the premises, eliminating the shopkeeper and his profit.

"The factory was so successful," Bahiru said, "that we have added three more buildings. Now more than 200 men work there."

Bahiru himself works at home but belongs to a cooperative through which he sells his cloth. "This is the best arrangement of all," he told me. "Factory owners have to pay the workers and get only a share of the profits. We have to pay a storekeeper, it's true, but otherwise we get all the profits ourselves."

Gome Fosters Businesslike Ways

Dorze have prospered in other businesses, too. I met Dorze owners of small inns, tearooms, and all kinds of shops, both in Addis and in the homeland.

What lies behind the successful transition of many of these onetime hill farmers into businessmen? Two reasons, at least, suggest themselves. One is the Dorze tradition of *gome*, or taboo. At first it might seem that taboos and divination—through the observation of cast stones and animal entrails—could contribute little to a people caught up in a developing economy.

But gome builds a sense of personal responsibility and control of one's fate. If illness strikes a man or one of his relatives, he asks a diviner to determine the cause. The diviner may attribute the illness to a breach of gome: an act of adultery, constant quarreling between man and wife, or a show of disrespect toward elders.

The system of gome then gives people guidelines for setting things right: confession of guilt, appropriate action to end the dispute

Magnet of tribal society, the Bodo market attracts the Dorze and their neighbors for a twice-weekly exchange of goods and gossip. Amid vendors hawking wares and buyers haggling over prices, marriageable girls cast covert glances at smartly dressed bachelors —many of them weavers from Addis Ababa who have come home to find Dorze brides.

Cash replaces barter, as profits collect in Dorze coffers. These members of a meat buyers' club pass out accumulated savings for the once-a-year splurge on Maskal, the chief Ethiopian holiday. Man at left puffs a water pipe.

or cessation of prohibited acts, and the sacrifice of an animal.

Thus the individual feels that his future is linked to his present actions, and if he makes a mistake, he can repair the damage. This way of thinking fosters active, responsible enterprise.

A second factor underlying Dorze success is a tribal tradition of community responsibility and cooperation. Throughout my stay, I noted how neighbors continually helped each other in ways small and large—such as the moving of a house (pages 126-7). And each district has a kind of town meeting where disputes not settled privately by the advice of respected neighbors are heard and judged. Murder and other felonies go directly to the Ethiopian police, but the Dorze themselves settle lesser problems that arise in the community. Elders sit in judgment, and the most respected of these are the *halakas*.

Lofty Position Bears High Price

Selected by local leaders, a halaka serves a limited term in office but retains the coveted title all his life. While the honor is great, so is the cost. The halaka must spend several hundred dollars on feasts and gifts during the period of his initiation.

Here taboo also plays a role. A candidate who refuses the honor (and the cost) violates the rules of gome. A man named Tolo declined the office during my stay. To no one's surprise, one of his wives soon fell seriously ill. Recognizing this as punishment for his flouting of gome, he begged the elders to let him become a halaka in the following year.

I met Tolo at the compulsory feast he was giving for the *puretsa*, a small group of men who inherit the title and its single privilege—that of attending such dinners.

The banquet started badly. The male guests rejected as too small the clay pot that would hold the wheat beer. The thrifty halaka produced two somewhat larger replacements, but these the guests also refused. "We're not beggars!"

I followed them into the courtyard and watched as Tolo persuaded them to return. Then he brought forth an enormous five-foot-high pot and the diners grunted in satisfaction as Tolo's female relatives filled it to the brim with beer.

The guests seemed ungrateful—even greedy, I thought. But then I realized they simply were hazing a candidate for office, not

New-generation Dorze, Girma Kodo, the author's assistant, attends high school in Arba Minch and hopes to go to college. To his Western dress he may add the traditional *gabi*—a heavy version of the shamma—when the weather cools. From Girma's hat sprouts a stalk of grass, signifying the start of the Maskal festival.

Where weavers unwind: City ways increasingly trickle into Dorze country, here in the form of a neighborhood tavern where a boy hovers in hopes of earning money by running errands. A non-Dorze presides as barmaid—a job Dorze women disdain.

Skullcap of butter, smeared thickly over a bride's hair, signifies her acceptance into her husband's clan. When the marriage rite ends, female relatives vie like bridesmaids for dollops of the ceremonial butter, which Dorze women esteem as a hair oil and skin conditioner.

Bridenapped! Dorze bachelors stage a kidnapping (**left**) and carry off a shrieking girl to the home of her husband-to-be, where she will be feted by welcoming in-laws. She wears some of her best clothes—a giveaway that the ambush was no surprise. The jovial abductors play their ritual roles with unconcealed delight, each aware that the others will someday snare a bride for him, too.

an uncommon practice throughout the world.

Afterward we marched in a procession to the crowded marketplace, and waded right through it—stepping over sacks of maize, ensete tubers, piles of coffee, and mounds of spices. Then we sat down beside the market for a final calabash of beer. This marketplace ritual, called *sofe*, seemed an appropriate rite for a people who have proved so adept at commerce.

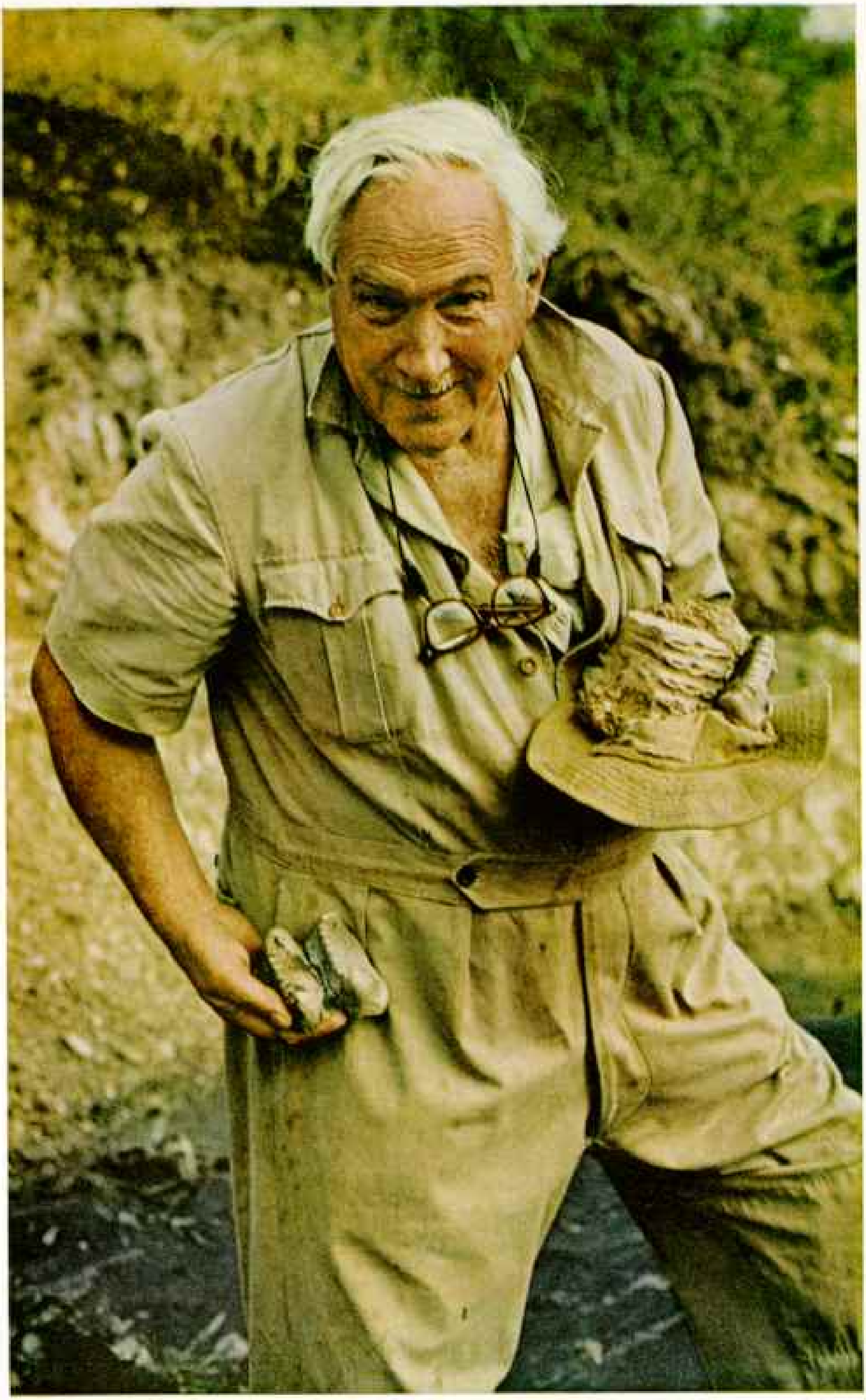
In my long stay in the Gemu highlands, I had learned many Dorze customs. One was the habit of arriving and departing without fanfare. So, on a bright April morning, I quietly left Bodo for the last time.

At the airport in Addis Ababa, I was startled to meet my old friend, Bahiru Mekuria, the leader of the Dorze self-help association in the capital.

"*Tani nena moizana*—I have come to see you off," he said, grinning. A Gemu highland custom, he reminded me, requires a host to accompany an honored guest part of the way home. Since no individual in Dorze had been my host, he now volunteered for the role in the name of the entire tribe.

We chatted over tea until the loudspeaker announced my flight. I walked toward the plane, warmed by Bahiru's thoughtful gesture.

It was a typical Dorze display of kindness, a fitting way to end two years of study among these unique and charming people. □



LOUIS S. B. LEAKEY 1903-1972

The Leakey Tradition Lives On

By MELVIN M. PAYNE, Sc.D.
PRESIDENT, NATIONAL GEOGRAPHIC SOCIETY

WHAT WAS Louis S. B. Leakey? A paleontologist or an ornithologist? A zoologist or an anthropologist? The curator of a great museum or a Kikuyu tribesman of Kenya's green uplands? Author of an authoritative book on cat's cradle or a renowned handwriting expert?

The incredible truth is that he was all these—and more.

To the chief of his tribe, Koinange, he was "the black man with a white face."

To Dr. Leonard Carmichael, former Secretary of the Smithsonian Institution and presently the National Geographic Society's Vice President for Research and Exploration, he was "the Darwin of human prehistory."

To me he was a beloved friend—a powerful, brilliant, hulking man who dedicated his life to pushing back the horizons of the past, no matter the cost to his health. Science—and the world—are poorer for his death in London on October 1, 1972, at 69.

Alone among God's creatures, man attempts to explore his past. Louis Leakey sought nothing less than our ultimate truly human ancestor—that creature who was no longer ape but early man, who through long millenniums acquired upright posture and, above all, invented language.

Born in Kenya on August 7, 1903, to an English missionary couple, Louis grew up with the Kikuyu tribesmen his parents sought to convert. Like his African playmates, he learned to throw his spear through a rolling hoop and to stalk small game stealthily enough to touch his quarry. At 13 he became a Kikuyu warrior, never to disclose his initiation rites; he died an elder of the tribe.

The imprint of this unusual boyhood never left Louis. Throughout his life, he once told me, he frequently *thought* in Kikuyu. The tribal traits of patience and observation, he maintained, contributed much to his success as a fossil hunter. He wrote a grammar of the Kikuyu language, and a monumental three-volume treatise on his tribe.

After taking his degree at Cambridge, Louis decided to seek the remains of early man in East Africa. His university advisers counseled him to dig in the Near East instead.

Fortunately, Louis stubbornly forged ahead. His astonishing fossil discoveries, and those of his wife, Dr. Mary Leakey—herself a distinguished prehistorian—have revolutionized our concept of man's development. Only recently scientists reckoned that the genus *Homo* had existed for perhaps half a million years. Louis and Mary put the figure at a minimum of two million years. Thanks to their work, East Africa has become the focal point in the study of man's origins.

Three Decades of Toil Rewarded

The Leakeys' major discoveries have come from Tanzania's Olduvai Gorge, a weathered, fossil-laden gash in the African plain. Expending their own resources, they scratched and probed at Olduvai in quest of early man for nearly three decades—but found only animal remains. Then, on July 17, 1959, Mary came upon part of a skull and two teeth. The fossil proved to be *Zinjanthropus*, a 1,750,000-year-old australopithecine, or near-man.

"What exasperated us both in those years at Olduvai," Mary Leakey recalls, "wasn't the heat or the living conditions. Rather it was knowing that revolutionary fossils were there for the finding, and that we hadn't the money for a decent campaign of excavation."

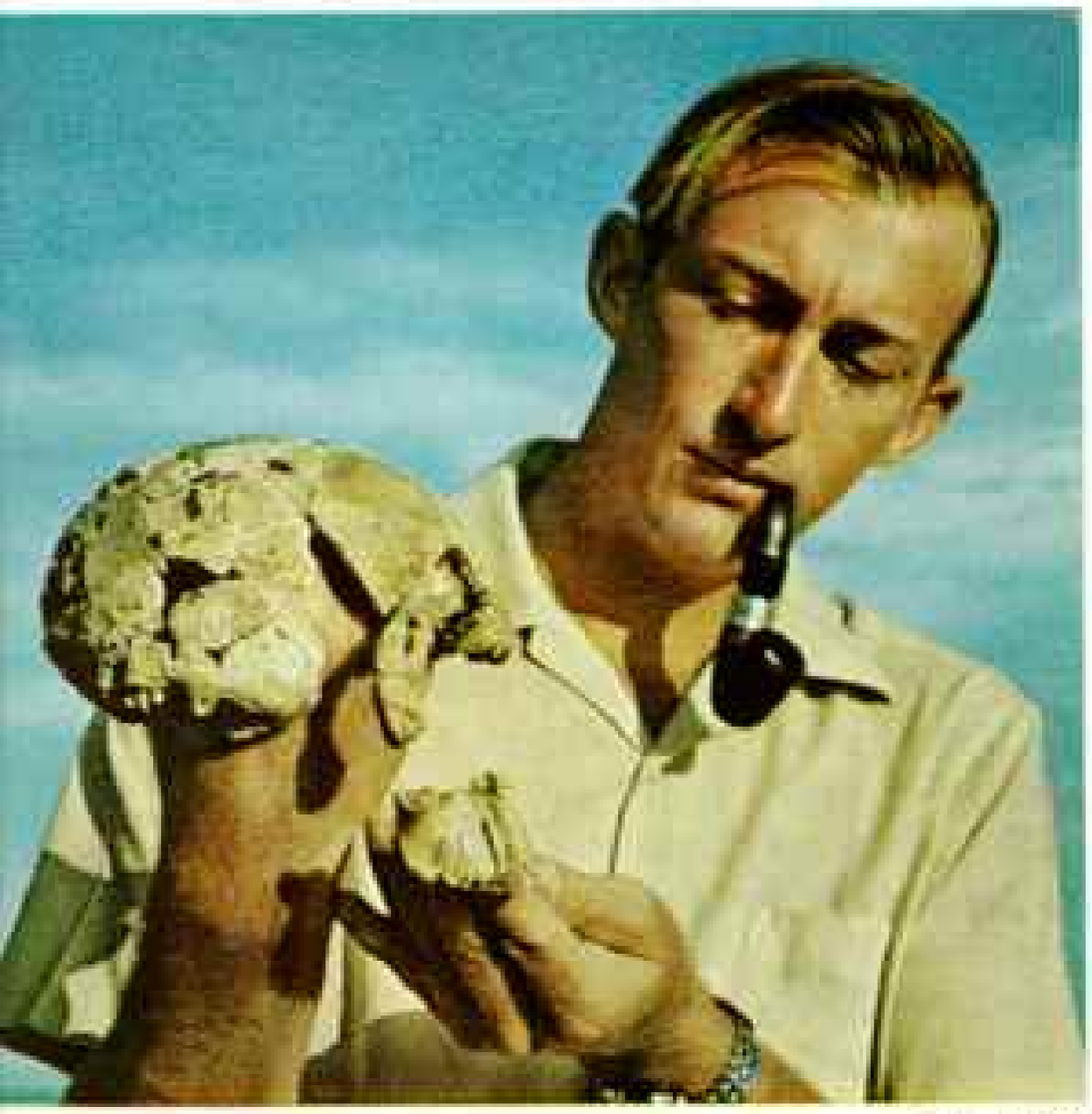
Support came from the National Geographic Society beginning in 1960, and it

Joy of discovery lights the face of Dr. Louis S. B. Leakey as he displays a fossilized elephant tooth on his hat and the broken molar of an extinct elephantlike dinotherium unearthed in Tanzania. His finds brilliantly rewrote the history of man and ancient African animals.

MELVILLE BELL GROSVENOR

MICHAEL BALL, NATIONAL GEOGRAPHIC STAFF

Partners in probing the distant past, Louis and Mary Leakey examine a hatful of fossils. Mary's first hominid find in 1959 pushed back the known age of the manlike creatures to 1,750,000 years.



BOB CAMPBELL

Carrying on the quest, son Richard Leakey displays a skull found in 1972 near Kenya's Lake Rudolf. He believes it to be that of a 2.6-million-year-old member of the genus *Homo*.

continues today. Louis once told me that the Society's early grants enabled them to accomplish more at Olduvai in two years than they had in the preceding thirty.

In 1960 Louis and Mary unearthed 1.8-million-year-old skull fragments of *Homo habilis*. Louis identified this "man with ability" as a tool maker.

Inevitably Louis's discoveries—or, more precisely, the conclusions he drew from them—came under fire from some academic quarters. He relished challenge, and I recall how he met it—with a typical crinkly smile about his eyes. Just as inevitably, the controversies proved enlightening.

A charismatic teacher, Louis inspired Jane van Lawick-Goodall to undertake a study of wild chimpanzees. Her startling findings, reported in your Society's journal, disclosed that these supposed vegetarians not only hunt and eat small game, but also fashion simple tools. A continuing study by Dian Fossey of another of man's close relatives, the shy, endangered mountain gorilla, also began under Louis's tutelage.

2.6-million-year-old Man?

Dr. Mary Leakey is carrying on the work at Olduvai. And for the past five years their son Richard has been working on the isolated eastern shore of Kenya's Lake Rudolf. His early explorations revealed stone tools antedating the oldest found at Olduvai by 850,000 years. So rich is the Lake Rudolf site that it has already produced the remains of more than 80 hominids.

This past August, Bernard Ngeneo, a Kenyan member of Richard's expedition, found an extraordinary skull, splintered into hundreds of fragments. In remarks prepared for delivery at a scientific meeting in London on November 9, 1972, Richard described the fossil as "almost certainly the oldest complete skull of early man." His estimate of its age: a breathtaking 2.6 million years.

It is reassuring to know that the vital work in East Africa will continue under Mary and Richard with the characteristic Leakey vigor and brilliance. Yet all who have known Louis Leakey will deeply miss this truly protean man. □

Your Society was Dr. Leakey's major financial supporter for 13 years and is now a principal sponsor of the early-man research being carried forward by Dr. Mary D. Leakey and Richard E. Leakey. The L. S. B. Leakey Foundation has also been a substantial contributor to these important projects and would welcome contributions as a living memorial to Dr. Leakey in furtherance of his life's work. Such gifts are tax deductible and should be sent to: *L. S. B. Leakey Foundation, 1100 Glendon Avenue, Suite 1634, Los Angeles, California 90024.*

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Louisville WHAS-TV (11)

LOUISIANA
Baton Rouge WAFB-TV (9)
Lafayette KLFY-TV (10)
Monroe KNOE-TV (8)
New Orleans WWL-TV (4)
Shreveport KSLA-TV (12)

MAINE
Bangor WABI-TV (5)
Portland WGAN-TV (13)
Presque Isle WAGM-TV (8)

MARYLAND
Baltimore WMAR-TV (2)
Salisbury WBOC-TV (16)

MASSACHUSETTS
Boston WNAC-TV (7)

MICHIGAN
Cadillac WWTV (9)
Detroit WJBK-TV (2)
Kalamazoo WKZO-TV (3)
Lansing WJIM-TV (6)
Marquette WLUC-TV (6)
Saginaw WNEM-TV (23)

MINNESOTA
Duluth KDAL-TV (3)
Mankato KEYC-TV (12)
Minneapolis WCCO-TV (4)

MISSISSIPPI
Columbus WCBI-TV (4)
Jackson WJTV (12)
Meridian WTOK-TV (11)

MISSOURI
Cape Girardeau KFVS-TV (12)
Jefferson City KRCG-TV (13)
Joplin KODE-TV (16)
Kansas City KCMO-TV (5)
St. Louis KMOX-TV (4)
Springfield KOLR (10)

MONTANA
Billings KOOK-TV (2)
Butte KXLF-TV (4)
Glendive KXGN-TV (5)
Great Falls KRTV (3)

NEBRASKA
Lincoln KOLN-TV (10)
Omaha WOW-TV (6)

NEVADA
Las Vegas KLAS-TV (8)
Reno KTVN (2)

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Albuquerque KOAT-TV (7)
Roswell KBIM-TV (10)

NEW YORK
Albany WRGB-TV (6)
Binghamton WNBF-TV (12)
Buffalo WKBW-TV (7)
New York WCBS-TV (2)
Rochester WHEC-TV (10)
Syracuse WSYR-TV (3)
Watertown WWNY-TV (7)

NORTH CAROLINA
Charlotte WBTV (3)
Durham WTVD (11)
Greensboro WFMY-TV (2)
Greenville WNCT-TV (9)

NORTH DAKOTA
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Dickinson KQCD-TV (2)
Fargo KXJB-TV (4)
Minot KMCI-TV (13)
Williston KUMV-TV (11)

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Cincinnati WCPO-TV (9)
Cleveland WJW-TV (8)
Columbus WBNS-TV (10)
Dayton WHIO-TV (7)
Toledo WTOL-TV (11)
Youngstown WKBN-TV (27)

OKLAHOMA
Oklahoma City KWTV (9)
Tulsa KOTV (6)

OREGON
Klamath Falls KOTI-TV (2)
Medford KOBI-TV (5)
Portland KOIN-TV (6)

PENNSYLVANIA
Altoona WFBG-TV (10)
Erie WICU-TV (35)
Harrisburg WHP-TV (21)
Johnstown WJAC-TV (19)
Lancaster-Lebanon WGAL-TV (15)
Philadelphia WCAU-TV (10)
Pittsburgh KDKA-TV (2)
Scranton WNEP-TV (22)
York WSBA-TV (43)

RHODE ISLAND
Providence WPRI-TV (12)

SOUTH CAROLINA
Anderson WAIM-TV (40)
Charleston WCSC-TV (5)
Columbia WNOK-TV (19)
Florence WBTW (13)

SOUTH DAKOTA
Rapid City KRSD-TV (7)
Sioux Falls KELO-TV (11)

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Chattanooga WDEF-TV (12)
Johnson City WJHL-TV (11)
Knoxville WBIR-TV (10)
Memphis WREC-TV (3)
Nashville WLAC-TV (5)

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Amarillo KFDA-TV (10)
Austin KTBC-TV (7)
Beaumont KFDM-TV (6)
Bryan KBTX-TV (3)
Corpus Christi KZTV (10)
Dallas KDFW-TV (4)
El Paso KROD-TV (4)
Harlingen KGBT-TV (4)
Houston KHOU-TV (11)
Lubbock KLBK-TV (13)
Odessa KOSA-TV (7)
San Angelo KCTV (8)
San Antonio KENS-TV (5)
Waco KWTX-TV (10)
Wichita Falls KAUZ-TV (6)

UTAH
Salt Lake City KSL-TV (5)

VERMONT
Burlington WCAX-TV (3)

VIRGINIA
Norfolk WTAR-TV (3)
Richmond WTVR (6)
Roanoke WDBJ-TV (7)

WASHINGTON
Bellingham KVOS-TV (12)
Pasco KEPR-TV (19)
Seattle KIRO-TV (7)
Spokane KXLY-TV (4)
Yakima KIMA-TV (29)

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Charleston WCHS-TV (8)
Steubenville WSTV-TV (9)
Wheeling WTRF-TV (7)

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Green Bay WBAY-TV (2)
La Crosse WKBT (8)
Madison WISC-TV (3)
Milwaukee WISN-TV (12)
Wausau WSAU-TV (7)

WYOMING
Casper KTWO-TV (2)
Cheyenne KFBC-TV (5)

*See neighboring states

144 A

FROM A NET ACROSS A CAVE ENTRANCE IN JAMAICA DR. NOVICK GENTLY PLUCKS A BEZZAR BAT FOR LABORATORY STUDIES OF ITS ABILITY TO NAVIGATE BY SOUND. BRUCE A. DALE © N.G.S.

THIS PAGE: TEARS OUT

Strange Creatures of the Night

REVEAL THEIR SECRETS TO DR. ALVIN NOVICK AND OTHER SCIENTISTS IN A NEW TV DOCUMENTARY

SEE IT IN COLOR
WEDNESDAY, JANUARY 17

They live by night

COME where man seldom ventures—into the realm of darkness, where so many of earth's animals hunt, travel, and mate. On January 17 the National Geographic Society opens its 1973 series of color documentaries on CBS-TV. A photographer in Minnesota follows a family of great horned owls from adolescence (**right**) to adulthood. In a dramatic underwater view (**lower right**), an alligator swims away with a mallard it stalked in a Florida swamp. You will see how these and other animals —bats, hyenas, salamanders—have adapted to darkness. Narrated by Leslie Nielsen, the program was produced in association with Wolper Productions and is sponsored by Western Electric Company, Inc., and Lincoln-Mercury.

Keen eyesight equips the douroucouli, or night monkey, for survival after sundown. This long-tailed New World primate lives in the Bronx Zoo's "World of Darkness." There, lighting reverses day and night, so that nocturnal creatures can be active during visiting hours.

MARTIN ROGERS (ABOVE); CARL HARROB (BELOW); JAMES BRANDENBURG

MAX PENNER (ABOVE); ANDRÉ GUNN (LEFT)

Piercing the veil of night, an image intensifier amplifies moonlight or starshine 20,000 times, permitting photography without disrupting animal behavior. A vampire bat in Mexico (**left**) taps blood from the neck of a cow, in a sequence made green by the intensifier's phosphor screen.

The 1973 Ford Country Squire. Now there are more reasons than ever to make it your next wagon.

Famous 3-Way Doorgate.

Dual facing rear seats.

Load space takes 4 x 8 building panels.

Reclining passenger seat.

Electric rear window defroster.

Power Mini-Vent windows.

One reason more people buy Ford wagons is our wide variety of features. Like the 3-Way Doorgate that opens out for people and down for cargo, and Ford's dual facing rear seats. Now we've added windshield washer jets mounted on the wiper arms. A spare tire extractor. Optional Power Mini-Vent windows. Ford wagons include the full-size Country Squire (above), mid-size Torinos and little Pintos. All with energy-absorbing bumpers and optional steel-belted radial ply tires tested to give the average driver 40,000 miles of tread life with normal driving. At your Ford Dealer.

LTD Country Squire. Standard features include woodgrain body-side, tailgate treatment, 3-Way Doorgate, automatic transmission, power steering and brakes. Other equipment shown is optional.

When it comes to wagons, nobody swings like Ford.

FORD WAGONS

FORD DIVISION Ford

How to get the for your money.

Buying stereo can be confusing.

One friend says you have to spend a mint. Another tells you about a "special" bargain on a foreign-made set. And overly enthusiastic salesmen might just confuse you with all kinds of technical specs.

Well, fact is you do have to know a little bit about stereo to make sure you're getting the most music for your money. But you don't have to be an engineer. Or even a buff. Just an intelligent shopper armed with a few basic facts.

So here they are.

Start with the Receiver

A good music system starts with a good stereo receiver. (A stereo receiver is a combination of a stereo amplifier and AM/FM/FM stereo tuner.) So that's a logical place to begin your buying.

But picking the right receiver is no picnic. Because receivers by themselves don't do a thing you can see or hear. They just receive tiny sound impulses from a record, tape, or radio station, magnify them millions of times, with as little distortion as possible, and drive the speakers with the magnified impulse.

All of which means that two of the most important things to look for in receivers are how much distortion takes place and how much power there is to drive the speakers.

Distortion ratings (called T.H.D.) are simple. The lower the number the better. For example, Sylvania receivers CR2742 and CR2743 both have a rating of 0.5% at full power output, which is considered good.

Power is a bit more complicated. There are several kinds of ratings. But the one that counts is the "continuous" or RMS rating. Here the higher the number, the more power you have to drive speakers. A receiver like the Sylvania CR2742, with a continuous power rating of 25 watts per channel, can easily drive four big speakers. If you want an even larger system, with speakers all over the house, the Sylvania CR2743 can handle them with a continuous power rating of 50 watts per channel. If you can't get a continuous power rating, be suspicious!

The next things to check are the features. A good stereo receiver should have solid-state circuitry, Field Effect Transistors (FET's), and ceramic filters. We won't go into their technical functions here, but be sure to look for them while buying. Quality receivers will have them.

Your receiver should also have a full-function jack panel (like the one on the back of the Sylvania CR2743 shown below) that allows you to add extra speakers, tape decks, headphones, or other equipment. And make sure there's built-in capability to adapt the new quadraphonic sound systems in case you want to expand in that direction.

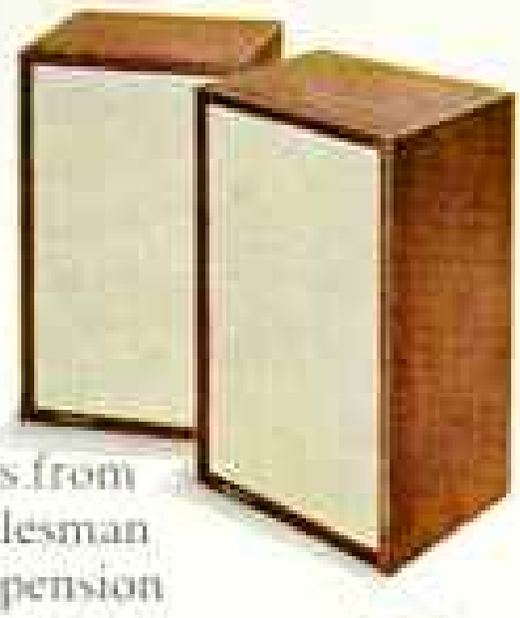
Every Sylvania receiver, for example, has built-in Phase Q4 matrix four-channel circuitry to enhance ordinary two-channel stereo. This gives the effect of four-channel sound. In addition, you can get true (discrete) four-channel sound simply by adding our special new DMQ2784W quadraphonic converter. (And of course in both cases you need two extra speakers.)

Finally, check the price. As a guide, the Sylvania CR2742 gives you 50 watts total continuous and all the rest for $199.95.* The CR2743 gives you all that and 100 watts total continuous for $279.95* So no matter what brand you choose, make sure you get just as much for just as little.

Onward to the Speakers

The technical stuff's out of the way. Now comes the fun part.

most music



The only way to buy speakers is to listen to them. Compare the different sounds from the different sizes. Ask the salesman about "air" or "acoustic" suspension speakers. In general, they deliver the most satisfying speaker sound.

Make the salesman work a little. Switch back and forth between the big, medium, and small speakers. Play it by ear. The ones that sound best to you are the ones to buy.

Just keep your eyes out for a few things while your ears are busy. Make sure the receiver driving the speakers you're hearing is the same as the one you're buying. Otherwise you won't be getting the same sound once you get the speakers home and hooked up to your receiver.

And remember, the word "speaker" refers to two things. It means the individual speakers . . . woofers, tweeter, etc. But it also refers to the whole speaker cabinet, which generally contains more than one individual speaker. Be sure to check out how many speakers there are in any speaker cabinet. Two, a woofer for low notes and a tweeter for high ones, is a minimum. Bigger speakers, like the Sylvania AS125A, will have at least three: a woofer, a dome mid-range, and a dome tweeter.

Prices range from $149.95* for the big Sylvania AS125A with three speakers to a cabinet, down to $59.95* a pair for the Sylvania AS1706W with two speakers each.

But above all else, pick the speakers that sound best to you.

Now It's the Turntable's Turn

There are a few manufacturers who specialize in making turntable mechanisms. It's their thing, and their product is definitely superior.

The only trick to buying a turntable, then, is to make sure that you get one whose guts come from one of these specialists.

Any audio manufacturer should be more than happy to tell you who made his turntable mechanism.

For example, Dual (one of the big names) made the changer in Sylvania's T2705 Automatic Turntable. Garrard (that's another big one) made the changer in our Model T2703.

Ask for magnetic cartridges on your turntable. They're more sophisticated and pick up sound impulses better than ceramic cartridges. Both Sylvania turntables have them.

Things like cue-pause control (which allows you to gently raise and lower the tone arm to any band you choose) and anti-skate control (which equalizes pressure on both walls of a record groove to give less sound distortion) are usually standard on quality turntables like a Sylvania.

E-x-p-a-n-d-i-n-g

Price guidelines are $139.95* for the T2705 and $79.95* for the T2703.

Adding tape facilities is a simple way to expand your basic stereo system.

You can add a Cassette Play/Record Tape Deck like the Sylvania CT160 to play pre-recorded cassette tapes over your speaker system. Or you can record your own in two-channel stereo.

Or, you can go the 8-track route, with a Playback Deck like the Sylvania ET2750W. That way you can use car stereo tapes at home, and vice versa.

Good Luck!

By now you're a lot smarter about stereo. You know basically what to look for. And you've got some guidelines on what to pay.

So now's the time to go shopping. Look around. Compare. Get the most music for your money.

And even if you don't pick a Sylvania, enjoy your stereo!

*Based on manufacturer's suggested list price.

GTE SYLVANIA
A part of General Telephone & Electronics

This Malagasy boatman steers from here to eternity

He stands over his crew and looks back. He sees a life spent at sea, lightering cargo from ships. And that is his epitaph, sculptured in wood and placed above his grave.

Such Madagascar "tombstones" celebrate life in the Malagasy Republic. One depicts a man beating a drum, another a herdsman tending his cattle. A carving of an airplane denotes that the person entombed once flew. Malagasy chieftains rate a tomb post suggestive of a totem pole. It may be 30 feet high, a panorama of life told in tiers of carvings that show him hunting, protecting his family, slaughtering a zebu, even making love.

Though nominally Christian, the Malagasy cling to ancient beliefs, holding that ancestors dictate health, wealth, and fertility of descendants. From tombs half above ground and half below, the departed are brought into the sunlight every four or five years and wrapped in new silk. Not a sad occasion, the reunion with an ancestor marks a time for singing and dancing. Celebrants joyfully toss the body into the air and catch it again. Cattle are sacrificed, their horns left to adorn the top of the tomb.

The body is re-interred, there to rest until the next *famadihana*, the turning of the dead.

Despite the nearness of Africa, the ancestry of Madagascar's peoples is predominately Malayan and Polynesian. Migrants, historians theorize, sailed across the Indian Ocean in outrigger canoes to colonize an island home like no other on earth. Here they found nightmarish forests of cactuslike *Didierea*. Here roamed monkey-like lemurs with bat's ears and flowing foxtails; primitive tenrecs pincushioned with quills; and aepyornis, the now-extinct flightless bird that weighed half a ton and laid 20-pound eggs.

Independent of France since 1958, Madagascar carves a niche in world society uniquely its own. To follow its saga of development, as well as that of other emerging nations, readers turn each month to the pages of NATIONAL GEOGRAPHIC.

There is a place that looks exactly like these postcards. Oddly enough it's where we took the pictures.

These pictures were not retouched, so when you come to Bermuda you will not be disappointed. We can promise you countless scenes like these, because, in reality, Bermuda is a 21-square-mile picture postcard. You'll enjoy everything here including some of the nicest people you've ever met—Bermudians. Bermuda is only 90 minutes away from the U.S. coast. See your travel agent. Or write Bermuda: 610 Fifth Ave., N.Y., N.Y. 10020—6 N. Michigan Ave., Chicago, Ill. 60602.

Bermuda

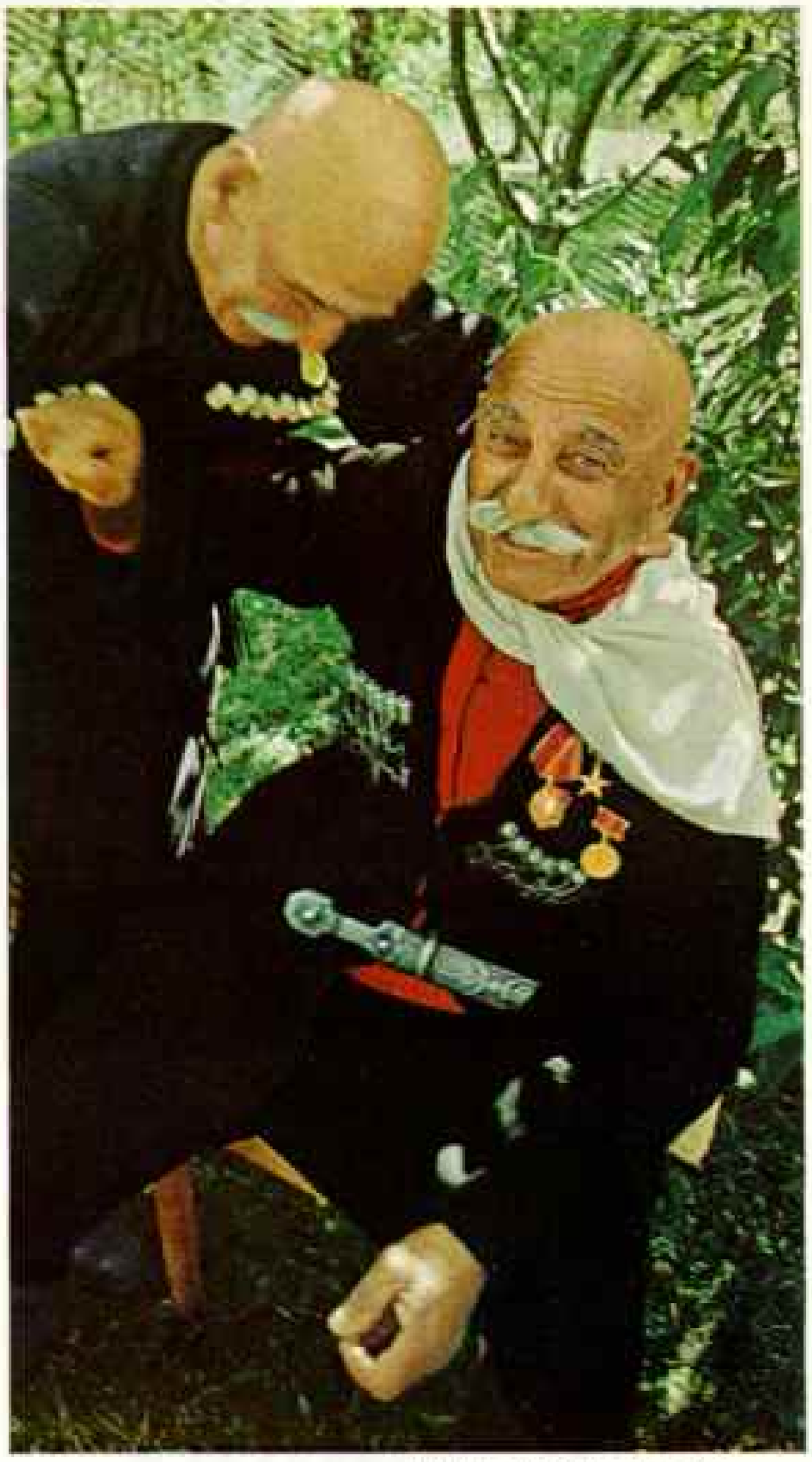
Wish you were here.

The mysteries of human longevity

HOW LONG can a person live? Why do some outlive others? Such questions sent Dr. Alexander Leaf, supported by the National Geographic Society, to the Ecuadorean village of Vilcabamba, to Hunza in Kashmir, and to the Caucasus. In each area, he examined hearty centenarians such as Hunzukut Tulah Beg, 110 (**below**), and Abkhazians Temur Tarba, 100, and Markhti Tarkil, 104 (**right**). A report by Dr. Leaf begins on page 93.

Born in Japan of Russian parents, Dr. Leaf—an American citizen since 1936—sees the aging process close up as Chief of Medical Services at Boston's Massachusetts General Hospital and as Jackson Professor of Clinical Medicine at Harvard Medical School.

Your membership helped support his research. Aid the efforts of others by nominating your friends on the form below.



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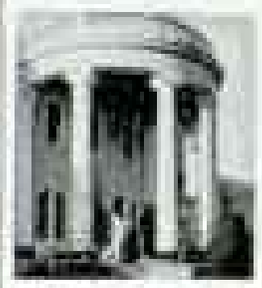

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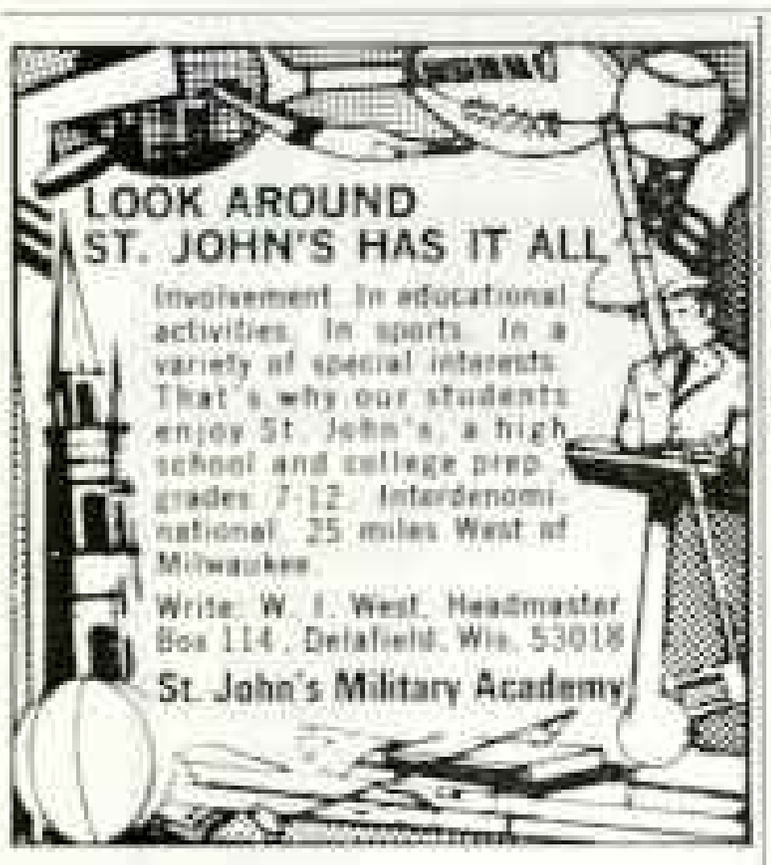

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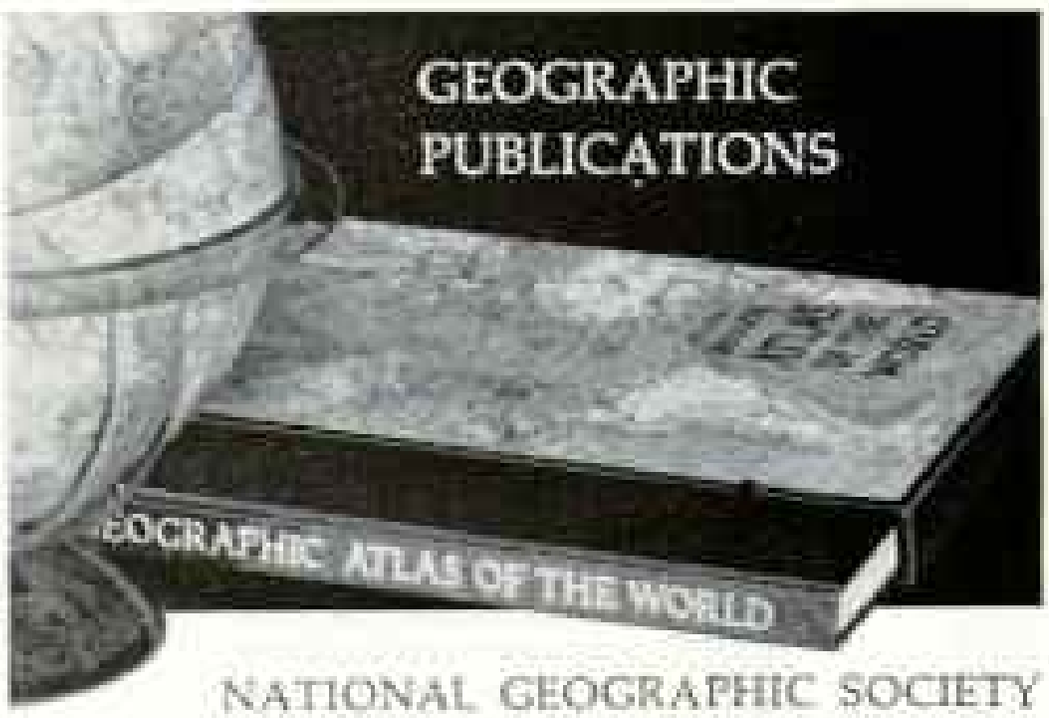

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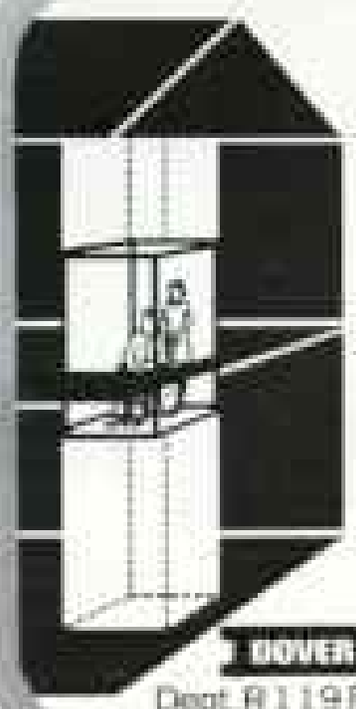

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