DOUBLE SUPPLEMENT: DINOSAURS

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Dinosaurs

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COVER: Dawn mist swirls around a Mongolian Saurolophus, *one of a fascinating array of giants that flourished 70 million years ago before the age of dinosaurs came to an end. Painting by John Gurche.*

Cover printed on recycled-content paper.

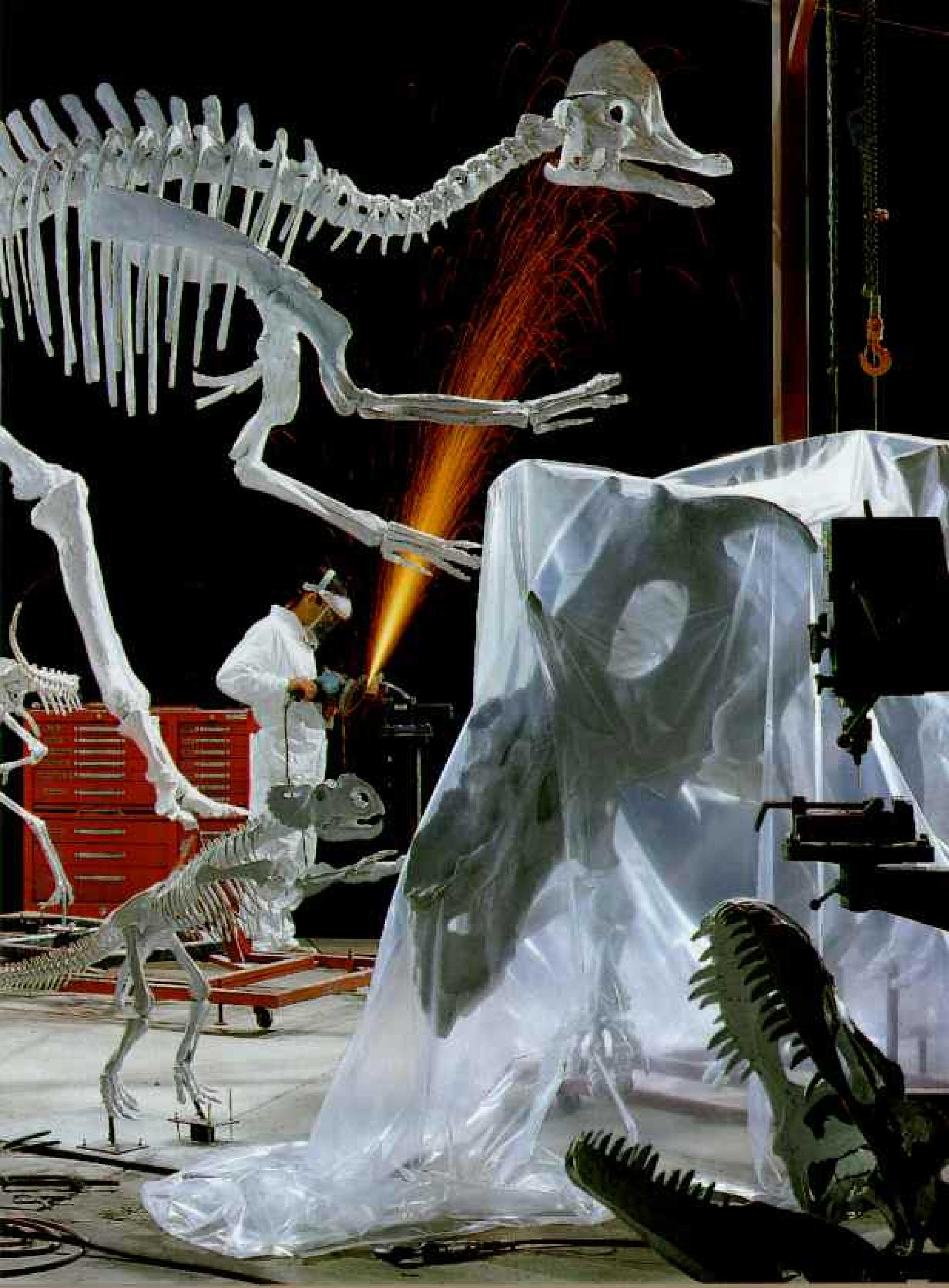
Dino

Battering a rival male, a one-ton, thick-skulled *Pachycephalosaurus* establishes dominance. New fossil evidence testifies to a variety

saurs

of social behaviors and an astonishing diversity of species during
the 165 million years that dinosaurs flourished on the earth.

FOSSIL FACTORY *In the clutter of a warehouse in Drumheller, Alberta, workers ready steel supports for cast skeletons of knife-toothed predators, peaceful browsers, and ostrich-like striders that will begin a world tour in May. The fossils were unearthed during*



five years of joint Canadian-Chinese expeditions. The more than 80 tons of specimens collected in both countries, which include new species as well as familiar ones found in new situations, seem likely to change dramatically our picture of how dinosaurs lived.

REX REDUX *A 129-foot-tall Tyrannosaurus rex hot-air balloon sails across 16,363-acre Dinosaur Provincial Park in Alberta. Today T-rex startles and delights. Seventy-five million years ago tyrannosaurs terrified other animals that paused here along lush river*

deltas and swamps during migrations. Fossils of more than 35 different dinosaur species, about 10 percent of all those known, litter the park's weathered sandstone badlands and have been collected for museums around the world since the 1880s.

By RICK GORE SENIOR ASSISTANT EDITOR
Photographs by LOUIE PSIHOYOS
Paintings by JOHN GURCHE

SOMETHING made Ricardo Martínez stop and pick the rock out of the red sands of the Ischigualasto badlands. Maybe it was the way the sun glanced shadows across this rugged terrain in northwestern Argentina. Maybe it was just a flash of good luck. Something made him look twice at the rock.

"I was about to throw it away," recalls the young paleontologist. "Then I saw the teeth." That rock, he realized, was encasing a skull, probably 225 million years old.

Now, as I arrive on the scene, members of this joint Argentine-American expedition are clustered around the abashed but delighted Martínez.

"*¡Fantástica!*" says one of his colleagues. "*¡Excelente!*" exclaims another. They are eagerly excavating not just the skull but also the entire skeleton of a long-extinct, sheep-size animal no one has ever seen before.

I have just driven from the team's camp with Paul Sereno, a 34-year-old professor from the University of Chicago and one of the leaders of this expedition. Sereno hurries to the skeleton and crouches over it. With a dental pick he begins scraping away the dirt of ages from a foot. He is anxious. He has a reputation for making lucky finds and hopes his luck still holds.

"This is an ungual [a small bone that supports a claw], and here's a curled toe—the fourth digit," he says. He moves to the ankle, talking to the bones: "Yes! Behave yourself and soon you'll be a dinosaur."

Few creatures excite our imagination as do the dinosaurs—those bizarre giants that first roamed the earth some 230 million years ago and then mysteriously disappeared. Since its founding 105 years ago, the National Geographic Society has sponsored scores of research projects on the dinosaurs. Many of the fascinating discoveries revealed in this article result from that support.

—THE EDITOR

Sereno knows that this animal is just as likely to be a primitive crocodile, another group evolving at the same time. When the rocks of this arid, brutal valley were laid down 225 million years ago, dinosaurs were rare and relatively small. The world was literally crawling with other beasts, many much larger and more fearsome.

Still, on an expedition here in 1988, Sereno had found the most complete skeleton of the earliest dinosaur then known, *Herrerasaurus*. It was a long-snouted creature, some 15 feet in length. Hopes for another such prize have drawn him back. This part of Argentina is one of the few places on earth that records the dawn of dinosaurs.

"It looks like we've got a dinosaur!" Sereno shouts. He has scraped clean enough bone near the ankle to be confident. All dinosaurs share about a dozen skeletal characteristics, mostly related to locomotion and posture. Ankles are diagnostic.

Leg structure in particular distinguishes dinosaurs from the creatures that went before them and from modern reptiles. The legs of crocodiles, for instance, sprawl out from the sides of their bodies. Dinosaur legs extended directly below, as in horses. This lifted their bellies off the ground and enabled them to walk upright and perhaps to move with more agility.

In the days that followed, Sereno developed a hunch that this dinosaur might be more primitive than *Herrerasaurus*. Months of work at the University of Chicago would prove him right and also throw new light on the beginnings of the dinosaur family tree.

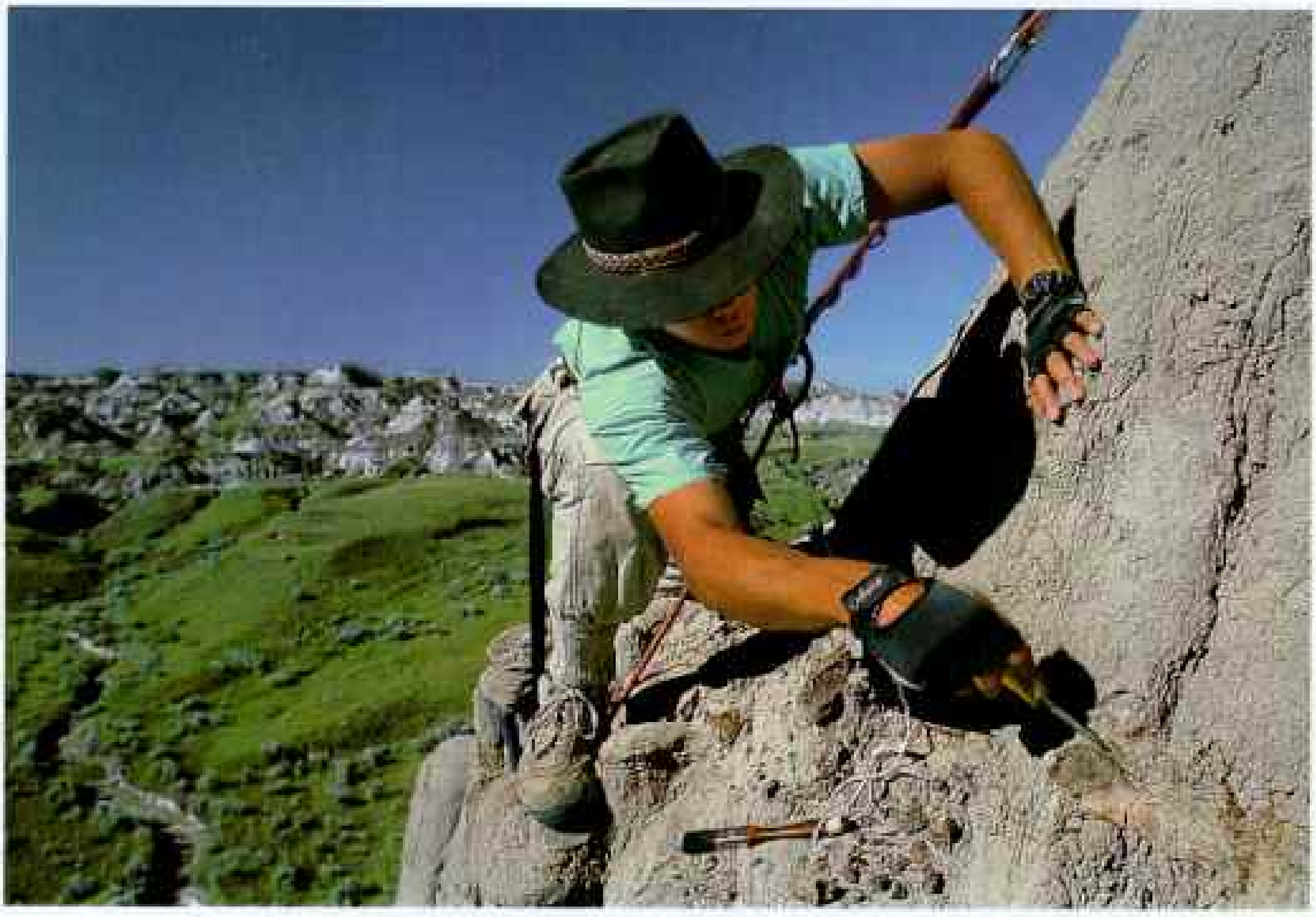
UNIVERSITY OF CHICAGO HOSPITALS

"This animal gives us a snapshot of what the very first dinosaurs looked like," says Paul Sereno, whose hand holds the skull of "Eoraptor," the most primitive dinosaur known, in a composite X-ray image. Sereno led a joint expedition that found this 228-million-year-old carnivore in Argentina. Radiography reveals interior structure without damaging the fossil.

As a science journalist, I have covered the ongoing debate over why dinosaurs became extinct about 65 million years ago. Were they chilled to death in the catastrophic aftermath of a comet or asteroid striking earth? Were they done in by a virus or by gradual climate change? The arguments have been heated—and unresolved. Meanwhile, a quieter and more important story has been developing. All over the world, often in harsh places like the Ischigualasto Valley, a relatively small number of paleontologists are rewriting the saga of how dinosaurs lived, not how they died.

Now, as I visit their field sites and museums, I find myself growing less interested in extinction than in origination. New beginnings. Biological invention and problem solving. Dinosaurs, we are learning, were extraordinary innovators. They were pioneers in metabolic efficiency, locomotion, and such

NEW TERROR AFOOT *On a verdant riverbank in what is now Argentina, Herrerasaurus, an early dinosaur, stalks its prey. Dinosaurs will soon rule the forest and many other environmental niches. Mammal-like reptiles, or cynodonts, cower before Herrerasaurus. Their descendants, small mammals, will keep to the shadows of creation until dinosaurs become extinct.*



Belayed for dear life in Dinosaur Provincial Park, university student Hans Larsson picks at a rhino-like Centrosaurus. Getting fossils out of the ground is the easy part; cleaning and study take years. Wade Miller, director of Brigham Young University's Earth Science Museum in Provo, Utah, checks on a hundred tons of unexamined fossils stored under the football stadium.

social behaviors as herding and parental care.

Even better news is that the great beasts of our fantasies are still alive. In the past decade most experts have concurred that, anatomically, birds belong on the dinosaur family tree.

As Kevin Padian of the University of California at Berkeley puts it: "Dinosaurs haven't gone extinct. You have a dinosaur bath in your backyard, roast dinosaur at Thanksgiving, and eat dinosaur nuggets at McDonald's."

The name dinosaur was first used in print in 1842 by the English anatomist Sir Richard Owen, when it became clear that newfound fossils were from an unrecognized animal group. Owen combined two Greek words—*deinos*, or "terrible," and *sauros*, or "lizard," to describe the remarkable creatures.

We know today that dinosaurs trod the earth for 165 million years, from about 230 million to 65 million years ago. Scientists count some 350 known species, half described in just the past 20 years. But they believe this represents only a fraction of the species that existed. All probably evolved from a scurrying, bipedal, pheasant-size reptile.

Back in Chicago, Sereno's analysis of his new dinosaur's skeleton convinces him it is indeed more primitive than *Herrerasaurus*. It lacks a flexible jaw that let *Herrerasaurus* and later carnivores snag and trap struggling prey. Thus Sereno believes this new creature is the closest fossil we have to the first dinosaur.

"I call it 'Eoraptor,'" he says. "Eos was the Greek goddess of dawn. Raptor means thief. It was a light-bodied little rascal. And it may have been a thief, dashing in to grab scraps of someone else's kill."

Moreover, Sereno says, the new dinosaur helps determine when the dinosaur family tree branched. Paleontologists have long recognized two major groups of dinosaurs—the saurischians, which had lizard-like hip structures, and the ornithischians, whose hips resembled those of birds. Scientists still don't understand how that different hip structure affected their locomotion. The two groups, nevertheless, evolved along distinct paths.

The saurischian branch would include many of the most famous dinosaurs: for instance, the sauropods—a grand group of


THORKTRUCK

huge, four-legged, long-necked plant-eaters, such as brontosaurs—and the theropods, the rapacious group of carnivores that led both to birds and to *Tyrannosaurus rex*.

The ornithischian branch, on the other hand, was strictly vegetarian. It too would give rise to well-known descendants. Many of them were bipedal, such as the duck-billed dinosaurs. Others, such as the armored stegosaurs and the horned ceratopsians, browsed on all fours.

Both dinosaurs found by Sereno were saurischians, and he notes that the earliest known ornithischian was also discovered near the Ischigualasto Valley. So, although the record is sketchy, the fossils of Argentina indicate that in those early years 225 million years ago the main pathways of dinosaur evolution had already emerged. Dinosaurs were evolving rapidly, perhaps explosively.

What were those early dinosaurs like? Their legs were long, Sereno told me, more like a gazelle's than a modern crocodile's, and they could move quickly and gracefully. They had well-developed grasping arms. "And most excelled as hunters, apparently eating whatever they could grab."

EVIDENCE FOR THAT VORACIOUSNESS lies far to the north of the Ischigualasto Valley in a small museum at the Ghost Ranch, a Presbyterian Church conference center in northern New Mexico. There museum curator Lynett Gillette shows me a skeleton of a slender adult theropod named *Coelophysis*. Inside its abdomen lie the bones of a devoured baby of its own species.

Hundreds of *Coelophysis* skeletons have been found close together, as if they had perished in some calamity. They have been excavated on the ranch since 1947 and hint at other innovations dinosaurs were making. They had clustered together and thus had evolved social organization.

Was it for hunting, feeding, or protection?

Perhaps, suggests Hans-Dieter Sues of the Royal Ontario Museum, we are seeing flocking—an intriguing insight, since birds now belong in the dinosaur family tree.

Coelophysis was built like a long-distance runner. "One reason for its speed and agility," says Gillette, "might be to escape guys like that phytosaur over there."

I turn to see the skeleton of a 19-foot-long monster behind us. This giant jaw with a tail was one of the crocodile-like animals that fed in lakes and streams. Not only these ferocious reptiles but also huge amphibians—imagine a cross between a salamander and an alligator—made life hazardous for a *Coelophysis*.

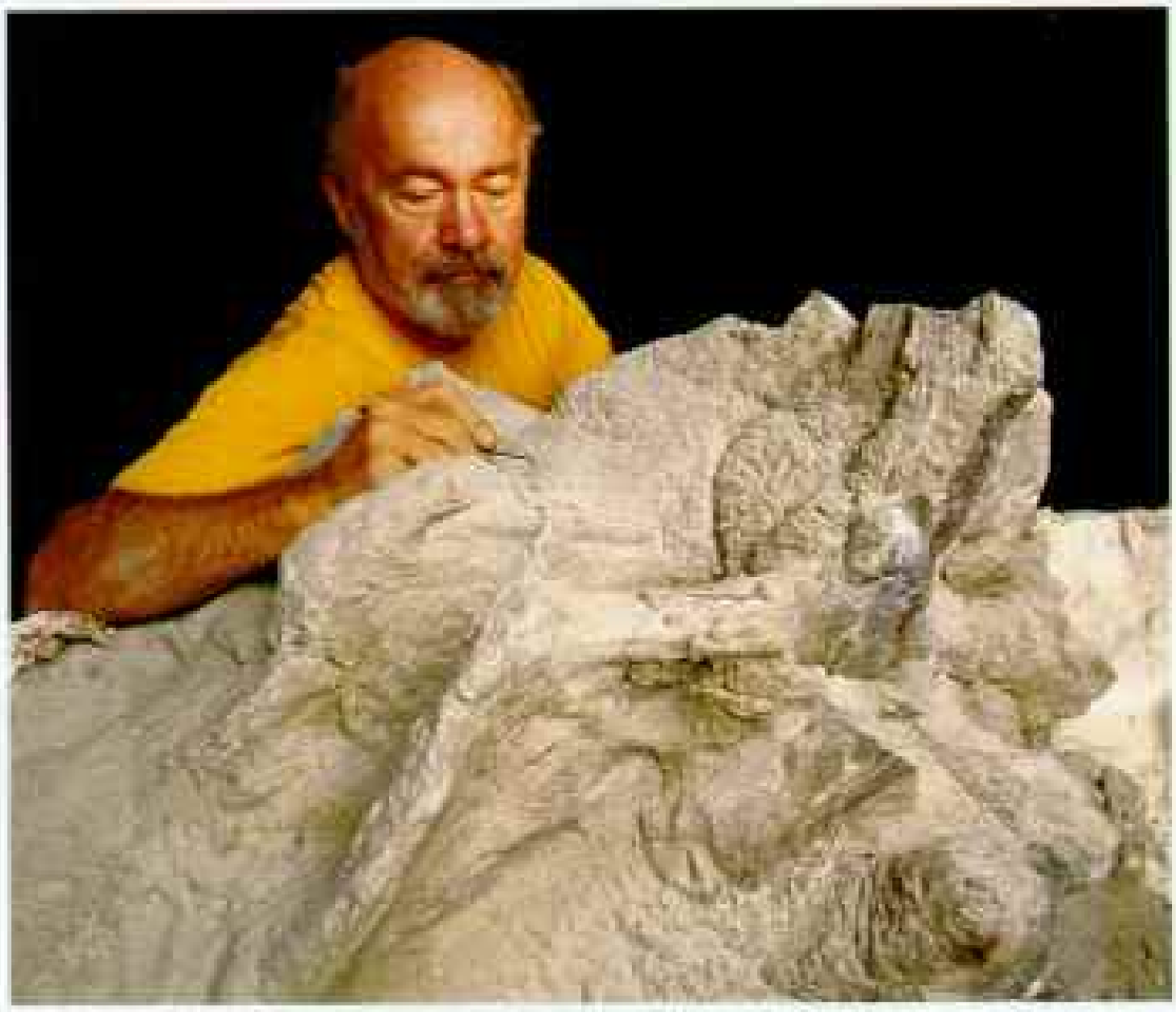
Coelophysis probably terrorized smaller animals—insects, amphibians, little reptiles, and perhaps the forerunners of mammals. The true mammals, furry and shrew-size, emerged about the same time as dinosaurs. Yet for 165 million years they would remain minor players on the land. No one knows why. Mammals even then had relatively large brains and presumably more efficient, warm-blooded metabolisms.

Dinosaurs themselves had evolved surprisingly sophisticated metabolic skills. That's one of the major recent discoveries. A generation ago, when dinosaurs were seen simply as big lizards, most experts believed they were all cold-blooded, or ectothermic as scientists phrase it. Cold-blooded animals, such as modern reptiles and amphibians, rely largely on their environment to regulate their internal temperatures. Basking in the sun thus energizes an alligator, while cool weather makes it sluggish. Such animals cannot be active on demand for long. On the other hand, warm-blooded, or endothermic, animals generate their own internal energy. This allows them to be active when they need to be.

In the late 1960s an iconoclastic young paleontologist named Robert Bakker triggered a revolution by noting that dinosaurs could never have taken over the land if they in fact had the metabolism of big lizards. He envisioned dinosaurs that galloped and reared up on their hind limbs to eat treetop foliage. Such behavior, he said, required warm-bloodedness.

Most scientists today reject an either-or position. "Dinosaurs could do almost anything metabolically," says Hans-Dieter Sues. Being innovators, they probably evolved a range of temperature-regulation techniques. Large animals, whose bodies retained heat well, could have tended toward ectothermy, while the smaller, active predators would have tended to be endothermic.

How did dinosaurs take over the land? All we can say is that near the end of the Triassic period, about 210 million years ago, something extraordinary happened on planet earth: a global mass extinction. Many species were hard hit, *(Continued on page 24)*



The right light makes all the difference to Dave Thomas as he frees a Seismosaurus from New Mexico sandstone as hard as concrete. In daylight he can hardly distinguish fossil from stone, but under ultraviolet light the fossil glows. With magnifying glass and dental pick, he removes the stone bit by bit, uncovering just a few square inches of dinosaur a day. At that rate it will take at least ten more years to prepare this fossil for display. One of the longest dinosaurs ever found, Seismosaurus may have measured 150 feet from nose to tail.

UP THE WALL. *Spread-eagled against an almost vertical rock face, Argentine geologist Ricardo Alonso aims a two-meter stick at ancient footprints. About 65 million years ago, long before tectonic forces tilted the landscape of the Andes, dinosaurs walked here along*

the wave-rippled shore of an inland sea. Several agile, bipedal creatures—perhaps hadrosaurs feeding on aquatic plants—left trails that crisscross. A claw-toed carnivore passed nearby, possibly coming to the water to drink or to stalk the hadrosaurs.

A MARCH ACROSS MILLENNIA

An extraordinary experiment in evolution, dinosaurs descended from an ancient line of reptiles during the Triassic, the first period of the Mesozoic era. As their world broke into island continents over the next 165 million years (shown on globes), they spread across a great range of habitats.

Evolving from a common ancestor, dinosaurs by the late Triassic had split into two large groups—ornithischians, or bird-hipped herbivores (top of tree), and saurischians, or lizard-hipped carnivores. In turn the saurischian line split into plant-eating sauropods and prosauropods (middle) and mostly meat-eating, bipedal theropods (bottom).

By the late Jurassic, communities of browsers like the strangely plated *Stegosaurus* and the long-bodied *Diplodocus* had developed along with large carnivores, such as the lethal-jawed *Allosaurus*.

New life-forms flourished in the Cretaceous. While flowering plants pushed aside conifers and cycads, herbivores with horns and head frills arose, and the great carnivores grew even larger.

As successful at adaptation as dinosaurs were, none but the birds survived the era.

ILLUSTRATION BY CHUCK CARTER; DINOSAURS BY GREGORY S. PAUL; MAPS PROVIDED BY DAVID B. ROWLEY, UNIVERSITY OF CHICAGO

DINOSAURS NOT SHOWN TO SCALE

Late Triassic
210 million years ago
Continents have collided into one large landmass, known as Pangaea, and are on the verge of splitting apart again. A tongue of water has already pushed between Africa and North America. Far from the moderating influence of oceans, many inland areas are deserts. Species of plants and animals disperse unhindered across the globe.

● MAJOR FOSSIL SITE

Bird-like hips
Many ornithischians, especially early species, had a new hip structure resembling that of modern birds, with the pubic bone (in red) deflected backward among the other pelvic bones.

Lizard-like hips
Saurischians retained their ancestral pelvic form, with the pubic bone projecting forward. Ironically, birds descended from lizard-hipped dinosaurs, only later developing deflected pelvic bones.

FABROSAURS

Lesothosaurus
Swift biped; arrowhead-like teeth chopped tough vegetation. Length 3 ft. Africa.

Plateosaurus
Earliest known large-bodied dinosaur; browsed on all fours or on hind legs. Length 26 ft. Europe, Greenland.

THEROPODS

HERRERASAURS

Herrerasaurus
Agile bipedal predator, whose jaws clamped down on a struggling victim while claws on hands held it fast. Length 15 ft. South America.

Late Jurassic

152 million years ago

Pangaea has moved apart, with ocean channels separating Antarctica from Africa, Africa and South America from North America, and North America from Europe. Global temperatures are generally warmer than today, allowing plants and animals to live at much higher northern and southern latitudes.

Stegosaurus
Browser whose bony plates may have regulated body temperature. Length 25 ft, western U. S.

ANKYLOSAURS

ORNITHOPODS

Iguanodon
Herding swamp dweller with iguana-like teeth and a large thumb spike, probably used for defense. Length 33 ft, Europe, western North America, northern Africa, Asia.

PACHYCEPHALOSAURS

PROSAUROPODS

Diplodocus
Huge long-bodied browser; at 11 tons, lighter than many other sauropods. Length 88 ft, western U. S.

Dilophosaurus
Carnivore whose thin, fluted head crests may have helped it attract mates. Length 20 ft, western North America, China.

Allosaurus
Large predator with sharp curved claws and long, serrated teeth able to stab and cut; may have attacked in packs. Length 30 ft, western North America.

ALLOSAURS

JURASSIC PERIOD ▲ 150

Late Cretaceous

74 million years ago

The world has assumed more of its modern appearance, though shallow seas flood low-lying areas. Dispersal of continents has separated communities of plants and animals to some extent; but intermittent connections allow migrations. With temperatures still warm, forests cover northern latitudes.

STEGOSAURS

Sauropelta
Broad-bodied browser protected by bony studs, pebbly plates, flanking fringe of spikes. Length 17 ft, western U. S.

Homalocephale
Thick-skulled species probably established dominance by butting rivals with a flat head studded with bony knobs. Length 10 ft, Mongolia.

Parasaurolophus
Plant-eater whose head crest may have resonated mating calls. Length 33 ft, western North America.

CERATOPSIANS

Triceratops
Herding browser protected by a short, solid neck frill and three facial horns. Length 30 ft, western North America.

SAUROPODS

CERATOSAURS

Deinonychus
Agile predator that probably hunted in packs and slashed at prey with sickle-like claws. Length 9 ft, western U. S.

DROMAEOSAURS

Sinornis
Link between Archaeopteryx, the earliest bird known, and modern birds. Length 7 inches, China.

BIRDS

Tyrannosaurus
Largest of the carnivores; tore apart prey with large saw-edged teeth set in massive, powerful jaws. Length 43 ft, western North America.

TYRANNOSAURS

CRETACEOUS PERIOD ▲ 100

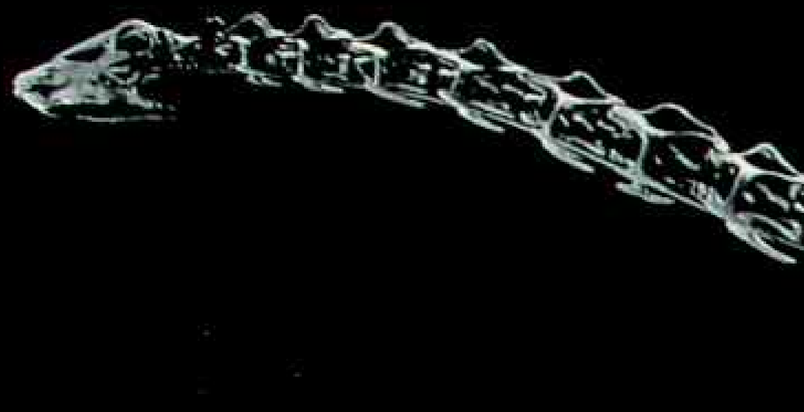
The bitter end

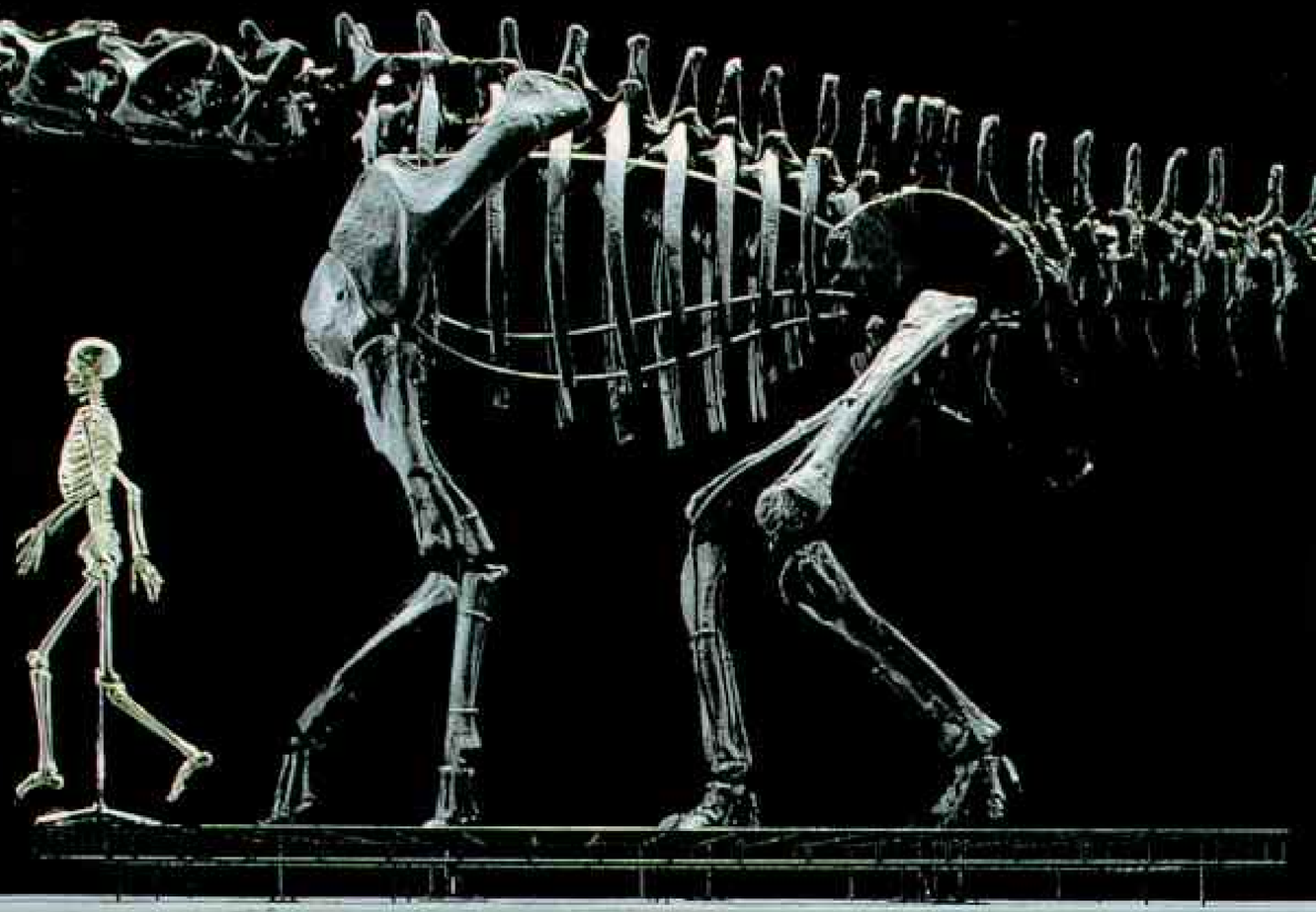
Diversity declined as climates became more seasonal at the end of the Cretaceous. Did the last of the dinosaurs die after an asteroid struck earth 65 million years ago, or were they already extinct? We may never know.

TERTIARY PERIOD ▲ 50

HOT-BLOODED DEBATE

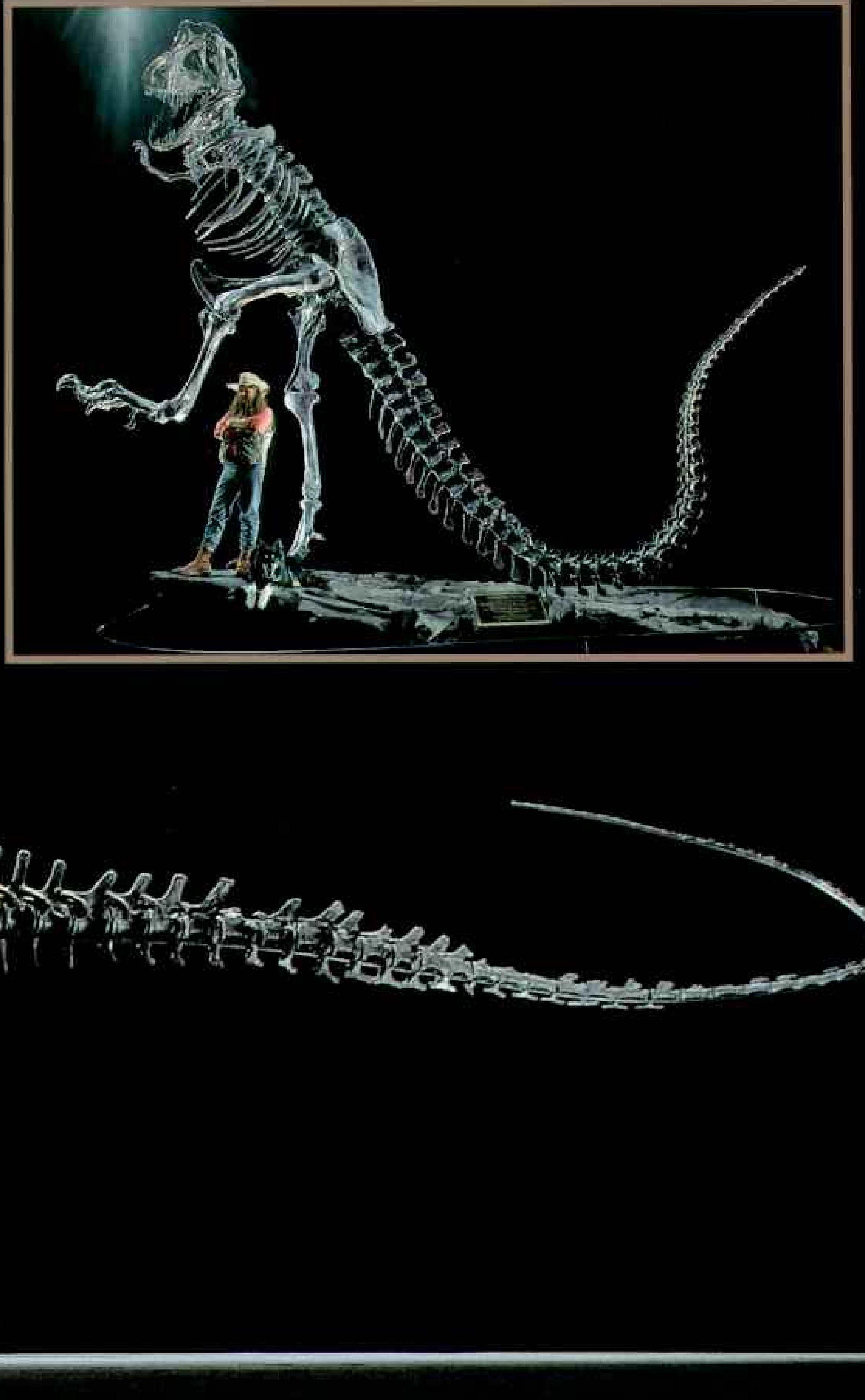
Fossils define size and shape, but dinosaurs' life-styles remain a riddle. John Ostrom (right) of Yale's Peabody Museum believes the Deinonychus *he discovered was an agile, probably warm-blooded predator. Arguing that all dinosaurs were warm-blooded and energetic, paleontologist Robert Bakker (far right) put the Denver Museum's* Tyrannosaurus *in an active pose. In New York's American Museum of Natural History a* Barosaurus *(left) rears 50 feet high to protect her young, a position some scientists find unlikely.*





OUT OF THE SWAMP

A long tail counterbalances the boomlike neck of this 65-foot-long Diplodocus *in Germany's Senckenberg Nature Museum. Such giants were once thought to be aquatic, with water supporting their weight. New theories put them on land, their tails lashing the air, some 145 million years before* Homo sapiens *strode forth.*



(Continued from page 14) and the great crocodile-like creatures that had flourished before completely disappeared. Most creatures that survived were small.

At first some scientists believed that a huge impact crater in Canada called Manicouagan explained the extinction. The impact, which left a crater more than 60 miles wide, could have created a cold dark dust cloud—blocking the sun, killing plants, and causing starvation among animals. (Many scientists believe a similar event wiped out the last of the dinosaurs 150 million years later.)

However, recent radiometric dating indicates the Manicouagan crater was formed several million years before the mass dying. Paleontologists can find no sign of biological turmoil in the fossil record to match the new date. Still, as Hans-Dieter Sues remarks, "The object that created Manicouagan was very large. If that didn't create a mass extinction, what could?"

Some scientists argue that the extinction was probably the result of gradual climate change. Earth's landmasses had long been assembled into one supercontinent called Pangaea. Then it began to break apart; this was accompanied by massive volcanism, mountain building, and the creation of new seas. All these could have altered weather patterns dramatically.

AFTER THE EXTINCTION dinosaur populations exploded across the land. Why the dinosaurs? A lot of new habitats had opened up. Perhaps the warmer world favored their physiologies. Perhaps it was just luck.

Understanding the triumph of the dinosaurs is difficult because there are few fossil-rich rocks from this period, the early and middle Jurassic, from 208 million to 157 million years ago. One of the most complete rock records spanning this period lies in China. Recently Chinese paleontologists have found many missing links.

Konglong means both "dinosaur" and "terrible dragon" in Chinese, and for centuries the Chinese have wondered about the dragon bones they found in their soil. Third-century A.D. writer Chang Qu explained the mystery: "A dragon ascended a mountain and went directly to the Gate of Heaven. The gate being locked, the dragon could not enter, and so fell back to earth and died at this spot. Later it sank into the earth."

"Many farmers still do not know the truth about dinosaur bones," says Dong Zhiming, China's leading dinosaur paleontologist, as we drive through rustic agrarian villages in Sichuan Province in south-central China. "If an old farmer finds a dragon bone, he'll take it home to use for medicine. The dragon is strong and brings good luck. The farmer thinks if he grinds and eats the bone, he too will become strong and lucky."

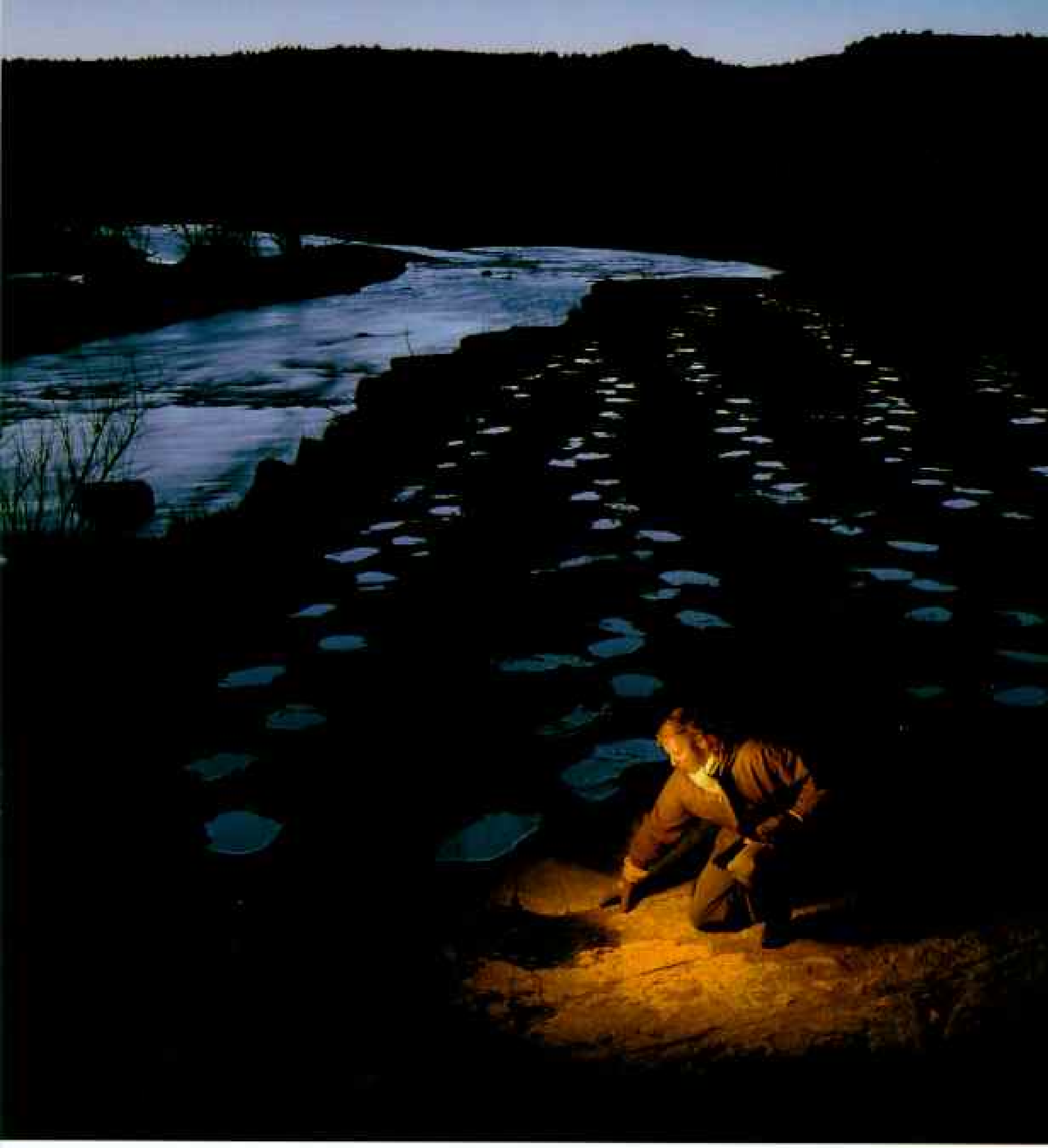
Dong works hard to get the truth about konglong to the people. We are headed for the provincial city of Zigong, where for years he excavated an enormous cache of middle Jurassic dinosaurs found in 1972 at a quarry called Dashanpu. The Chinese government has built a splendid museum over the site, which is the size of a football field.

As we bounce for hours on torturous roads, Dong explains how China reveals the evolution of the great families of dinosaurs. In nearby Yunnan Province, where farmers use dinosaur bones as building stones for pigpens, the early Jurassic left its records. Rock beds there show how theropods like *Coelophysis*, the small beast of Ghost Ranch, changed after squeaking through the great extinction. In 1987 farmers found a relative 15 feet long. The creature was found interlocked with a larger herbivore. "I think they died in combat," says Dong. "Perhaps they were struggling on a lake bed and got bogged down in quicksand."

The newer and larger Chinese theropod, a new species of *Dilophosaurus*, has two bony ornamental crests on its head. It also has hints of a narrow curved beak, says Dong. He suggests that, like a vulture, it could tear into the skins and abdomens of larger animals.

Also in Yunnan Province, farmers uncovered an early sauropod, called "Kunmingosaurus." Only 22 feet long, this creature lacked the long neck and huge size that would be attained by later sauropods. But Kunmingosaurus's heavy body, supported by four

Sparks cascade as a welder finishes supports for a cast of a T-rex nicknamed Black Beauty for its ebony sheen. Known only from Black Beauty's skeleton and ten others, this large carnivore was probably rare among the creatures it preyed upon during the last few million years of the dinosaurs' reign.

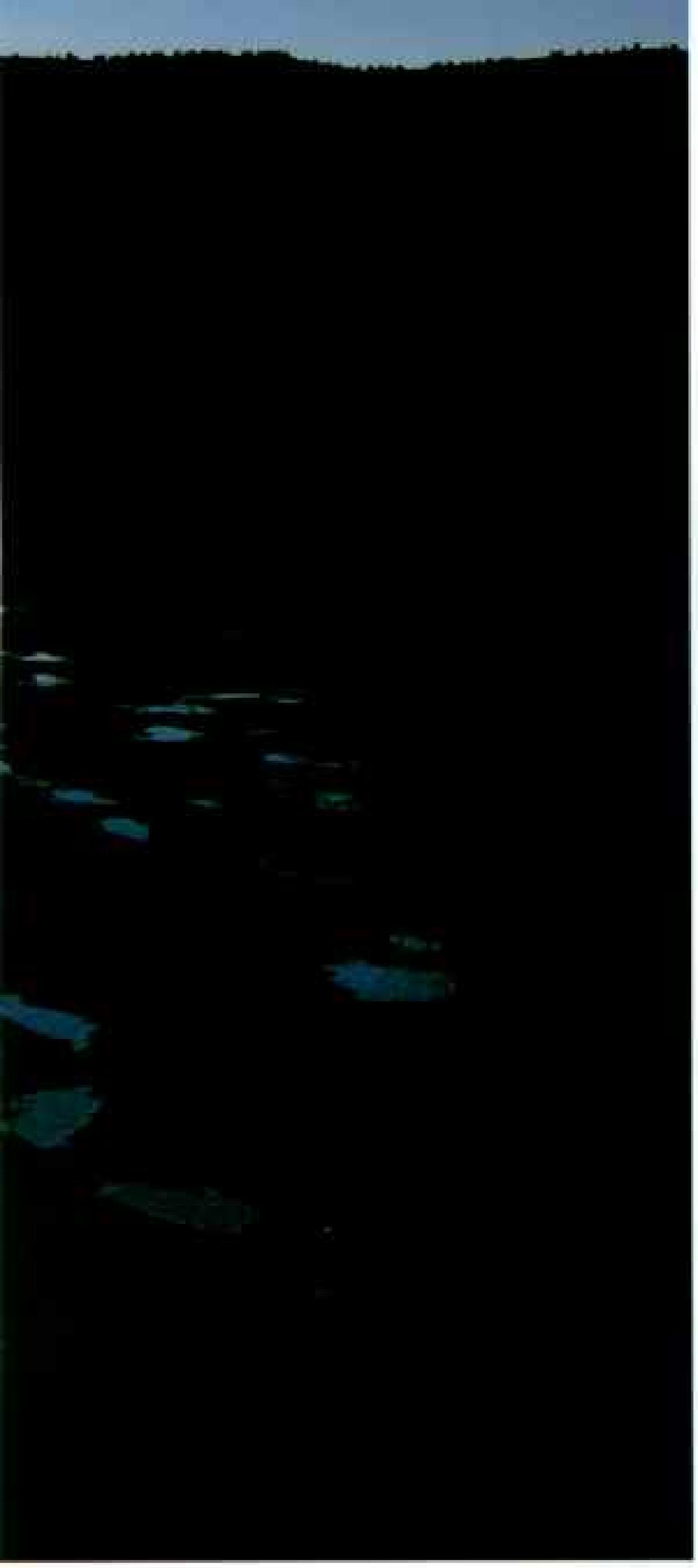


pillar-like legs, gives an unmistakable glimpse of what was to come.

And what was to come is dramatically on display at the Zigong Dinosaur Museum. This site of mass death, probably from flooding, records the surge of giantism in the middle Jurassic. Dong and I carefully descend to the mudstone floor and walk amid a petrified forest of bones.

What bones they are. Mammoth vertebrae outline a great curving tail. Giant ribs, femurs, and tibias protrude from a vast cemetery of gray mudstone. Most belong to a sauropod named *Shunosaurus*. Three skeletons of this curious beast stand in the museum's main gallery. They resemble elephants with long necks. Those necks point to another dinosaur innovation—browsing well off the ground, reaching higher into the trees.

Shunosaurus looks anatomically reasonable. However, its neighbor in the gallery—a monster named *Omeisaurus*—has a neck 30 feet long! (A giraffe's neck might grow to six feet.) Probably few sauropods could hold their



necks continuously high, as cartoons and old drawings often depict. Their neck structures would prevent that, as would the need to pump blood up to the brain over such distance. Even held level, however, long necks greatly extended the area the animals could browse without moving their huge bulk.

The creatures' tails also show invention. Heavy clubs rise on the ends—an indication that sauropods were land dwellers. Presumably used in fighting or self-defense, the clubs would pack no punch underwater.

"These dinosaurs walked like birds flying in formation," notes trackways expert Martin Lockley, examining 150-million-year-old footprints by Colorado's Purgatoire River. "They were five brontosaurs, all the same size, moving in the same direction along a lakeshore. That's good evidence for gregarious behavior."

Dashanpu quarry also preserved a splendid pterosaur, a flying reptile with a featherless wing membrane. Often mistaken for flying dinosaurs, pterosaurs were only distant cousins. But as the Jurassic moved toward its close, dinosaurs too began to experiment with wings. To find out about this, I flew to London.

"HERE ARE THE SACRED RELICS," says paleontologist Angela Milner as we reach the basement of Britain's Natural History Museum. "Everyone puts dinosaurs in the basement. The bones are just too big to keep anywhere else."

But I have come to see a small fossil, the famous, feathered *Archaeopteryx*. Thought to be a missing link between birds and reptiles when discovered in 1861, *Archaeopteryx* is now regarded by most experts as the earliest known bird.

We pass rows of cabinets that tell the early story of the discovery of dinosaurs. So we are sidetracked, for the moment, by their history.

I run my finger along the edge of one of the large dinosaur teeth found by Dr. Gideon Mantell and his wife about 1820. "These teeth made Mantell wonder if perhaps there had been giant reptiles in the past," says Milner.

At that time the idea of extinct animals that might have predated the biblical Flood was heretical. So, despite Mantell's determined efforts to interest influential scientists, his discoveries were at first dismissed.

Milner opens another drawer, containing three large dinosaur bone fragments discovered even earlier—in 1809—by the eminent geologist William Smith. "He had no idea what they were," she says.

Nor did geologist William Buckland know what to make of the lower jaw of a *Megalosaurus* found by quarry workers around 1818. In 1824 he described it as an ancient lizard. In fact, dinosaur bones had been found as early as 1676. A *Megalosaurus* bone was at first mistaken for the thigh bone of a giant human.

Nearly a century later, Dr. Richard Brookes had another idea. He named the fossil Scrotum Humanum, because it resembled a giant set of human testicles.

In the early 19th century "bird" footprints and bones that later would prove to be dinosaurian were reported in the United States. By the 1870s two American paleontologists, O. C. Marsh and Edward Cope, were waging a bitter dinosaur war in the Rocky Mountain West. The archrivals' teams used shameless trickery to outdo each other. In the process they found numerous huge beasts—*Diplodocus*, *Stegosaurus*, *Triceratops*. Marsh also discovered "Brontosaurus," which is now usually called by its genus name, *Apatosaurus*.

Meanwhile, German quarry workers in 1861 turned up the first *Archaeopteryx* skeleton, the only fossil the Natural History Museum keeps under separate lock and key. This animal, which fell into a stagnant lagoon on an ordinary Jurassic day, is one of the most important dinosaurian fossils ever found.

"A visiting Japanese professor I brought down here actually fell on his knees in awe," says Milner.

The creature *is* a wonder. "See how the individual feathers are preserved in minute detail," says Milner. "Without them most people would have interpreted this as a small dinosaur. Actually it's quite possible some dinosaurs had feathers too."

Most of the fossil is preserved in two stone slabs, but a large piece of the skull was removed so its details could be studied better. Milner takes the skull out of a small box. Comparing the pieces, I see that *Archaeopteryx* had teeth, like a dinosaur, and no beak.

The long, sweeping, bony tail is classic dinosaur, not stubby as in most birds. But fanning out from the wings and tail is that array of feathers. It is these feathers that scientists find so critical. They indicate that one member of the dinosaur family had learned to fly. A wishbone underscores further that dinosaurs were becoming something different by the late Jurassic. I am looking at the emergence of birds!

Six *Archaeopteryx* skeletons are now known. The most complete and beautiful has long resided in the former East Berlin, under the guardianship of paleontologist Hermann Jaeger at the Humboldt University Museum of Natural History. Jaeger's once grand museum is only now beginning to recover from decades of neglect before the Berlin Wall came down.

One gallery remains bombed out from

Impressions of feathers fan out around the dinosaur-like skeleton of Archaeopteryx, found in a German limestone quarry in 1876. This pigeon-size fossil strongly supports the prevailing theory that Archaeopteryx was a link in the evolutionary chain between dinosaurs and their modern descendants, the birds.

World War II. Jaeger himself seems like a man released from prison, elated to be receiving Western visitors and showing off treasures too long concealed from much of the world. One of these is his graceful *Archaeopteryx*.

But I have come to Jaeger's beleaguered museum primarily to see his grandest specimen—his *Brachiosaurus*, the largest dinosaur ever exhibited.

AT THE SAME TIME in the late Jurassic when the first birds emerged, there also appeared the largest animals ever to walk the earth. Sauropods, those long-necked, four-legged, and small-headed plant-eaters I met in China, were entering their grandest epoch. They became supergiants, dominating the late Jurassic landscape.

Seventy-five feet long and nearly 40 feet tall, this *Brachiosaurus* skeleton contains pieces of two animals brought back from Africa between 1909 and 1912.

"All my life I have defended these dinosaurs," says Jaeger, explaining that in 1984 the former government ordered the museum to disassemble *Brachiosaurus* and ship it to Japan for an exhibit. "I protested. I was then threatened, insulted, punished, and it went. Now the communist bosses are subdued, and never again will our dinosaurs leave here."

Brachiosaurs, he points out, are the only known sauropods with front legs longer than their rear. Why? Those longer legs may have lifted the animals' heads closer to the treetops that they browsed. Their spoon-shaped teeth seem built for grabbing and ripping off coarse conifer needles. They contrast with the peglike teeth of other sauropods, such as a smaller but still huge *Diplodocus* mounted in this same hall. Its teeth seem designed for browsing on softer low-growing or aquatic plants.

"Sauropods had a tough diet," Jaeger explains. "Grasses and flowering plants had not evolved. They had only conifers, ferns, cycads, ginkgo trees—hard things to digest."

And dinosaurs had not yet refined the art of chewing. Nevertheless, sauropods had a solution—grinding mills in their guts.

Near Albuquerque, New Mexico, a hundred smooth stones are being spread out on a field table by sauropod specialist Dave Gillette and two colleagues, Wilson and Peggy Bechtel. These stones, known as gastroliths, were uncovered just a few yards away lying in two clusters.

Ducks don't know what to make of the skull of a distant relative nicknamed for them: a Mongolian duck-billed dinosaur displayed at Moscow's paleontological museum. Though the shape of their bills is the same, ducks swallow food whole, while dinosaurs in this family crushed food with rasplike banks of teeth.

MATERNAL INSTINCTS *At first light 70 million years ago a Saurolophus nesting colony in Mongolia begins to stir. Like other duck-billed dinosaurs, or hadrosaurs, the Saurolophus likely laid her eggs at the same time and place as the rest of her herd. Too heavy to sit on the nest, she probably covered it with vegetation, then tended her young once they hatched.*

About 150 million years ago these stones were swallowed by one of the longest dinosaurs known. It was named *Seismosaurus*, because it must have made the earth quake when it walked on its four massive legs. With a snaking 50-foot-long neck and 75-foot-long tail, it measured perhaps 150 feet. Those dimensions are based on various bones found near the gastroliths.

The stones suggest that sauropods had muscular chambers for crushing food, much as birds, lacking teeth, have gizzards to grind tough meals. Many birds swallow grit to line their gizzards. Dinosaurs ate rocks. *Seismosaurus* may have had two grinding chambers—one at the base of the esophagus and the other between the stomach and small intestine.

"This might be what killed him," says Gillette, holding a grapefruit-size gastrolith. "It could have gotten stuck in the esophagus or trachea. Some of these stones are as small as peach pits, others baseball size. This one's atypically large."

Gillette, now Utah's state paleontologist, began excavating *Seismosaurus* in 1985, when he was a curator at the New Mexico Museum of Natural History. Most of the bones have been extricated. At Brigham Young University in Provo, Utah, we see the sacrum, a pelvic bone structure about five feet long. It is still partly encased in sandstone.

"It took six months to get that sacrum out of the ground," says Gillette. "It weighed 3,200 pounds. It's already taken a year to prepare it. The rock surrounding it is like concrete—we only expose a few square inches of new bone a day."

Perhaps the slow pace of geologic time inspires dinosaur bone preparators, but I have never met a more patient lot. They move, often using a microscope, with an artist's delicacy, picking away the eons almost grain by grain. Nowhere is patience needed more than here at BYU's Earth Science Museum, where more than a hundred tons of giant bones, still wrapped in the plaster casts in which they were placed as they were excavated, sit by the score in storage under the stands of the school's football stadium. Most are the legacy of retired, self-taught curator James "Dinosaur Jim" Jensen, who for years mined the Dry Mesa quarry in Colorado, bringing to light astonishing evidence of how big sauropods once grew.

Jensen's successor, Wade Miller, shows me a shoulder blade eight feet ten inches long from a sauropod Jensen named *Supersaurus*, estimated to have been 50 feet tall. Another scapula came from a sauropod that may have stood 55 feet tall and 100 feet long.

"I'm amazed animals could get this big—ten times bigger than an elephant," declares Gillette. "At rest each hip socket would have had to support the weight of three elephants. They would have had to eat at every chance. If they lived in herds, as sauropod footprints suggest, they would have left a wake of habitat destruction."

Why did they get so big?

"A response to environment," Gillette responds.

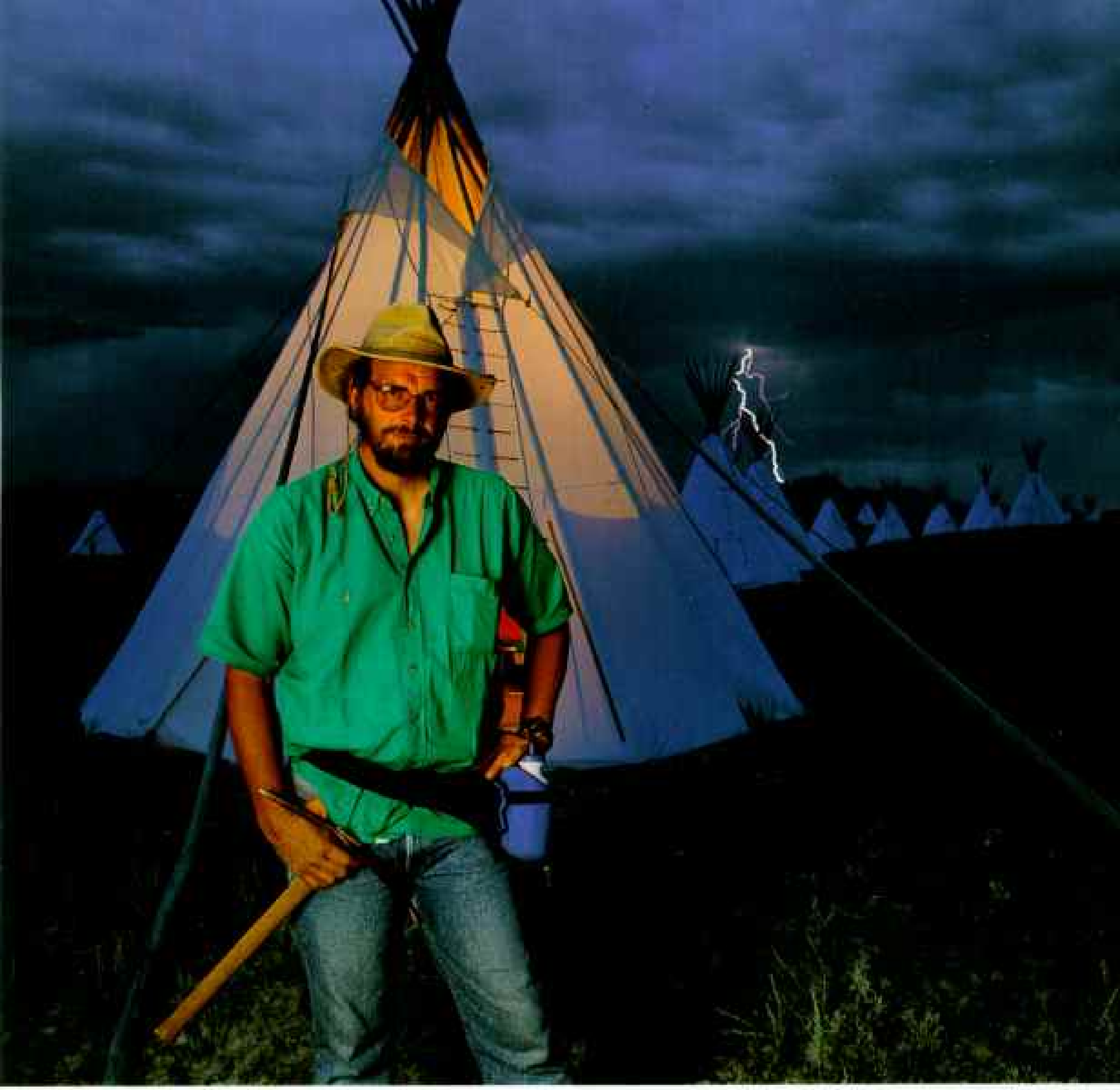
IN NORTH AMERICA the climate was growing more arid in the late Jurassic, some experts believe, with pronounced dry seasons. Being forced into a feast-or-famine lifestyle, sauropods may have migrated long distances.

"The larger you are the more you can eat," says Gillette, "and the longer you can go without eating. Big tails, thighs, and necks are great places to store fat."

Other factors were involved. Sauropods may have been more cold-blooded than later dinosaurs. If so, a sauropod might grow to a hundred tons but only require as much food as two six-ton elephants. Their giant legs, some experts argue, would let them use less energy migrating, pound for pound. Staying bigger than predators could have been another driving force. However, in the late Jurassic, few predators exceeded three tons—far smaller than the seven tons reached much later by *Tyrannosaurus rex*.

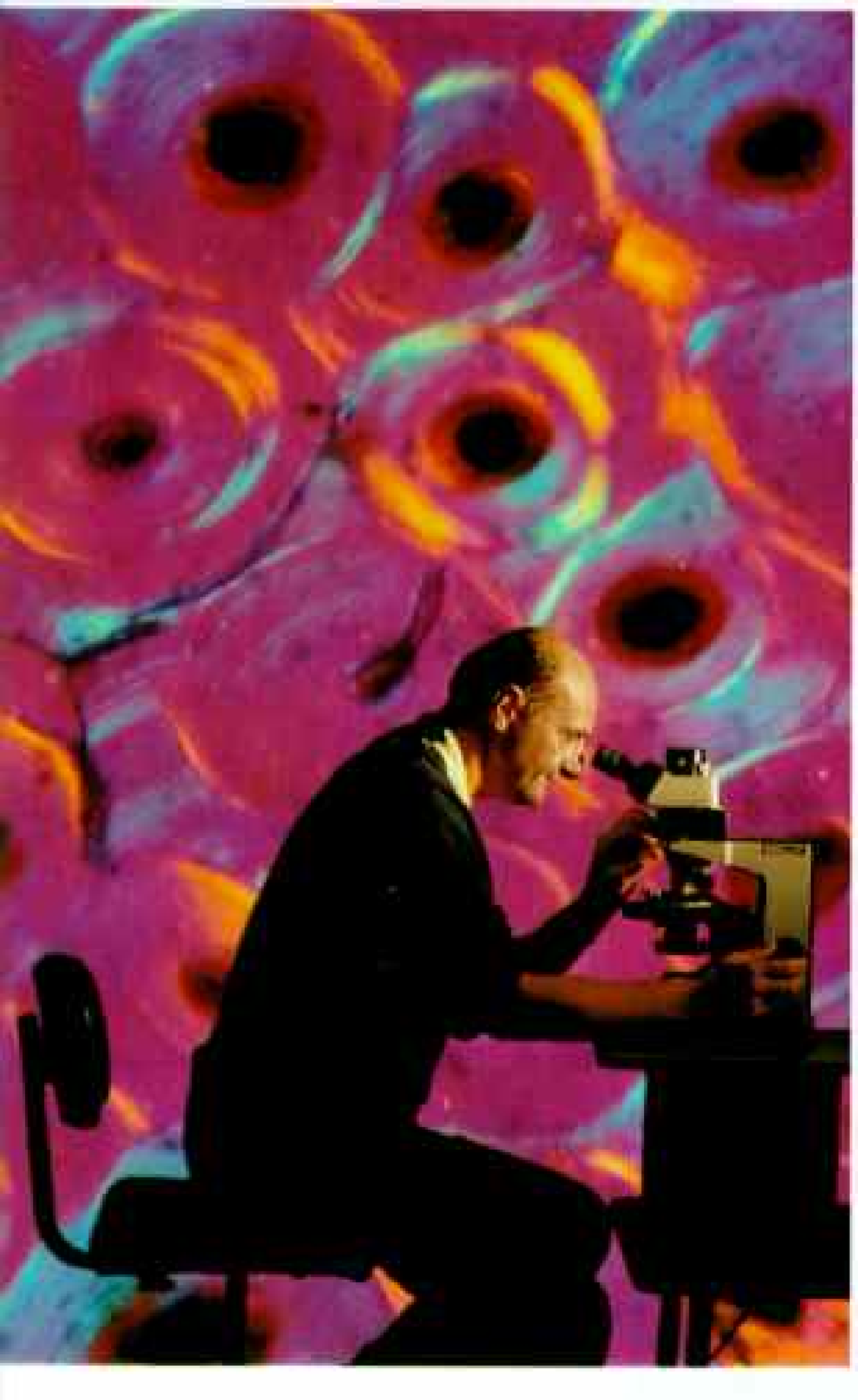
Why didn't those predators keep up in size with the herbivores? Bob Bakker, still probably paleontology's most controversial spokesman, has an answer.

I met Bakker at Como Bluff, Wyoming, which in Wild West days witnessed the dinosaur wars between those two rival eastern professors, O. C. Marsh and Edward Cope. "Dinosaur bones just came tumbling out of the earth here," says Bakker, as we hike among quarries established by Marsh. One of the dinosaurs unearthed was *Allosaurus*. It was actually rustled by Cope's agents from under the noses of Marsh's men. Decades later



Luck struck like lightning when Jack Horner found hadrosaur nests, eggs, and the first evidence for parenting near Choteau, Montana, in the late 1970s. His team named the genus Maiasaura, or good mother lizard. Unearthed as a flattened fossil just 100 yards outside camp, a Maiasaura hatchling has been reconstructed as it looked in life. "Dinosaurs basically aren't any different from animals alive today," Horner says. "They just looked different."

"This is the largest dinosaur ever found," says Jim Jensen, showing off a reconstruction of a leg he unearthed in Colorado (facing page). The huge sauropod has more in common with a humble turkey than size might indicate. Silhouetted against a slide of dinosaur bone, University of Paris paleohistologist Armand de Ricqlès finds similar tissue patterns in bones of dinosaurs, large birds, and mammals, but rarely in reptiles.



the creature was recognized as probably the most significant predator of the late Jurassic. Imagine a 30-foot-long, two-legged cross between a crocodile and a mountain lion. Add a huge skull and the predatory behavior of a shark. That's *Allosaurus*.

Today the bleak Como Bluff rangeland is deserted except for antelope, prairie dogs, and me, trying to keep up with the striding, long-haired Bakker as he hikes familiar terrain, using a ski pole for a walking stick. Bakker has been working these hills since 1974, a few years after making his first heretical proposal—that all dinosaurs were warm-blooded. Later he would argue that it was exotic diseases that did in the dinosaurs and publish drawings of dancing sauropods rearing up in acrobatic stances, drawings that make more conservative scientists flash and stammer.

Bakker seems to concoct new ideas as he walks. He often stops, borrows my pen and notebook, and draws cartoons to illustrate those ideas. He sketches an *Allosaurus* skull. It is elongated, with rows of saw-sharp teeth.

"This jaw explains why *Allosaurus* didn't grow larger," he says. "It didn't need to. It could open its mouth so wide that its entire upper jaw acted as one sharp tooth. It also had the fastest acting neck muscles in the dinosaur world. These animals would have attacked those huge sauropods the same way saber-toothed tigers killed mammoths—by jumping and slashing repeatedly—20, 30, 40 times."

The age of the great sauropods was now coming to an end—at least on the North American continent. Bakker, in fact, calls Como Bluff the dinosaurs' "mid-life crisis." One by one the supergiant sauropod families disappeared, and as they died out, so did *Allosaurus*. Smaller sauropods would persist on other continents, even thriving in South America. An allosaur fossil found in Australia indicates that those animals survived another 20 million years there.

The next great geologic period, the Cretaceous—from 146 to 65 million years ago—begins in a Como Bluff formation called Breakfast Bench. We hike up to its soft gray soils. Here, a summer earlier, Bakker's associates had found an apatosaur. Nicknamed Bernice, the huge sauropod is but a remnant of the age of giants. Mostly Breakfast Bench abounds in little creatures—turtles, frogs, and a tiny dinosaur Bakker named *Drinker*—the middle name of dinosaur pioneer Edward Cope. Two feet long and weighing about 20 pounds, *Drinker* had extremely complex leaf-cutting teeth and large feet adapted for walking on soggy ground. Baby *Drinker* bones, among the smallest dinosaur bones ever found, are pigeon size.

"We found a whole pod of these little dinosaurs," says Bakker. "It must have been a strange world—giant dinosaurs giving way to

little ones. Dinosaurs weren't the kings of creation any more. They could be eaten by crocodiles again—or even by a big fish."

What caused this "mid-life crisis" on the North American continent? Bakker thinks that little *Drinker* was one agent. Now and then sea levels fell, creating land bridges between Asia and North America.

"Animals spread, bringing exotic pests," he says. "*Drinker*, for instance, brought diseases. Maybe one of those infected the brontosaurs, which may already have been reeling from earlier imported diseases."

Perhaps more important, the planet was profoundly changing. The continents rifted farther apart. The northern and southern landmasses separated, and a great equatorial seaway formed. The semiarid landscapes of the late Jurassic faded. The world grew hot and humid.

In the Cretaceous, as the huge sauropods diminished, the second great branch of dinosaurs, the bird-hipped, plant-eating ornithischians, began to dominate the land. By the late Cretaceous immense herds of these creatures, which included many varieties of duck-billed dinosaurs and the rhino-like ceratopsians, ranged like bison across western North America (see supplement map).

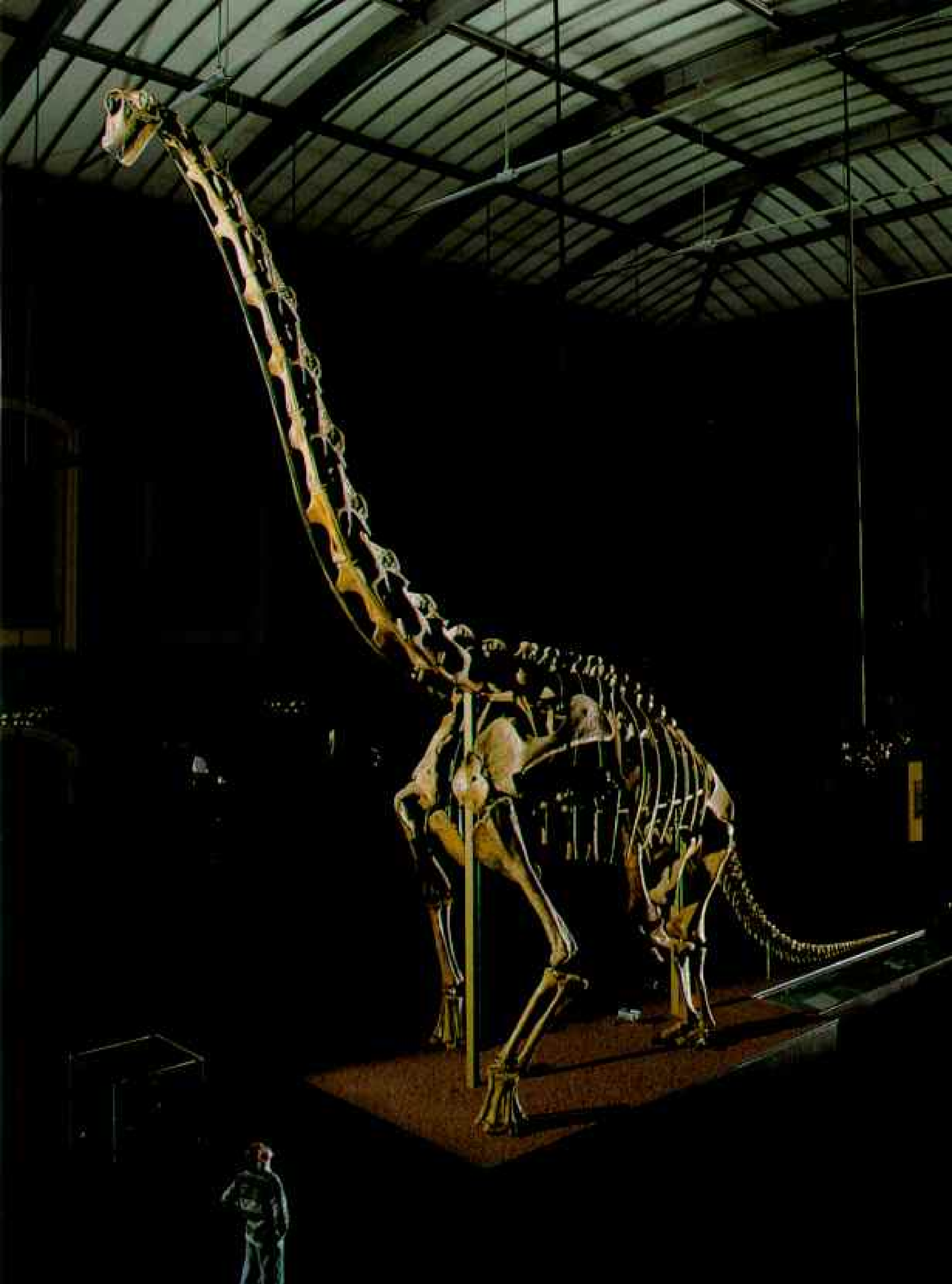
Why the ornithischians? Probably because they developed more efficient ways to feed. An ornithischian called *Iguanodon* illustrates one important innovation.

IGUANODON, SO NAMED IN 1825, was one of the first dinosaurs discovered. A model of *Iguanodon*, built in London in 1854 for the great Crystal Palace exhibition, helped excite the world for the first time about dinosaurs. The model still stares out at passersby from an island in a small lake in the Crystal Palace Park, but it is an anatomically incorrect vision of this prehistoric beast. For example, it has a horn on its snout. We know now that that "horn" was in fact a dagger-like spike located on its hand.

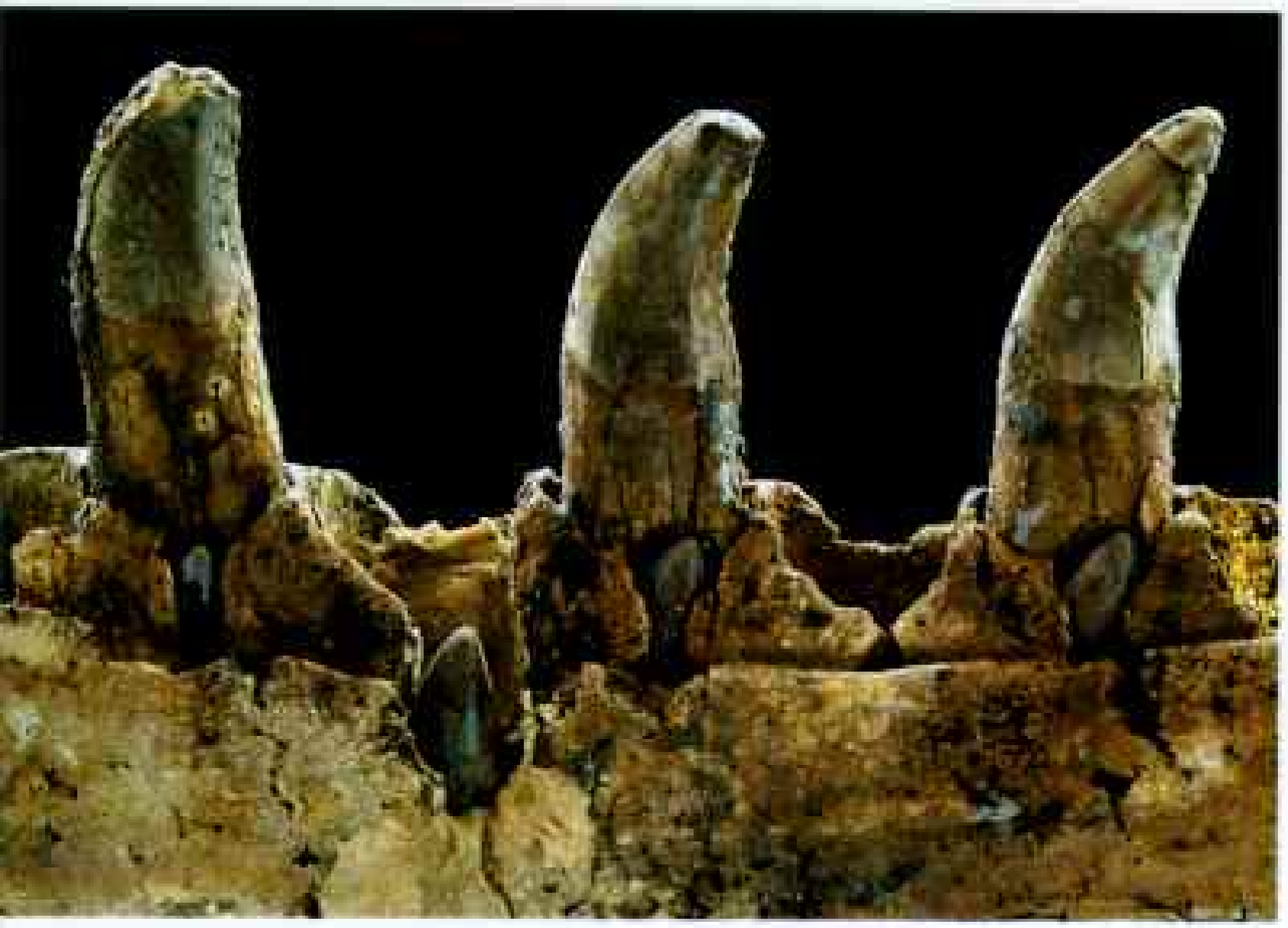
"It's inconvenient that dinosaurs are extinct. They can't just step on a scale," says Indiana paleontologist James Farlow. Measuring the water a model displaces, he figures a Chinese Mamenchisaurus weighed about 23 tons. With that information he can estimate growth and reproduction rates. The largest dinosaur ever displayed, the Brachiosaurus in Berlin's Humboldt University Museum (facing page) may have weighed 80 tons when alive.

Iguanodonts also had beaks to help crop vegetation. Perhaps their most significant feature, however, lay in their jaws. They could rotate their banks of densely packed teeth in a grinding motion. Thus, *Iguanodon* had mastered the fine art of chewing.

The Cretaceous reveals other innovative behavior by the dinosaurs. One example came in 1985 when a team led by Bill Clemens of the University of California at Berkeley and Carole Allison of the University of Alaska reported finding large numbers of Cretaceous dinosaur bones on Alaska's North Slope. That was astonishing. Even though the Cretaceous was much warmer than today, the polar regions would still have been chilly for dinosaurs in winter. And while nonstop daylight in summer would have encouraged lush plant growth, the long winter's night would have forced plant-eaters, especially if they



As sharp as saws, new teeth in the jaw of a Megalosaurus replace worn ones, a lifelong process for every toothed dinosaur. All carnivorous dinosaurs had serrated teeth similar to these, while herbivores' dentition varied. In Alberta's ancient forests herbivores may have browsed on a recently discovered cedar-like plant (bottom, at left). A modern relative of this fossil, from the mountains of New Guinea, stands on a pinhead beside it.



tended toward cold-bloodedness, to hibernate or migrate. Either behavior would be surprising. Today polar dinosaurs have been found at 15 different sites.

One of the most intriguing polar fossils has been found recently along the storm-bashed coast of southern Australia.

"A hundred six million years ago these rocks were 35 to 40 degrees farther south—inside the Antarctic Circle," says Tom Rich, a paleontologist from the Museum of Victoria in Melbourne. "The mean annual temperature here was near freezing."

We are descending, using ropes at times, a steep and muddy 300-foot slope. Below us lies a bay that Rich calls Dinosaur Cove, although he admits the rocks here have fewer dinosaurs than any other major dig in the world. No one would bother to excavate in these concrete-hard cliffs, he says, if Australian dinosaurs were not so rare.

For seven years Rich and his wife, Monash University paleontologist Patricia Vickers-Rich, have been leading, with grants from the National Geographic Society, what amounts to a mining expedition. Because the rock is so hard, they have had to dynamite their way into the cliffs. Then with picks and chisels they dig into the fossil zone.

We enter one of two tunnels they have blasted and stand along what had been an ancient stream. Rich points to the gray mud floor.

"We found *Leaellynasaura* there," he says, referring to a new, chicken-size ornithischian they named for their daughter, herself an avid fossil hunter. "Or rather we found a limb, some vertebrae, and a skull with cavities for very large optic lobes." The optic lobes are those parts of the brain that process visual information. The large lobes, the Riches believe, suggest that *Leaellynasaura* had enhanced night vision for polar living.

"The dinosaurs here could have been running around in a dark, snowy world," he says. "They weren't hibernating. I think they were active when it was really cold. These dinosaurs were probably warm-blooded animals."

DINOSAURS were also evolving socially during the Cretaceous. Evidence lies along an enchanting stretch of South Korean coastline known as Samchonpo, or "three thousand bays." Here embedded in petrified mud lies one of the world's richest concentrations of dinosaur footprints.

"You could walk this beach all day and not run out of footprints," says paleontologist Martin Lockley of the University of Colorado at Denver. Lockley, a dinosaur trackways specialist, was invited here by Korean colleagues. Squalls from an approaching typhoon pelt us and obscure the craggy islands offshore. The *gongyong balzaguk*, or dinosaur footprints, normally draw many tourists, but today only an occasional family or group of schoolchildren walk the Cretaceous mud flats.

We stop to look at some tracks.

"These belong to adult iguanodonts," says Lockley. "A herd was moving through, marching four or five abreast, like soldiers."

Nearby we find the three-toed tracks of an unknown theropod in a run. Then we reach a chaotic patch of ancient mud. It looks like a trampled circus ground, pocked with footprints of sauropods—new proof that even though that venerable family had all but disappeared in North America in the Cretaceous, it persisted elsewhere. But these footprints tell us even more.

Lockley takes out a measuring tape and kneels over one set of tracks. "Hind foot—eight inches long and five and a half wide," he notes. "Front—six by four. The step is 14 inches." He calculates a moment. "The height at the hip would therefore be about three feet. This animal would be like a large dog with a long neck and tail—something you could put in a petting zoo. That's a really small sauropod. It must have been young."

The ground around us is stomped over with similar diminutive tracks. Lockley has identified at least a hundred individuals here. He concludes that most of the tracks were made by animals in their first year of life.

"Kindergarten might be a good term for this place," he says. "They aren't long out of the nesting colony. They are meandering about. Maybe they are just putting on weight."

I try to imagine this colony of juveniles clustered around an ancient lake, and I recall great rookeries I have seen. Here was evidence, surely, of birdlike parental care by dinosaurs.

The evidence would grow stronger in Montana. There Jack Horner of the Museum of the Rockies at Montana State University in Bozeman has found signs of parenting among a new genus of hadrosaurs, a family known as duckbilled dinosaurs for their elongated snouts. Descendants of iguanodonts, duckbills had become the most common dinosaurs of North America by the late Cretaceous. Horner and colleague Bob Makela named this new genus

SOME SPECIMENS FROM CANADIAN MUSEUM OF NATURE, OTTAWA

Dinosaur droppings from throughout North America surround University of California graduate student Karen Chin, who looks for microscopic evidence of diet and digestive processes. "In the Jurassic period, there were great sauropods but no flowering plants. What were those animals eating to make them so large?" she wonders. "And how did Cretaceous hadrosaurs maintain large herds in what appear to have been semiarid environments?"

ARCTIC ATTACK *Midnight sun gilds Alaska peaks 66 million years ago as young edmontosaurs browse in a conifer forest. Their inexperience has led them blithely into danger—a tyrannosaur lurking among the trees. Whether dinosaurs managed to survive here or migrated south when winter's darkness and cold descended remains a mystery.*

Maiasaura—Greek for "good mother lizard."

"Baby jaws—we've got lots of them," says Horner, sorting through the museum drawers his team has filled with pieces of *Maiasaura* infants, hatchlings, and embryos. All lived 75 million years ago, a time when the Rockies were beginning to rise and the global sea level was so high that an inland ocean dissected North America. Rivers flowed into this mid-continental sea from uplands. It was in that ancient high country that Horner's team found the *Maiasaura* babies.

The story began in 1978 when Horner and Makela came across the bones of a baby hadrosaur in a western Montana rock shop. At that time baby dinosaurs were extremely rare. Dinosaur nests and eggs had been found in Mongolia in the 1920s, but it was long assumed that, like most modern reptiles, these ancient big lizards let their young fend for themselves after hatching. We now know that crocodiles guard their nests and young, but in 1978 there was no evidence to even hint that dinosaurs could be nurturing parents.

Horner traced the rock-shop baby back to a scarred, eroding patch of pastureland, where his team uncovered a giant salad-bowl-shaped nest containing 15 three-foot-long babies and lots of crushed eggshells. The crushed eggshells indicated the babies had stayed around the site, stepping on the shells time and again. Then the detective work started.

How did the babies die? Illness was a possibility. So was starvation. Their teeth were worn, indicating they had been eating for a while. Therefore, wouldn't 15 hungry young hadrosaurs leave their nest in search of food? Not if they were being fed by a parent—in this case, one who then died.

"A baby herbivore is not going to be ferocious enough to survive on its own," says Horner. "So it made sense—they stayed in the nest and were getting parental care. Still, the idea was startling."

By 1981 Horner's team had found eight nests. They were spaced 23 feet apart—the average length of an adult *Maiasaura*. This spacing—as in many bird rookeries where nests are separated by the pecking distance of an adult—gave the parent room to maneuver, while maximizing the togetherness of the colony. Eventually Horner's team found 14 *Maiasaura* nests, 42 eggs, and 31 babies.

Meanwhile, on a nearby site, they began finding a different kind of dinosaur egg. The new site, called Egg Mountain, had been an island or peninsula in a shallow lake. The eggs, laid in spiral clutches by a dinosaur now identified as the hypsilophodont *Orodromeus*, were carefully arranged. So Horner thinks parents tended them. But *Orodromeus* was clearly less attentive than the "good mother" *Maiasaura*. The team found no crushed eggshells, suggesting the babies did not stay around the nest tramping the earth. They must have been better equipped to fend for themselves. This Egg Mountain site has several layers of nests, indicating that dinosaurs returned here year after year.

On yet another site Horner found a clutch of 19 eggs, all containing embryos. These embryos, along with the babies, help him tackle the question of how rapidly dinosaurs grew. He is finding a much faster growth rate than in modern cold-blooded animals, supporting the idea that by this time most dinosaurs had evolved warm-blooded metabolisms.

Horner is also intrigued by what he calls the "cuteness" question.

"You can always tell a baby bird or mammal," he says. "They are cute. Baby lizards and snakes aren't; they look like little adults."

But baby dinosaurs, he says, also have cute features—big eyes, short snouts, retarded horn or crest development.

"I'm wondering now if these features stimulate caretaking behavior, just as when we see a baby, a puppy, or a kitten, we feel like we want to take care of it."

BESIDES PARENTAL CARE, by the late Cretaceous dinosaurs had clearly developed herding instincts. In 1984 Horner's team found a bone bed where at least 10,000 maiasaurs had perished in a Mount St. Helens-style volcanic eruption. More recently the team also has found new hadrosaur nesting grounds a quarter of a mile wide and two miles long.

Earlier evidence of huge dinosaur herds had come from rocks in Dinosaur Provincial Park in Alberta, Canada.

"This was the first confirmed mass death of a dinosaur herd," says Philip Currie of Alberta's Royal Tyrrell Museum of Palaeontology. We have hiked with his colleagues Darren Tanke and Gilles Danis across yet another cracked and gnarled badland. In dinosaur days this park was all lush, warm coastal

In almost perfect condition, the skull of the largest, most complete Tyrannosaurus rex *known emerges from South Dakota sandstone through the efforts of commercial collectors Pete (left) and Neal Larson. Nicknamed Sue after a friend of the Larsons who found it on a private ranch within an Indian reservation, the fossil has become the subject of a legal battle for ownership.*

wetlands. Dinosaurs were "in full bloom," says Currie. More than 35 different dinosaur species have been found here.

This was the era of the tyrannosaurs, a family of carnivorous dinosaurs that culminated in the famous *Tyrannosaurus rex*. The scene may have resembled a wetter version of today's Serengeti Plain in East Africa, except there was no grass. It hadn't evolved yet. Other flowering plants, or angiosperms, had, however. Fast growing and reproducing by seed, they created a vast new food source. So water lilies and groves of magnolias and sycamores would have helped support a diverse zoo of browsing dinosaurs.

Graceful hopping dinosaurs would have darted between bison-like herds of duckbills, while lumbering ceratopsians marched along streambeds, perhaps wallowing in the cooling mud on a hot day. At any moment the peace might have been broken by the bellows of a charging tyrannosaur—the predator of these plains—and the bleating of fleeing duckbills.

This part of Alberta may have been a gathering spot—a wintering site or stopover for dinosaurs migrating to Alaska. Today brown scraps of dinosaur bones litter the ground and protrude from the eroded hillsides. Tanke picks up a tyrannosaur tooth. "I wonder what this has run through," he says. Within the next few minutes we find 20 more teeth.

"Like most dinosaurs, a tyrannosaur was always losing its teeth when it fed, and always growing new ones," says Currie.

We are headed for what must have been a tyrannosaur banquet—a bed where Currie

MENACING MOUTHFUL *Jaws agape, a Mongolian Tarbosaurus greets visitors to Ulan Bator's State Central Museum. Though it has more teeth and a longer face, this central Asian carnivore closely resembles North America's Tyrannosaurus rex. Both may*

have descended from dinosaurs that crossed an intercontinental land bridge during the late Cretaceous period. Or they may have belonged to the same genus. Ongoing expeditions to the rich bone beds of the Far East seek answers to such puzzles.

and colleagues have excavated about 80 *Triceratops*-like animals called *Centrosaurus*.

"It looks like a catastrophe," says Currie. "We think a herd was trying to cross a river in flood. These animals weren't too bright.

"All that meat drew carnivores. We've found a lot of shed teeth and bones with tooth marks. Also, a lot of the bones were broken. Others were pushed—probably trampled—into the mud."

Sickle-clawed Deinocheirus *would have made short work of creatures the size of Altangerel Perle (facing page), of Ulan Bator's museum. Lethal arms are all that survive of this dinosaur that roamed the Nemegt Valley some 70 million years ago. In the same museum a schoolboy measures himself against a sauropod leg bone. Expeditions amid Mongolia's searing heat and swirling dust have uncovered numerous fossils since the 1920s.*

Many of the tooth marks were those of tyrannosaurs. But scavenging was probably not the favorite feeding style of *Tyrannosaurus rex*, the 45-foot-long theropod nicknamed T-rex by paleontologists.

"Those jaws were killing machines," says Currie. "The teeth were designed for biting through bone and flesh. Everything about T-rex's body design was for pursuit and kill. Its limbs tell us it could move much faster than most predators.

"Because its head was so large, T-rex had to reduce weight elsewhere on its front end. That's why its arms were relatively small. They weren't useless, though. They could dead-lift 600 pounds. And the claws were massive."

At the museum Currie shows me a recent find—a T-rex skull, called Black Beauty for its ebony patina. It was the first complete T-rex skull. In fact, for decades only three T-rex skeletons were known.

"It's ironic that the best known dinosaur has been one of the least studied," says Currie. "That's changing. Recently seven more skeletons have been found."

Last May perhaps the best preserved new T-rex, nicknamed Sue after the fossil hunter who discovered it, Sue Hendrickson, provoked a major controversy when it was seized by federal agents in South Dakota. Excavated by collectors from the Black Hills Institute of Geological Research near Rapid City, Sue was rumored to be worth several million dollars. Paleontologists argue that no museum could pay that cost. Its real worth, they say, lies in what it can tell us about T-rex. The Cheyenne River Sioux Tribe charges that Sue should belong to them since it was found within their reservation, even though it was on a private ranch. The institute claims to have paid the ranch owner for the rights to the fossil. Clearly, Sue's fate will be determined by a *Homo sapiens* innovation—litigation.

THE DAKOTAS ARE A FITTING locale for a controversy over the fate of T-rex and the other dinosaurs, for the Dakotas and eastern Montana contain one of the few rock formations on earth that record in detail the great beasts' final two million years. Called the Hell Creek formation, this area contains a thin band of the exotic element iridium. Rare on earth, iridium is common in asteroids.

Similar iridium bands have been found in 65-million-year-old deposits across the world. Most scientists now accept the bands as convincing evidence for a tremendous extraterrestrial impact at the close of the Cretaceous. A 65-million-year-old buried crater—110 miles in diameter—has recently been located in Mexico's Yucatán Peninsula.

I visit the Hell Creek formation with Berkeley paleontologists Don Lofgren and Kevin Padian. Lofgren is struggling to work out the complex stratigraphy of this rapidly eroding dinosaur deathbed. He meets me at a lonely Montana crossroads, and we drive to a site where their team has uncovered the skull of a big-horned *Triceratops*.

The *Triceratops* lies about six feet below the level of the iridium layer. Those six feet of rock could have been laid down in a few hundred years, says Lofgren, or over a million years. No one knows. That is just one of the uncertainties surrounding the disappearance of the dinosaurs. Some scientists believe they had already vanished by the time of the great impact. Others argue that, rather than one great impact, there was a shower of impacts over several million years that progressively weakened ecosystems.

"Dinosaurs were always going extinct," says Padian, as his team extracts the new *Triceratops* skull. "This time why didn't any of them—except the birds—generate new species? I say they were no longer thriving. It was a complex time. The mid-continental sea was drying up. The climate was becoming more seasonal—colder in the winter. New plants were moving down from the north. Dinosaur environments became patchy—as with elephants' today. The dinosaurs got confined, and they overgrazed. Their habitats couldn't support them."

Others reject the idea that dinosaurs were in decline at the end of the Cretaceous. Peter Sheehan of the Milwaukee Public Museum and David Fastovsky of the University of Rhode Island recently analyzed thousands of small scraps of dinosaur bones found over a three-summer search of Hell Creek. They see dinosaurs flourishing until the end.

They cite, moreover, strong fossil evidence for an asteroid-induced crisis among land plants and light-dependent plankton at sea.

"The plant fossils show exactly what a dark, sooty cloud after an impact would create," says Sheehan. "If an asteroid cloud kills off all the plants, the next thing to go would be the large herbivores, then the carnivores that fed on them."

He argues that the animals least tied to living plants were the small mammals that fed on insect larvae that ate dead plant matter.

It was, of course, mammals that rose to fill the niches left vacant by the dinosaurs. Today it is we mammals who can reflect and debate and care about our ancient rivals.

Computers control a Maiasaura being tested by engineers at Kokoro, the Tokyo-based pioneer in animating dinosaur models. Steven Spielberg's film Jurassic Park, premiering this summer, has taken robotics to an even higher level. Fleshed out under tight security near Hollywood, its T-rex (right) promises nothing less than a lifelike performance.

MONSTER MELEE *A prehistoric menagerie produced by Kokoro gets a final check before installment in a dinosaur theme park near Tokyo. Supplying clients around the world, Kokoro incorporates the latest research into its museum-quality models. In the company's*

workshop artists sculpt polyurethane bodies over pneumatically driven metal skeletons, then texture and paint the silicone rubber skin. No one knows what colors dinosaurs were, but scientists surmise a variety as great as today's birds.

AND CARE WE DO. At the Stan Winston Studio in Los Angeles, I see a fleet of dinosaurs being built to star in the Steven Spielberg movie *Jurassic Park*, based on the best-selling novel by Michael Crichton. Crichton imagines that bioengineers clone a zoo of dinosaurs from ancient DNA. They collect that DNA from dinosaur-biting insects preserved in amber. The clones are raised on a private island off Costa Rica as the stars of an intended theme park. A series of technical breakdowns lets the animals escape. Some spread to the Central American mainland, presumably to breed in the wild and eventually terrorize the world.

"This could be the *Jaws* of the nineties," says spokesman Marvin Levy. "It's had the longest preproduction of any of Steven's films. We've come a long way from Godzilla. These dinosaurs will move so fluidly you won't realize they aren't living animals."

"We have five main characters," says studio art coordinator John Rosengrant. "A T-rex, a sick *Triceratops*, a spitting *Dilophosaurus*, a *Brachiosaurus*—and the velociraptors."

I meet each one. T-rex is the biggest—but it's only a mechanized black frame at this stage. The *Brachiosaurus* would be larger, but the studio is re-creating just its head and neck. The velociraptors are the most sinister—pack hunters displaying almost human intelligence. Their cold eyes, their open mouths that seem to salivate like fairy-tale wolves approaching wounded prey are designed to scare the summer doldrums out of moviegoers.

Velociraptors were among the dinosaurs with the largest brains, relative to body size. But were they really intelligent? I ask Dale Russell of the Canadian Museum of Nature, who has long pondered such questions.

Russell, in fact, has built a "dinosauroid." It's a model of what he thinks the dinosaur with proportionally the largest brain—a wildcat-size creature called *Troodon*—would have looked like today had dinosaurs not become extinct. The model resembles a cross between a lizard and a human. Russell believes that traits he sees as advantageous, such as bipedalism, larger brain cases, and manual dexterity, would have continued to develop.

"If dinosaurs like *Troodon* had survived, they'd have evolved human-size brains by now. Look, birds survived, and parrots now have the same brain-body ratios as gorillas."

Many scientists would challenge Russell's assumption that evolution moves in any particular direction. Evolution, they believe, is more random. Also, a bigger brain does not always mean higher intelligence. Nevertheless, most would concur with Russell that the smartest dinosaurs—including the velociraptors in *Jurassic Park*—were about as intelligent as chickens.

Russell rejects the idea that escaped dinosaurs could threaten the modern world.

"Dinosaurs couldn't survive long today," he says. "They'd be too dumb and not agile enough. Plants have evolved advanced defenses, such as thorns and chemical repellents. Prey animals have quicker responses. Humans challenge every living thing. Modern ecosystems would simply overpower them."

Still, we can only speculate about such things. And it is perhaps our own vulnerability to unseen evolutionary forces, such as new viruses, along with our fear that monsters—maybe of our own making—could at any time return that makes both *Jurassic Park* and dinosaurs so fascinating.

So what are we to conclude about the reign of dinosaurs?

"What did they achieve?" I once asked Jack Horner, the *Maiasaura* baby expert. He laughed. "Dinosaurs were not trying to *achieve* anything. What have we humans achieved? Thinking? Intelligence? We can't tell yet whether that's been beneficial biologically. It might create more problems than advantages."

I think of Horner's remarks one evening as I am stuck in traffic on a Potomac River bridge in Washington, D. C., and watch birds gliding freely above the river. We humans often perceive ourselves as the inheritors of the planet. But there are 9,000 species of birds out there, versus 4,600 mammals. And they have the air! Could it be, I wondered, that dinosaurs were just a phase life went through on the road—not to humans—but to birds? □

Like a little Godzilla captured in a sci-fi film, a fiberglass Allosaurus tests restraints in its sculptor's pickup near Albuquerque. Far from being figments of the imagination—or symbols of dim-witted obsolescence—flesh-and-blood dinosaurs met the challenges of their changing world over tens of millions of years, leaving wonder in their trails.

Wide Open Wyoming

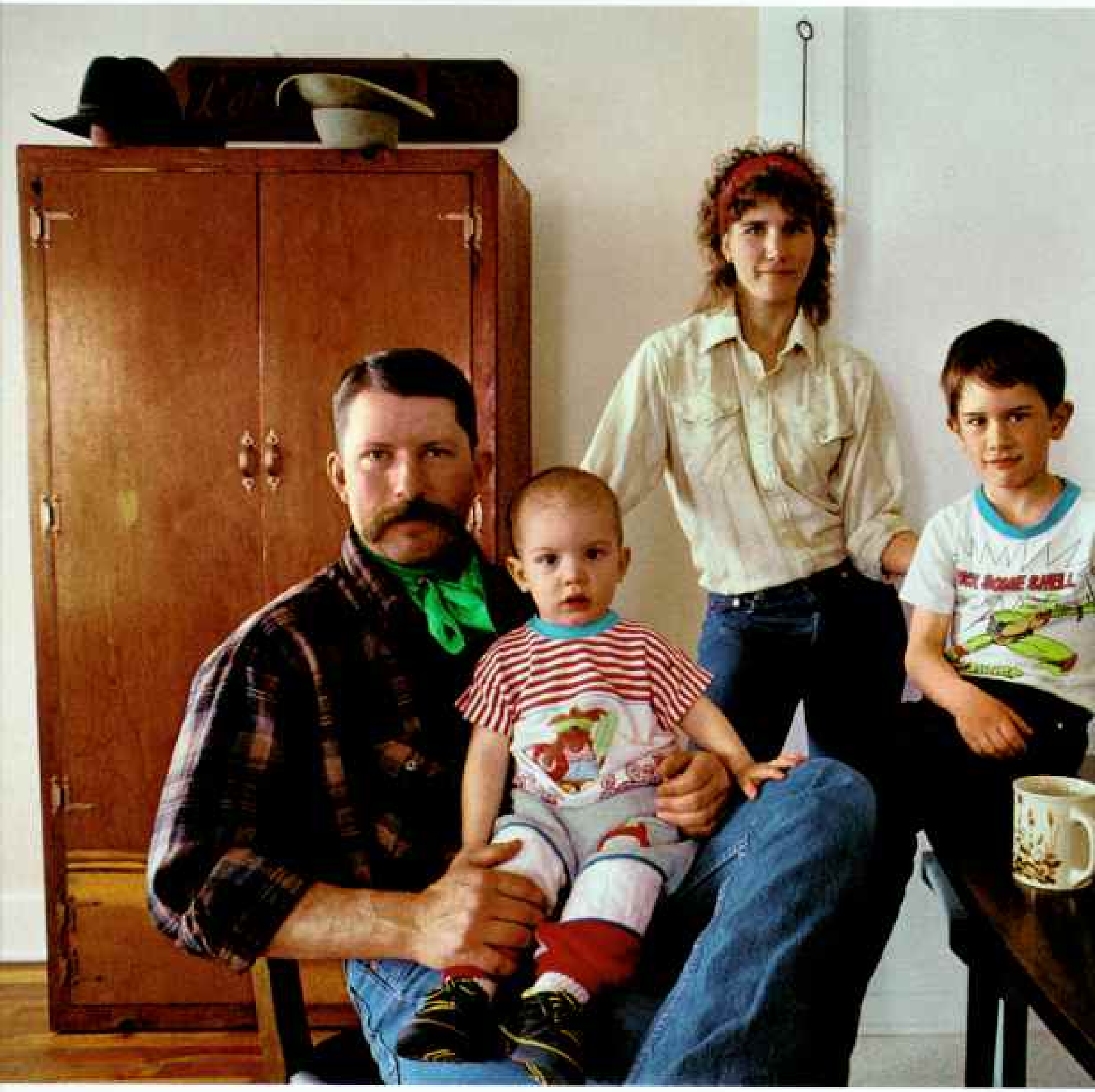
By THOMAS J. ABERCROMBIE
NATIONAL GEOGRAPHIC SENIOR WRITER

Photographs by RICHARD OLSENIUS

A cowboy moves a mailbox across the road to comply with a newly enforced postal regulation—a rare intrusion on the spirit of freedom that ranges across the nation's least populated state.

BRUTAL WINTER WINDS SWEEP A GRAVEL ROAD near Jeffrey City and help weed out transplanted Wyoming "wannabes" from the state's hardy, weatherworn souls.

"A GUY DOESN'T WANT TO SHELTER YOUNG'NS too much, because then they're easy prey when they hit the open society," says cowboy Matt Miller. He and his wife, Debbie, are raising sons Colten and Jared on Padlock Ranch in northern Wyoming. "They'll grow up knowing how to work," says Matt, "and knowing how to raise a little Cain."



CIRCLING through the snow on a roan gelding, slapping leather and waving his big black hat, Greg Gardner shouts a dozen stray cows and calves off a ridge on De Ranch.

"Eeeeaaagh! Eeeeaaagh! Git down outa there, you lazy sons!"

Wide-eyed, heads high, the cattle scamper downhill through the early October blizzard and dissolve into the swelling herd, a black-and-white torrent stomping down the draw and trailing clouds of snowflakes. Cutting back and forth behind the herd, Greg's wife, Barbara, gently keeps them moving.

I peel two cows off my side of the hill, then pull up to scan the blinding whiteness. Top hand Charlie Needham finds a cow I missed, hidden in the brush, camouflaged by an inch of snow on her back. I can hardly see 50 feet. I scrape hoarfrost off my mustache and rub my hands together. My feet feel frozen to the stirrups. With a crunch of hoofs and the creak of leather, Charlie reins up beside me and spanks the snow off his chaps.

"Smell that perfume?" he smiles. "Is there anything sweeter than fresh snow on the sage!"

Charlie was actually enjoying this. For a greenhorn like me, raising beefsteaks seemed a hard way to make a living, but for Wyoming's guts-and-leather cowboys a frosty roundup is all in a day's work.

Greg and Barbara Gardner are the managers of De Ranch, 40,000 acres on Bridger Creek at the foot of the Bighorn Mountains, near the center of this big square state (map, page 61). Only the week before, a new bronc had snapped Greg off, then stomped him. Greg was limping, but riding out every day. The last half of his 600 Angus and white-faced Herefords had to be moved off their 6,500-foot-high summer pasture.

The week-long roundup had begun under a sapphire-clear autumn sky. Crimson thickets lined the creeks under parasols of tall golden cottonwoods. This last day we woke up knee-deep in winter. It was late afternoon when, chilled to the bone, our horses snorting steam, we finally rounded snow-layered Arapahoe Butte and drove the bawling herd into the corral pasture below the white Victorian ranch house.

A few weeks later, when melting snow had turned the back roads to pudding, Greg sold 319 yearlings by phone to a Nebraska feedlot for a handsome price. "In 20 years of hard ranching, this is the first time we're square with the bank," he said. "There's even enough left over for the new pickup we've been needing."

People say that living in Wyoming gives them a sense of freedom. In my winter journey around this untamed state I saw them earn it. Anyone worried that the American character is becoming too homogenized can take heart: The frontier spirit is alive and well.

The name Wyoming comes from an Indian

word, but not from the local Shoshone or Arapaho. It is a Delaware Indian word, first given to Pennsylvania's Wyoming Valley. It means "big river flats," and it suits this state that straddles the Continental Divide with a series of dry basin floors.

God is still architect here. His cathedral mountains and awesome, endless prairies dwarf all human refinements. In Wyoming's far northwest corner the sudden majesty of the Tetons borders the granddaddy of national parks, Yellowstone.

No other state has fewer people—only 465,000. There are no big cities. The largest city, capital Cheyenne, is home to 50,000.

Driver's licenses can be had at age 14, but only for driving to school. The De Ranch managers' daughter got hers last year. "Heidi's thrilled," said Barbara, "and it saves me two 30-mile round-trips a day to the bus."

Driving is what you do a lot of in Wyoming. Here, where the sky is half a man's world, you can take true measure of yourself and have the time to do so. As I wheeled past grazing cattle and sheep—even the occasional herd of domesticated buffalo—country and western music helped pass the long miles: "Hands that worked so hard all day need someone soft to hold. . . ."

THOSE HANDS these days are less likely to be roping cattle than mining Wyoming's vast energy deposits. The state now leads the U. S. in coal production, and half its tax revenue flows from more than 13,000 oil and gas wells.

Natural gas wellheads and pipeline stations dot the sagebrush in the state's center. People have hit gas just drilling water wells. Some can light a blue flame at their kitchen faucet. And a story is told of a man in Bonneville who lit up a cigarette in his root cellar and blew himself clean out the door. But the real gas bonanza lies much deeper.

With Connie Hawkins, staff geologist with the Louisiana Land and Exploration Company, I climbed steel steps up to the enclosed drill platform on a derrick rising 190 feet above the Bridger Trail near Lysite.

The drill crew, maneuvering a 40-ton block and tackle, was wrenching up four miles of pipe, 90 feet at a time, to change the diamond drill bit. Mud pumps and generators whined, and roaring fans blasted away clouds of steam.

"Temperature at the bottom is 423 degrees," Hawkins shouted over the din while he scanned the monitors. "We're at 22,295 feet right now, headed for nearly five miles down."

Drilling deep has its dangers. A few months after I left Lysite, the well exploded, shooting mud and flames hundreds of feet into the air and destroying the giant derrick.

Coal underlies 55 percent of Wyoming, but the greatest concentration is in the Powder River basin on the state's northeastern high plains. Towering coal silos announce from a distance that you are approaching the largest

TOO MUCH SILT? TOO LITTLE OXYGEN? Environmental technician Gary Holt, an Arapaho, tests the water on the Wind River Indian Reservation, which has waged a 16-year legal battle to reassert tribal water rights, possibly limiting the diversion of rivers by local farmers.

coal mine in the Americas, Black Thunder.

"We mine about a ton a second," said Ken Miller, engineering manager at the 7,500-acre site, owned by ARCO. "We fill up eight or nine trains, each a mile long, every day."

Most of Black Thunder's low-sulfur bituminous coal goes to fire power plants in the South and the Midwest. Lying as thick as 70 feet, the coal seam is mined in 60-acre strips, which are then refilled. At the edge of the black chasm I met the pilots of the mine's massive machines.

Tom Murray operates Thor, a 70-foot-tall dragline extending a 310-foot boom. In his cab he needs only to touch fingertip controls to send a shiny steel scoop the size of a swimming pool out under the boom, lower it, and claw away the overburden.

"No vehicle is big enough to move a 3,600-ton rig like this," Tom said. "We had to assemble it right here on the spot." The dragline moves around the site by "walking" on giant steel shoes.

It was a 14-step climb to the driver's seat of King of the Lode, by far the biggest dump truck I had ever seen. I fastened my seat belt,

WYOMING

AREA: 97,809 square miles. **POPULATION:** 465,000. **MAJOR CITIES:** Cheyenne, Casper, Laramie. **INDUSTRY:** mining, tourism, public utilities. **AGRICULTURE:** cattle, alfalfa hay, sugar beets.

LAND OF COWBOYS and mountain men, Wyoming was nicknamed the Equality State for its progressive treatment of women. Most notably, in 1869 the Wyoming Territorial Legislature became the first governing body in the world to grant women the right to vote and to hold public office. A radical change, yes, but not revolutionary: There were six men for every woman old enough to vote.

BUCKING FOR THE TOP, Wes Miller rides a barrel jerked by his dad. "I've wanted to be a world champion bull rider ever since I was a little kid," says this 11-year-old.

TEARING TUMBLEWEEDS FROM HIS BARBED-WIRE FENCE, Ronnie Brown recalls a bit of Western lore. "There used to be a lonely ranch widow who attached notes to tumbleweeds and set them free, like a sailor putting notes in bottles," says Ronnie. "Ranchers found them, but she never signed her name."

and the driver, in hard hat, sunglasses, and plaid wool coat shook my hand: "Hi, I'm Barb Hazelton."

Leaning out the window, the petite woman glanced at her rearview mirrors, sounded the loud air horn, then eased us down a long ramp into the canyon of coal. We sidled up to a groaning electric shovel.

Whoooosh! Forty tons of coal dropped into the back of the truck. Whoooosh! Another avalanche, then another—240 tons all together. We rumbled uphill toward the crusher with enough coal to heat an average home through 40 nasty Wyoming winters.

"These are marvelous trucks," Barb said as she deftly backed up to the crusher hopper and raised the dumper. "Power brakes. Power steering. It's as easy to drive as my little Ford pickup."

Strip mining once slaughtered the landscape, but nowadays the prairie is painstakingly reclaimed, a result of ever stricter environmental laws. Thor's huge bucket replaces excavated overburden. Earth movers and graders shape the topsoil as close as possible to the original contours; even rock outcroppings and meandering streambeds are reworked into the landscape.

"Then we put in 21 species of native plants," Ken Miller told me. "On reclaimed

acreage our test cattle fattened faster than on natural rangeland."

About a third of Black Thunder's employees live in Wright, population 1,236, built by ARCO in the late 1970s. Coal's steady growth has given Wright and other nearby communities stability. Meanwhile the state's uranium boomtowns collapsed, as cheaper foreign uranium became available.

A boom-and-bust history has peppered Wyoming with abandoned settlements. One ghost town guidebook lists nearly a hundred. Other isolated hamlets hang on, barely.

LOST SPRINGS
POP 9
ELEV 4996

reads the sign on a two-lane highway heading toward the Nebraska border. Only four buildings define the town, once a bustling railhead for cattle. Today cattle are trucked to market directly from ranches. Ranchers need fewer cowboys to work roundups, and that means fewer customers for Lost Springs. Except for the moan of a distant coal train, all was quiet as dust when I stepped into Clara Stringham's antique shop.

"There's only *five* people left now," Clara told me. She stood surrounded by yesterday—rusty hand pumps, stacks of Woolworth glassware, secondhand cowboy novels, and old Wyoming license plates fashioned into clocks by her husband, Bob.

"In fact, Clara, since our son went off to the Army, we're down to four," Bob corrected.

The Stringhams introduced me to Lost Springs' mayor, Leda Price, an energetic woman in her 40s who runs the Lost Bar across the road, in what used to be the bank. The town's other resident was off shopping in Douglas, 25 miles away.

I asked her why Lost Springs needs a mayor.

She looked insulted. "We must be the smallest incorporated town in America with a post office," said Leda. "Of course we need a mayor! Someone has to make sure the street is in repair. And I'm overseeing the remodeling of our old town hall. It's still used for wedding receptions and other special events. Today I'm busy with the contractors installing modern facilities in our park. I earn my salary: three dollars a year."

No one else came into the bar as we talked.

"Oh, it's quiet here now in winter," she said. "But during our June antique auction or our Rocky Mountain Oyster Fry—and especially during antelope or deer season—four or five hundred visitors crowd into town.

"I've never been bored a minute since I moved out here from Wisconsin 25 years ago. And I'm just getting started."

"AT HEART, Wyoming is just one big small town with very long streets," Mike Sullivan told me. "I try to cruise them all."

Wyoming's governor may be a lawyer from the state's oil center, Casper, but his boots and broad-brimmed hat match a casual trailside manner.

"Constituents sometimes feel remote from their capital because Cheyenne lies in the very southeast corner of our state," Sullivan said. "So I began the Capital for a Day program, to bring the governor and state officials to the people four or five times a year."

Long drive to Muddy Creek

COYOTES TORE UP *some of his sheep a few years ago, but Bob Britain bounced back. Last January, with a new flock 300 strong, he left on an eight-day trek to his winter range near Muddy Creek. Along the way he tied up traffic outside Shoshoni (below) and met up with his wife, Peggy, who delivered hamburgers and a hug (bottom).*

Shortly after the drive 20 ewes died while lambing, forcing Bob to shelter the orphans in his trailer. To control the mess, he dressed his roommates in disposable diapers. ("They stank," he says, "but not as bad as a baby's.") Spirits undampened, Bob sees his experience in broad perspective. "I know of only one profession where you can start at the top and work down," he says, "and that's posthole digger."

He invited me to join him when the capital moved to Fort Bridger, Mountain View, and Lyman—a cluster of small towns 300 miles due west of Cheyenne near the Utah border.

A crowd of 50 or so gathered to greet Governor Sullivan and his party at the lonely Fort Bridger airport. They waved the Stars and Stripes and the Wyoming state flag—a white buffalo on a blue field. The Lyman High School band struck up "My country, 'tis of thee. . . ."

Trailing dust, the 20-car motorcade swept away to visit schools, a new highway interchange, a sewage treatment plant.

Before the banquet at Lyman High School, Governor Sullivan told the story of how weather froze out his first Capital for a Day program back in 1987.

"We took off for Douglas," he began, "but before we could land, snow closed the airport. We flew on to Casper, but it also had shut down. Disappointed, we returned to Cheyenne—only to find it too socked in.

"So, all cranked up to bring state government to the people, we landed at the only airport still not closed by the blizzard: Fort Collins/Loveland in Colorado!"

Snow has closed Wyoming's main highway, I-80, in every month but July and August. An infamous 1984 spring blizzard froze 200,000 sheep and cattle. It was an October storm that nearly killed Basque sheepherder Sebastian Legarretaechevarria. He told me his sobering story in the town of Riverton, where his rescuers had brought him.

Sebastian wore baggy wool pants and a red-checkered shirt, and chain-smoked nervously. He had just turned 50, but he looked

20 years older. We talked outside his small sheep wagon that offers room only for a bunk, a hefty iron stove, and a few sacks of provisions. This is his home as he follows his employer's flock. His dogs, Pinto and Montes, hopped around looking for an ear scratch. They were as anxious as their master to get back to the countryside.

"The cities are too crowded. Not friendly. I prefer to be with my animals," Sebastian said. "They are more human than people."

He peeled back thick bandages on his swollen hands—the fingernails ready to fall off—and drew off a boot to preface his tale. His frostbitten toes were charcoal black. Yet his smile was undimmed. He knew he was lucky to be alive.

"I was breaking camp on Crooks Mountain, bringing in 1,700 sheep, when the storm hit," he said. "Everything went white. I couldn't find my way back to my wagon. It was the only time in my life I ever got lost.

"For two days I kept going through the drifts, afraid to stop moving. Crossing Willow Creek, I broke through the ice up to my waist. After that my legs wouldn't move. I crawled under the shelter of a pine tree. My last match was gone. I had no food.

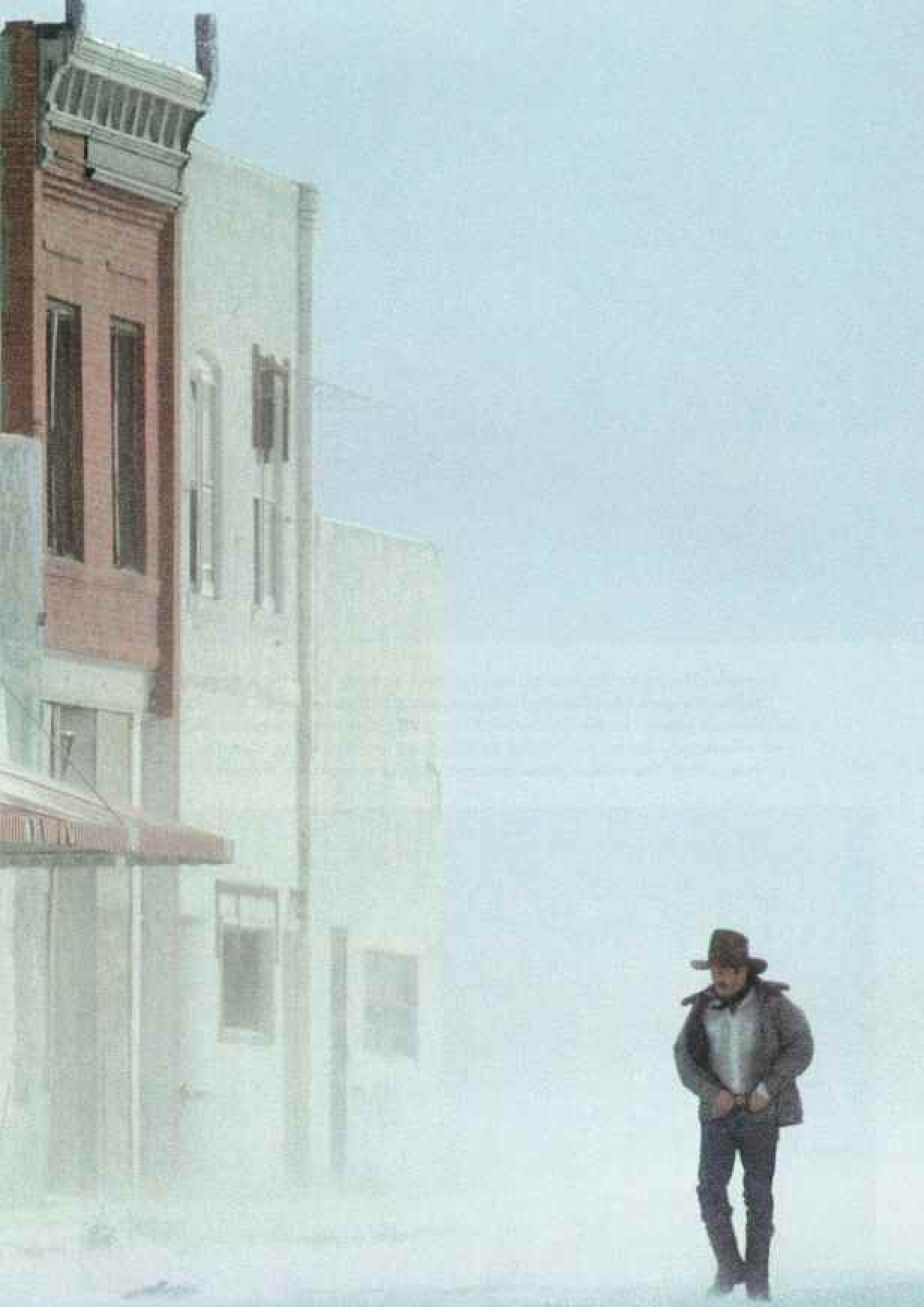
"For three more days I stayed under that tree, half crazy with cold. I dreamed about thick steaks and mushroom sauce. Finally, I prayed to God to take me to him."

The sheriff's rescue team found him 15 miles from his wagon.

"It was the dogs that saved me," Sebastian said. He was hugging Pinto, a Border collie, and tears began welling in his hollow eyes. "They stayed with me. We huddled together

A HUGE DRAGLINE scrapes away earth at Black Thunder Mine—largest open-pit coal mine in the Western Hemisphere. Hauled to electric utilities on mile-long trains (above), low-sulfur coal sells quickly because it burns relatively cleanly. Emission standards have spurred Wyoming to play this ace in the hole.

GONE ARE THE GLORY DAYS IN SHOSHONI—the railhead, the homesteaders, the cattle drives, the oil boom. Although a few stores survive elsewhere in town, its vital signs are fading.



THE ONLY COED HIGH SCHOOL BASKETBALL TEAM IN WYOMING—the Jeffrey City Longhorns—gets a halftime pep talk from coach Kelly Proctor, who couldn't find enough players for his boys' team. Three girls got their shot because student enrollment plummeted from 600 to 40 after local uranium mines closed in the early 1980s. The exodus gutted the town, leaving apartments abandoned.

to keep warm. I wouldn't sell these dogs for a million bucks."

SEBASTIAN'S MISADVENTURE had unfolded near South Pass among the wagon ruts of the old Oregon Trail. With its gentle grades and ample grass and water, 7,412-foot South Pass offered the easiest wagon route over the Rockies.

"Had it not been for South Pass, the U.S.A. might be a lot smaller today," said archaeologist Todd Guenther, curator of South Pass City State Historic Site. "After the Oregon Trail opened in the 1840s, 350,000 pioneers rolled through here. The cultural weight of these settlers ultimately annexed Mexican California and the British northwest to America's domain."

South Pass City, born in a gold boom, played another key role in U. S. history. It was here in December 1869 that William H. Bright of the Wyoming Territorial Legislature persuaded his colleagues to become the first in the world to extend full voting rights to women. Two months later South Pass newcomer Esther Hobart Morris became the town's justice of the peace—America's first female judge.

Worried that woman suffrage would spread, Congress nearly denied Wyoming statehood in 1890. The territory retorted: "We will remain out of the Union a hundred years rather than come in without the women."

Why did this rough-and-tumble land show so much respect for women? Perhaps in part because there were so few of them. Even today men outnumber women here.

I met two men trying to balance the equation at Table Rock, a natural gas processing plant in Wyoming's Red Desert Basin. In the no-frills bar of the desolate prefab town they were hunched over what looked like a high school yearbook of smiling female portraits.

"We got this matchmaker's catalog from a want ad in the *Casper Star-Tribune*," said the guy named Dennis. "What do you think of this one?" Eager for my opinion, he pointed to one of the Philippine beauties. Mail-order brides!

"I'm going to write to her," he told me. With the barmaid's help he had already begun the letter.

"I know it sounds crazy," he shrugged, "but a cousin of mine found himself a wife this way. Brought her over four years ago and married her. It's still working out just fine.

"For a lot of women, a place like Table Rock is just too small, too far away from it all," said Dennis.

For a lot of men like Dennis, "The wages out here are too good to pass up. I need the job. But it cost me a divorce from my wife."

Too many wives was the problem for settlers who founded Freedom in 1879. Straddling the Idaho Territory line, the town allowed polygamous Mormons in Idaho to escape prosecution simply by stepping across the street to "freedom" in Wyoming.

There today at Freedom Arms Inc., a small gun factory, Wayne Baker and Dick Casull cater to another freedom, the right to bear arms. In Wyoming it is perfectly legal to strap on a pistol as long as you do not conceal it.

Typical of Wyoming factories, theirs is a craftsmen's workshop. Hectic assembly lines run counter to the state's personality.

"Here at Freedom we make the Rolls-Royce of revolvers—the 454 Casull, with double the power of the .44 magnum," said Wayne Baker.

I hefted one of his gleaming thousand-dollar five-shooters. Looking through the telescopic sight, Wayne easily boomed all five shots into a one-inch circle 75 feet away.

Its designer, master gunsmith Dick Casull, showed me the first pistol he ever made—at age 12, in his dad's car-repair shop, using the axle off a Model A Ford. At his home nearby we tested Dick's latest prototype, a submachine gun designed for prison guards.

"Try it, see how smooth it fires," Dick said.

I put the long weapon to my shoulder and sprayed his backyard woodpile with several bursts, sending splinters flying. The amazing weapon held perfectly steady on target.

"Go ahead, keep shooting. The drum holds 354 rounds," said Dick, then cautioned, "Just, ah, mind the satellite antenna."

THE WEAPONS that were drawn in Wyoming's most pitched modern battle were subpoenas and depositions. In the dry basins, with barely ten inches of rain a year, water is cause for contention.

The case of *Wyoming* v. *the United States* regarding water rights on the Wind River Indian Reservation may have appeared concluded in 1989, when the U. S. Supreme Court ruled that the reservation's Shoshone and Arapaho residents were entitled to "senior"

YET ANOTHER CHRISTMAS SEASON DAWNS on the National Elk Refuge near Grand Teton for resident Al Ridgway: "I keep reminding myself not to take it for granted."

water rights on the Wind River and its tributaries. But last June the Wyoming Supreme Court seemed to attach some limits to those rights—thereby guaranteeing more lawsuits.

Irrigation from the sure-flowing Wind makes farms on the reservation among the richest in the state. Most are owned by whites. At the turn of the century the U. S. government opened tracts on reservation land to homesteaders, creating a checkerboard pattern of land ownership that led to this struggle for water rights. "What the 'senior rights' ruling meant," one non-Indian told me, "was that in a dry year us farmers would get only the last trickle for our hay and sugar beets."

The reservation council insists this is not true. But they do want to devote more water to tourism that will bolster the reservation's economy. Former councilman Wes Martel explained: "We want to allot water to 'in-stream' development—to keep it in place so we can stock it with brown trout and rainbow.

"On our reservation wilderness land we have 1,100 miles of river and creek frontage and 265 lakes—a potential paradise for fishermen and campers," said Wes.

I explored some of that wilderness at the foot of the Owl Creek Mountains with a young Shoshone trapper, Western "Gus" Thayer. Steeped in traditional animal lore, and with a degree in wildlife management as well, Gus is at home in the backcountry.

It was warm for January, already above zero at 8 a.m. Before we turned off the pavement near Crowheart Butte, Gus stopped the pickup by a fresh road kill.

"Perfect bait," he said, tossing the flat, frozen jackrabbit in the truck. "Cold, stormy weather is actually better for trapping. It gets the animals moving, and with fresh snow it's easier to track them.

"Bobcats are what pay—about $200 a pelt," Gus told me as we bounced over the rough road. Bobcats are common here. The pelts Gus sells are made into coats. "I get some coyotes, but it hardly pays to skin them. Now and then a porcupine. Indian women still weave the quills to make small purses or to decorate clothing."

We stopped to set a trap. A round pattern of padded toes freshly set in the snow, and a wisp of fur caught on a bush, signaled there was a bobcat nearby.

Gus rubbed his hands with sagebrush to cover his scent, then dug a small hole for the trap and wired it to a sapling, so the cat could not run off with it. Sifting soil through a sieve, he covered the deadly rig, then carefully arranged twigs around it to guide the cat's paw onto the buried trigger. He split the rabbit bait with a mattock and tucked half in a nearby crevice. Lastly, he sprinkled the site with bobcat urine from a small plastic bottle.

"Summers are more profitable," Gus said, as we took our lunch of elk sausage and hot coffee back in the truck. "I collect elk horns shed in the higher valleys." The horns are in demand in China and Japan for medicinal tonics, he explained. "I get nine dollars a pound. Some days I collect enough to fill the pickup."

THE WHITE MEN who explored Wyoming in the 1820s and '30s were trappers, men like Jim Bridger, Jedediah Smith, and Kit Carson. On beaver pelts a fortune could be made. These mountain men learned much from Native Americans—they thought like Indians, even dressed like Indians; many took Indian wives. Once a year they gathered for a "rendezvous" to sell their furs, stock up on supplies, and swap tales.

I fell in with a new breed of part-time pioneers at the 19th annual Mountain Man Rendezvous in Fort Bridger. Lawyers, plumbers, and accountants from all around the country were decked out in fringed buckskins and hats of bobcat fur. Tepees were their living quarters for four days of shooting, tomahawk throwing, and nightly Indian dancing around a big council fire.

Superb craftsmen among them set out wares on trading blankets: bowie knives, candles, moose-hide moccasins, flintlocks, snowshoes, pewter cups, and hand-rolled stogies.

I tried on a floppy, wide-brimmed cowboy hat crafted of beaver felt, far too droopy for the fashion on today's range. No problem. The grizzled trader showed me how to shape it with a can of hair spray. I handed over seven dollars, proud now to be a mountain man, at least from the ears up.

To try on their own piece of Wyoming, most of the state's five million annual visitors head for the northwest corner to Grand Teton National Park, Jackson Hole, and Yellowstone.

Ringed by mountains, the Western-chic town of Jackson sits on the southern edge of the valley called Jackson Hole. On a busy summer day 60,000 tourists pack its boutiques,

KEEPING COUNTRY AND WESTERN DANCE ALIVE, the *Fremont County Freesteppers can't stop swinging even after finishing their performance at a Riverton hotel. Moved by the Christmas spirit, itinerant construction worker Ron Gillaspie celebrates with two friends at Medicine Bow's Old West Bar.*

restaurants, art galleries, and ski shops.

Skiers cause the town's winter gridlock. At the top of Rendezvous Mountain some 400 inches of snowfall makes for plenty of good powder on the longest vertical run in the United States, 4,139 feet. But with the steep slopes and thick snow comes a danger: avalanches. Whenever I ventured into the mountains, I first dialed Jackson's avalanche hotline.

"The problem is that more and more skiers are leaving the crowded downhill slopes for the remote cross-country trails," said Rod Newcomb, director of the American Avalanche Institute in Wilson. AAI conducts training courses throughout the Rockies in snow evaluation and rescue techniques.

Jackson ski mountaineer Doug Marden figures avalanche survival training saved his life.

"My roommate Dave and I were skiing the east face of 10,552-foot Albright Peak in Grand Teton National Park. We crossed a steep snow valley—moving one at a time for safety's sake—just below the summit.

"Suddenly the crust split above me with a crack! The world started sliding away under my skis. All hell broke loose. The white mass engulfed me, and the world went black. I was struggling to breathe, pitching headfirst at maybe 60 miles an hour.

"Then my survival training kicked in. Somehow I got the skis off and began 'swimming' in the dark turbulence, a kind of breaststroke to claw snow away from my face.

"Farther down my pack hit a pine, which slowed me up, then I managed to grab a second tree and hold on. The avalanche slid past me.

"It was a 2,000-foot vertical drop, lasting no more than two minutes," Doug said. "But it seemed like a lifetime."

LIVING IN WYOMING seems to bring out the storyteller in a person—and often the poet. Maybe that's to be expected in this land that can invigorate your soul one moment and try to kill you the next.

At the annual Wyoming Cowboy Poetry Round-Up in Riverton, I listened to silver-tongued wranglers recite—or grab a guitar and croon—verses on the freedom of ranch life: "His hat was throwed back and his spurs was ajinglin'. . . ."

Or tales of Wyoming's awesome storms: ". . . the wind with its sabre unsheathed / Led the charge with the scream of a demon."

More often there was humor. Memories of chuck-wagon coffee so bad that "you don't pour a cup, you twist off a swaller."

Afterward, poet-rancher Pete Cameron and his partner, Sara Merkel, invited me to see the views that inspire them: Hoback Basin, 30 miles southeast of Jackson. North of Bondurant, I turned into Dell Creek Ranch, set amid snowy pastures and hills of fir and pine.

Pete was setting out to gather firewood. Outside his barn he harnessed husky draft horses Buck and Dusty to a sleigh, then loaded up saws, axes, and chains.

"Hop on!" Pete shouted back to me. I was floundering in the deep snow. "Better to ride—that's what horses were invented for."

A mile or so up the trail we unhitched the team and began felling a half dozen tall, brittle firs killed by a recent fire. Pete fitted Dusty with a skidding chain and worked him skillfully with "clicks" and "whoas" to drag the

CROSS A RODEO COWBOY WITH A SNOWMOBILE and you get "sno-d-o." Scooting after an iron steer pulled by another snowmobile, ropers try to beat the clock and the blahs during long, blustery Wyoming winters.

heavy trunks and muscle the ends onto the sleigh. Hanging off the back, the logs would brake us on the steep descent.

At the cozy ranch house we ate Sara's elk stew and home-baked bread by the big kitchen woodstove. After the meal, while our gloves were drying on the open oven door, I pressed Pete for some of his poetry. He obliged with a long tribute he had composed to his horses, which concluded:

Compare them to a tractor,
Yes, those big horses burn a lot of hay.
But in the cold, deep winter snow,
I'll take a team and sleigh.

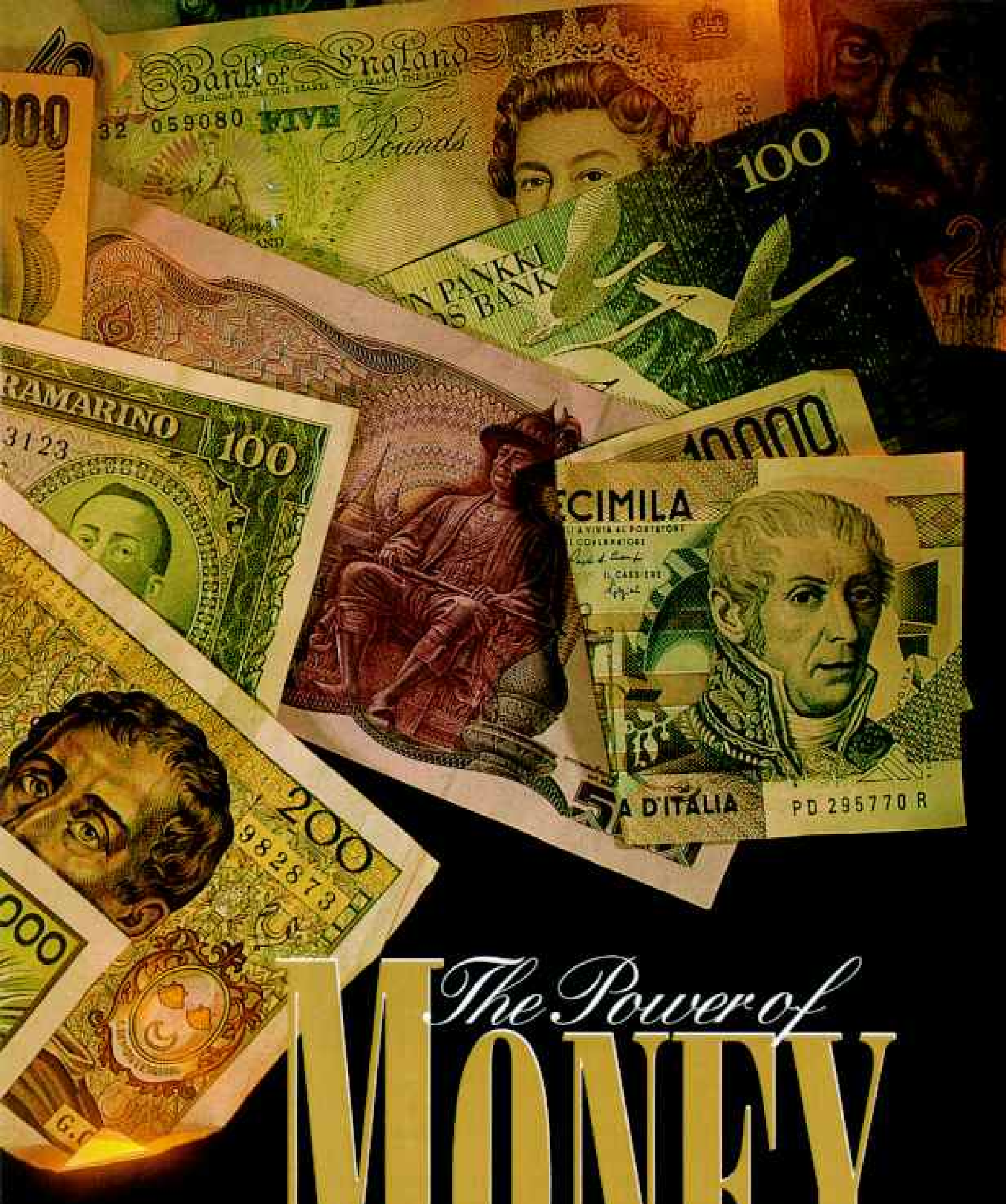
Later, as we unloaded logs, 44-year-old Pete sighed, "This ol' place keeps us busy."

Besides raising cattle and boarding horses, he and Sara feed elk for the Wyoming Game and Fish Department. Pete guides tourist pack trips into the Gros Ventre Range. Sara works as a nurse three days a week at the hospital in Jackson and has just added two rams and a flock of sheep to her chores. "Anything to pay for this scenery," said Pete.

"It's a simple life," he mused, "and in winter it's not for the faint of heart. But Wyoming's well worth it."

A pale winter sun had broken through. It warmed our faces and wrapped the hills in a wondrous glow. Our eyes followed a squadron of tiny snowbirds skimming across frozen pastures where a lone white horse galloped, its mane flying with the wind. □

One of humanity's oldest, if not always most reliable, inventions, money—from gold coins to gold cards—supports the human need to buy and sell, save and spend. Shown is a sampling of currencies, the cash of everyday commerce.



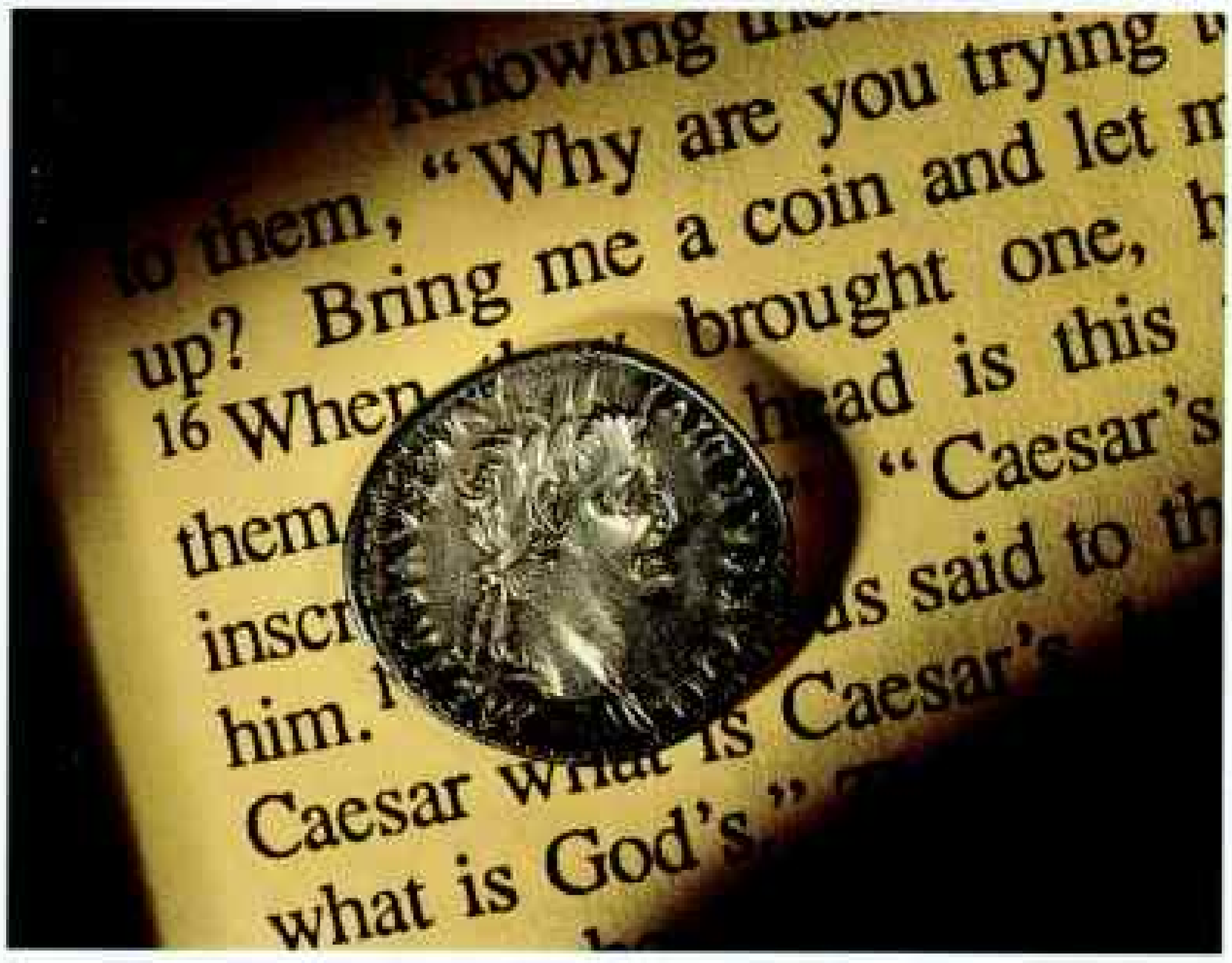
Text by PETER T. WHITE
ASSISTANT EDITOR

Photographs by CHARLES O'REAR

SAY I'M IN PARIS, it's late evening, and I need money, quickly. The bank I go to is closed, of course, but outside sits an ATM, an automated teller machine—and look what can be made to happen, thanks to computers and high-speed telecommunications.

I insert my ATM card from my bank in Washington, D. C., and punch in my identification number and the amount of 1,500 francs, roughly equivalent to $300. The French bank's computers detect that it's not their card, so my request goes to the CIRRUS system's inter-European switching center in Belgium, which detects that it's not a European card. The electronic message is then transmitted to the global switching center in Detroit, which recognizes that it's from my bank in Washington. The request goes there, and my bank verifies that there's more than $300 in my account and deducts $300 plus a fee of $1.50. Then it's back to Detroit, to Belgium, and to the Paris bank and its ATM—and out comes $300 in French francs. Total elapsed time: 16 seconds.

This intercontinental electronic wizardry is merely the latest chapter



A day's wage for a Roman soldier, a silver denarius displays the portrait of Emperor Tiberius, who ordered the coin minted during his reign, A.D. 14-37. Jesus likely held such a coin—about the size of a penny—when he upbraided the Pharisees, saying: "Give to Caesar what is Caesar's, but give to God what is God's."

To lend money an aura of stability and value, images of deities and rulers have long adorned coins, introduced in Asia Minor during the seventh century B.C.

in the history of that infinitely influential creation of the human mind, money—meaning something that's accepted as a medium of exchange and a store of value because it exists only in limited quantities and, above all, because people have confidence in it.

Ah, money! I'd long thought about it—what a story it would make, to journey around the globe and across centuries, tracing the beginnings of coinage in antiquity and of modern banking in the late Middle Ages, investigating how today money is created by your bank around the corner, discovering what determines the interest rates you must pay on loans for your house or car and how the Japanese got all those dollars to buy up so much of the United States lately. How money launderers do their dirty work. And with the proliferation of credit cards, are we really headed for a cashless society?

My journey began in Philadelphia, at the United States Mint. In a

hall the size of a zeppelin hangar I see high-speed presses strike pennies; yellow sodium-vapor lights and bluish mercury-vapor lights alternating overhead make the outpouring of coins look like a stream of gold.

"Each machine strikes 200 times a minute," says a Mint official. "And we don't call them pennies; we call them cents." They're 97.5 percent zinc; the rest is copper. To make one in 1991 cost .92 cents.

That's $9.20 per thousand, so the Mint makes a profit of 80 cents on every ten dollars' worth? "We don't call it profit. It's seigniorage." Very well, the 1991 seigniorage on all U. S. coins, meaning the difference between their face value and the metal value plus the cost of making them, was 428 million dollars.

In Washington, and of late also in Fort Worth, Texas, the U. S. Treasury Department's Bureau of Engraving and Printing turns out paper money—it's actually 75 percent cotton and 25 percent linen. In 1991 it added up to 108 billion dollars' worth. Nearly half the notes are one-dollar bills; these last an average of 18 months before they're worn out. Turned in by a bank, they will be destroyed by shredding. But should you have bills that have been carbonized and shrunk in a

Worth nothing in itself, paper money, when backed by governments and banks, can exceed the value of precious metals. For more than 2,000 years, gold and silver coins served as the primary medium of exchange in commercial societies. But for convenience' sake guaranteed bank notes began to replace coins, first in 11th-century China.

Future legal tender may look like the plastic $50 note issued by Singapore. An iridescent image on both sides is designed to thwart forgery.

fire, gnawed by termites, or accidentally bleached in a washing machine, the bureau's Mutilated Currency Section in Washington, D. C., may be able to help. Turn in at least 51 percent of a bill and you'll get a full refund.

Bills and coins make up about 8 percent of the U. S. money supply—the rest is in bank accounts, including checkbook money; at this writing the sum total is 3.5 trillion dollars, says the Fed—the Federal Reserve System, which is the central bank of the government of the United States—and that is three billion more than a month ago. This is how that happens.

Every business day, after a telephone conference call at 11:15 a.m., the Federal Reserve Bank of New York, acting on directives from the Federal Open Market Committee at Fed headquarters in Washington, buys U. S. government securities from major banks and brokerage

houses, or sells some—usually U. S. Treasury bills, which in effect are government promissory notes. Say today the Fed buys a hundred million dollars in Treasury bills from those big securities dealers, who keep a stock of them to trade with the public. When the Fed pays the dealers, a hundred million dollars will thereby be added to the country's money supply, because the dealers will be credited that amount by their banks, which now have that much more on deposit.

But where did the Fed get that hundred million dollars?

"We created it," a Fed official tells me. He means that anytime the central bank writes a check, so to speak, it creates money. "It's money that didn't exist before," he says.

Is there any limit on that?

"No limit. Only the good judgment and the conscience of the responsible Federal Reserve people."

And where did they get this vast authority?

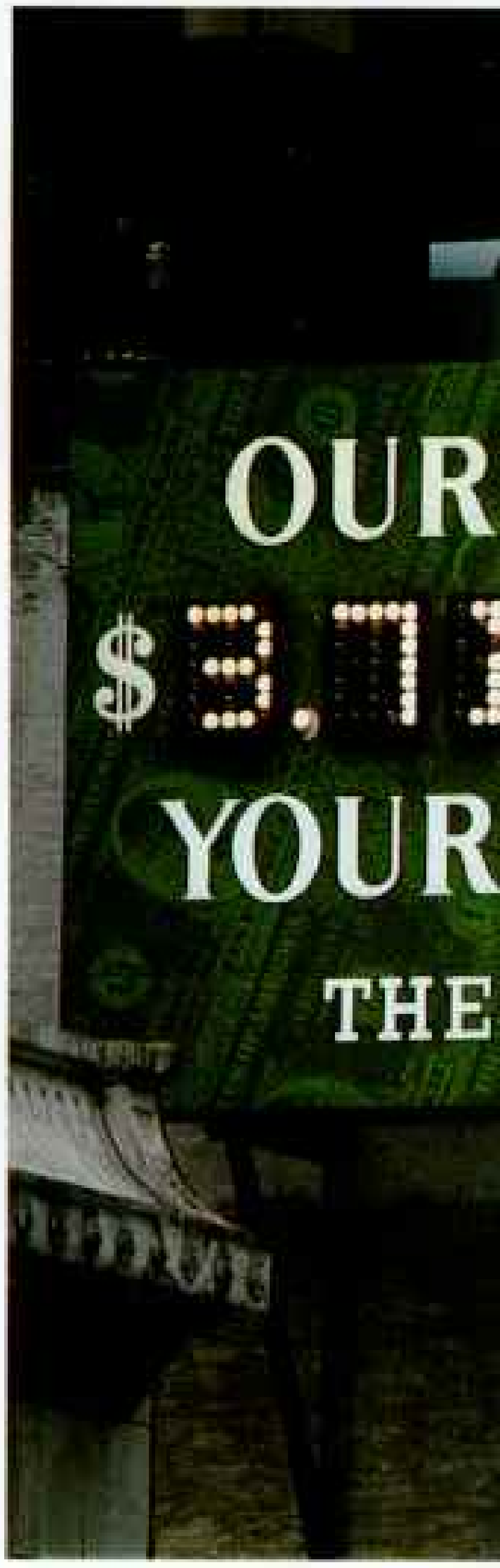
"It was delegated to them in the Federal Reserve Act of 1913, based on the Constitution, Article I, Section 8. 'Congress shall have the power . . . to coin money, regulate the value thereof. . . .' "

Now watch how that Fed-created money lets our commercial banking system create even more. The Fed requires banks to put aside a portion of their depositors' funds as reserves. Say this reserve ratio is set at 10 percent—then for every $1,000 in new deposits, a bank must keep at least $100 in reserve but can loan out the rest, namely $900. On the bank's books this loan remains as an asset, earning interest until it is paid off. The customer who got the loan is likely to spend it right away, say for a used car. The car dealer deposits the $900 check in his bank, which then has an additional $900 in reserves and can in turn loan out 90 percent of that—$810. And so on and on, until the original $1,000 put into one bank may enable dozens of banks to issue a total of $9,000 in new loans.

Thus a hundred million dollars injected by the Fed into the commercial banking system could theoretically stimulate the appearance

The avid pursuit of money fuels feverish activity on the floor of the New York Stock Exchange (NYSE). Four to six billion dollars' worth of securities are bought and sold each day, the deals struck by stock specialists and brokers at stalls tentacled with computer screens. More than 2,000 corporations are listed on the NYSE. The sale of their shares raises capital and spreads ownership.

Money doesn't change hands, it changes screens in the world of investor Ralph Bothne. Specially designed software and satellite linkups to the latest market data enable him to trade currencies from his California home.



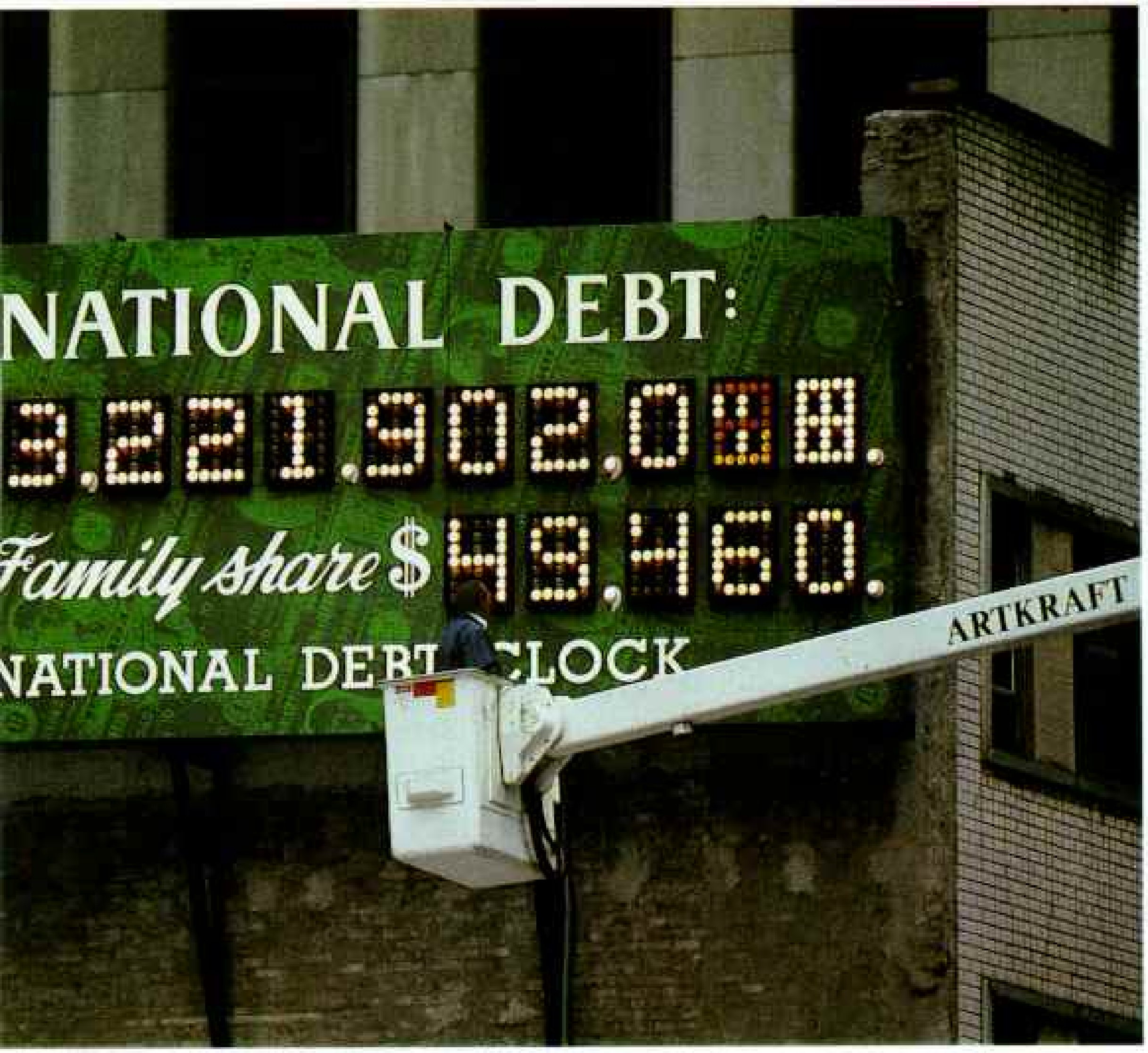
of 900 million dollars in new checkbook money—money that didn't exist before. And it's all built on the assumption that the system is sound.

WE'LL RETURN TO THE FED LATER, but now I'm off to Yemen, where, so I've heard, quite a few people cling to old-fashioned views on what sort of money one can have confidence in, what can be considered sound. At Suq al Talh, the Saturday market not far from the Saudi Arabian border and close to the ancient city of Sadah, I see bearded money changers sitting on concrete steps, curved daggers strapped around their waists, automatic rifles across their laps or propped within reach. In front of them are bundles of bank notes—Yemeni rials—and stacks of coins the size of U. S. silver dollars. These are silver too, but they're all dated 1780, and the large-chested lady portrayed on them is the Austrian empress Maria Theresa. A man just bought a thousand of them for 75,000 rials, and I ask him why.

"It is the main currency," he says. Isn't that what the rial is? He says in this area these coins are *omla saaba*, meaning hard currency,

Personal debt can lead to bankruptcy today. On the steps of the Travis County Court House (above left) in Austin, Texas, foreclosed properties—mostly homes—are auctioned off on the first Tuesday of every month.

Representing banks holding defaulted loans, Susan Mills of Trustees of Texas takes bids. Only money orders, cashier's checks, and, of course, cash are accepted.



National debt may lead to bankruptcy tomorrow. The accumulation of yearly budget deficits, the debt climbs steadily on a sign above Avenue of the Americas in New York City. In July 1992 it topped four trillion dollars. Interest alone on the debt equals 40 percent of personal income tax collected.

and off he goes with 60 pounds of silver in a woven bag. "He bought them to make a profit," another man tells me—they've been going up in price; or, one might say, the rial has been going down.

"The people you saw in Sadah may be illiterate, but they know economic affairs," says Mohamed Said Al-Attar, the minister of industry, who has long been active in the country's financial affairs. Back in the capital, Sanaa, he tells me that in the 18th century, when French traders came to the port of Mocha to buy coffee, the Yemenis didn't want French money, but they liked the Austrian coin, called a taler, because of its high silver content. (From "taler," incidentally, comes the word "dollar.")

The reputation of the Austrian taler spread to much of the Arabian Peninsula and to Ethiopia, where the coin circulated until the 1950s. "We introduced the rial bank note," Dr. Al-Attar adds, "after the 1962 revolution had ousted the monarchy. But for years we had difficulty getting people to trust paper money."

Today the official Austrian mint in Vienna still turns out Maria Theresa talers, still dated 1780. So do imitators elsewhere, notably in Saudi Arabia, says a merchant in the Sanaa suq. "They have agents

in Yemen buy talers, which are 83 percent silver," Dr. Al-Attar tells me. "They melt them down, strike new ones, and send them back to Yemen—less than 80 percent silver." Alas, debasing coinage for a bit of profit is almost as old as coinage itself.

Many of today's currencies, the Italian lira, the British pound, the peso and peseta of Spanish-speaking countries, are named for units of weight once used to measure amounts of metal—mostly silver, which along with gold and copper has functioned as money throughout most of recorded history. The earliest documented use of silver for payment appears around 2500 B.C. in Mesopotamian cuneiform tablets.

SOME OF THE OLDEST known coins were struck in Asia Minor, in the ancient kingdom of Lydia, in the seventh century B.C.—tiny to thumbnail-size lumps of electrum, a pale yellow alloy of gold and silver, washed down by streams from limestone mountains. Such Lydian coins, of specific weight, eventually bore the royal emblem of a lion's head.

The late Oxford scholar Colin Kraay surmised that they were conceived as a convenience to the state, as a standard medium for payments to officials and for public expenditures, also for the collection of taxes and fines. But merchants, long accustomed to settling accounts in precious metals, must have found them useful too; by using coins, they didn't have to do as much weighing for each transaction.

The idea of coinage spread from Asia Minor across the Mediterranean world. By the fourth century B.C. a weight unit called the shekel, used by ancient Babylonians, Phoenicians, and Israelites, had lent its name to silver coins in the Middle East; some weighed half an ounce, slightly heavier than the silver Kennedy half-dollar of 1964. As for gold, it was coined into the aureus of the Roman Empire and the solidus of Byzantium, also the dinar of Muslim lands, the florin of Florence, and the ducat of Venice.

Coins may have begun as a convenience, but some of them have taken on fabulous value today. In southwestern Anatolia I found the Turkish countryside crawling with folks bent on finding an ancient bonanza. Coins of Greece and Persia, Rome and Byzantium are often turned up by rain or the plow, and people prowl with metal detectors, seeking a hoard like the one reportedly dug up in a field in 1984.

Near the little town of Elmalı, in the valley between the mountain ranges called Ak and Bey, I'm shown the spot where I'm told a detector discovered a terra-cotta jar holding 1,900 pieces of silver, possibly

A course in body language teaches clerks at the Chicago Mercantile Exchange to "flash" orders to the trading pit. Here trainees confirm an order to sell 50 futures contracts. Traders at the Merc speculate on future prices of items ranging from foreign currencies to pork bellies. At the Tokyo Stock Exchange a robot shows how to signal a flesh-and-blood decision to sell.

Hand Signal Robot

buried by a Greek commander getting ready to battle the Persians around 465 B.C. Included were 14 brilliant ten-drachma coins thought to have been struck by the Athenians to commemorate their victory over the Persians at Marathon.

Most of those decadrachms are said to have wound up with a millionaire investor in Boston, with one piece going to a collector in Beverly Hills for $600,000. Illegally, according to the Turkish government. Turkish law says you must turn in such finds to the local museum; if they're valuable, you'll get a small reward.

The earliest paper currency issued by a government appeared in China in the 11th century. In Persia the Mongol ruler Geikhatu decreed paper money in 1294, but merchants refused to accept it. They closed their shops and hid their goods. Trade stopped. Facing revolt, Geikhatu rescinded his edict; the official who had suggested it in the first place was torn to pieces in the bazaar. The first European bank notes were printed in Sweden in 1661, when coins were in short supply.

But money hasn't always been metal or paper. One of the oldest forms may well be a shiny white or straw-colored mollusk shell, about an inch long, from the Indian Ocean—the cowrie; from it derives the Chinese character *cai*, standing for wealth, money.

I remember a display of other forms brought to a coin collector's convention in Seattle by John Lenker, then head of the International Primitive Money Society. A bronze drum from Malaysia. A block of salt from Ethiopia. From Fiji a kava bowl with 11 legs. And wampum, once prized by North American Indians—tiny clamshell pieces laboriously drilled and strung together like beads. "All these tell stories just as coins do," said Mr. Lenker. (See "Money From the Sea," pages 109-117.)

No smoking, no drinking, just make money are the rules inside the world's largest trading room in Tokyo. In a cavernous hall 350 employees of Sanyo Securities play the market, trying to cash in on Japan's export-driven economic boom.

In 1991 the baburu keizai, *or bubble economy, based on inflated real estate and stock prices, finally burst. Facing reduced bonuses, stressed-out traders on break fill their heads with soothing music.*

THE HISTORIAN Fernand Braudel has pointed out that for most of recorded history the majority of people, living off the bounty of the land, hardly required money for day-to-day needs, and this was still true for many Americans early in this century when my father-in-law was young. He never forgot the exciting day, once a year after the harvest, when his grandfather hitched up the horses to drive a couple of miles to the little town of Greenfield, Illinois, with the wagon full of wheat.

Fred Heck, the miller, would grind it into flour, keeping a bag for payment. Then to Samuel Wilhite's grocery, to leave flour for a year's supply of sugar and salt, canned goods and candy. Finally Fred Quast, the blacksmith, got flour for shoeing the horses and sharpening the plowshare.

"Everybody knew the flour price," Dad told me, "it was in the paper every day." Payments could have been in those green dollar bills with yellow backs—gold certificates that could be redeemed anytime for gold coins. But it wasn't necessary.

Historian Braudel also delineated how in the Middle Ages the role of money, and hence trade and the entire economy of Europe, got a boost from Italian ingenuity. A new way was found to get around the ban of the church on usury, the lending of money at interest. Merchants of Tuscany, especially from Siena and Florence, employed this new wrinkle at the fairs in the Champagne region of northeastern France in the 13th century. It was called the bill of exchange, and it opened the door to modern banking.

Treasure hunter armed with a metal detector risks jail looking for ancient coins near Elmalı, Turkey. In 1984 a cache of 1,900 silver pieces from the fifth century B.C., valued as high as ten million dollars, was allegedly discovered in a field nearby and smuggled to overseas collectors. A recent find unearthed coins made of electrum, an alloy of gold and silver, that may date from the seventh century B.C. (right). Experts debate their authenticity.

Michele Cassandro, professor of modern economic history at the University of Siena, tells me how it worked: "It would say, for example, 'Signor A, having received so many Sienese scudi, will pay to Signor B so many Florentine florins at such and such a place on such and such a date.' That looks like a currency exchange transaction, but in fact it is a loan agreement, with the interest hidden in the amount of florins Signor A will be paying. But it doesn't say loan, it doesn't mention interest—so, no usury!"

From Siena I drive an hour through the sunny Tuscan countryside to wallow in the state archive of Florence; it's a treasury of neatly written documents chronicling the ups and downs of medieval financial giants. Occasionally they found themselves *bancarotta*—the words mean "broken bank." Hence our word bankrupt—another Italian contribution to the language of money.

Here are the records from three centuries of the Medici, cloth merchants and bankers who became popes and grand dukes of Tuscany. Where else, I thought, would you find the 1457 tax return of Cosimo

COINS FROM TEMIR ARCHAEOLOGICAL MUSEUM

de' Medici, one of the greatest of the clan? He paid one-half of one percent. Property tax, that is.

Back in Siena, outside the Renaissance palace of the Monte dei Paschi di Siena bank—it traces its beginnings to 1472 and is still going strong—I run into more Italian ingenuity: a foreign-exchange machine, operating around the clock for the convenience of tourists. Put in bank notes in any of a dozen European currencies, or Japanese yen, or dollars Canadian, Australian, or U. S. In no more than 15 seconds a compartment opens—there's the equivalent in Italian lire, down to the last small coin. An electronic display shows the exchange rates, fluctuating daily.

For many years after World War II, foreign-exchange rates were pretty much fixed. I recall a Washington, D. C., exhibit of bank notes from nearly every country in the world, each with a notation of its value in terms of the U. S. dollar; under the dollar bill it said "equal to one thirty-fifth of a troy ounce of gold." Foreign governments were

A bartered bride, 12-year-old Karok, of the Dani people of Irian Jaya, stands before pigs used in prenuptial negotiations. In exchange for her hand Karok's father asked the groom for 20 pigs—commonly used as currency—but settled for 11.

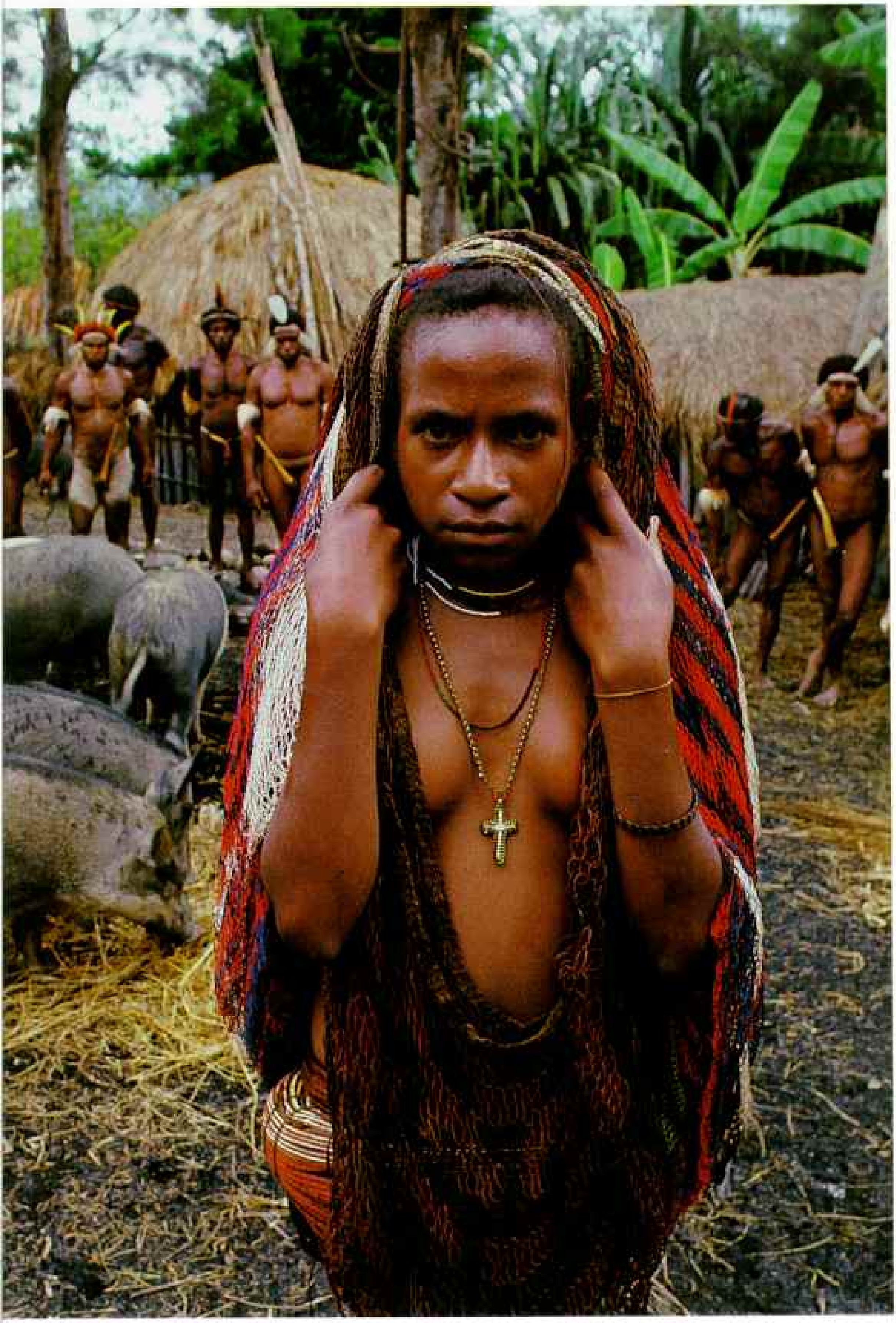
On the island of Yap in Micronesia, Louis Pitmag and his brothers received a piece of stone money as payment for fish. Some stones change ownership but are never moved.

Whether stones, shells, metal, or paper, money can be most anything people agree upon as a medium of exchange.

allowed to redeem dollars for gold at the U. S. Treasury. But eventually the demand increased so much that the "gold-exchange standard" was suspended in 1971 and formally abandoned in 1978.

Not that the world's governments have discarded their gold bars. They keep lots of them as part of their reserves, with some 60 countries storing about 10,000 tons—or a hundred billion dollars' worth, if valued at $350 a troy ounce—in the world's largest gold depository, the subterranean vaults of the Federal Reserve Bank of New York. The U. S. Treasury holds some 9,000 tons, mainly in the legendary vaults of Fort Knox, Kentucky, at West Point, New York, and in Denver, Colorado. Back in 1960 the U. S. had 19,000 tons.

Ever since that direct link of gold to currencies was cut, currencies have been "floating" against one another, at prices reflecting demand and supply. Governments strive to keep such prices within certain limits, but, as recent events have shown, market forces can bring



about more drastic fluctuations. In any case, today's worldwide foreign-exchange market is the biggest trading system ever, with an estimated daily turnover of one trillion dollars. In the trading room of an international bank in downtown New York City, I get a whiff of the world of the big-time foreign-currency traders.

"They've got to be young, aggressive, and hungry," says the supervisor. Next to each, four video screens bring economic news, rumors, and price quotations punched up with a tap on a keyboard—Chicago, London, Frankfurt. Half a dozen loudspeakers offer quotes too. Eighty buttons control phone lines to trading partners.

The name of the game is speculation—betting one currency will go up and another will go down. And arbitrage, taking advantage of differences in the price of the same currency in different places—location irrelevant—differences as small as 1/100 of a cent.

You've got to do it fast—a quote more than a few seconds old is history. So, spot a good one. Grab it. But don't get stuck, get out and cut your losses and get in again. Stress, yes, but what a thrill!

I ask a young woman doing British pounds how one can make money on such tiny margins. It's called scalping the market, she says, a matter of volume. She shows me her profit and loss statement for yesterday: On 120 trades—164 million pounds bought, 160 million sold, a total of 324 million traded—she made $12,000. For the bank, that is. It may not seem like all that much, but that's how thin the margins are.

Top hats are de rigueur for Bank of England officials in London when they call on specialty banks, or discount houses, to discuss the economic outlook.

Paper money, bank drafts, and wire transfers long ago replaced the need to exchange precious metals. Yet wealth is still often stored in gold, such as the trove at Zürich's Credit Suisse, where ultrasonic waves check the integrity of bullion.

TRADERS THRIVE on ups and downs; governments seek stability. That's a principal goal of the U. S. central bank, the Fed. Charged by Congress to do what it can to promote price stability domestically, along with steady economic growth, it faces an endless dilemma.

It can influence the money supply, as we've seen, and thereby affect interest rates via "tight money" or "easy money." It can also vary the so-called discount rate—the rate at which commercial banks, savings and loans, and credit unions may borrow from the Fed; when that rises or drops, the loan rates that they charge their customers usually follow suit. But here, as the Fed sees it, is the quintessential problem:

If the Fed provides too little money, interest rates tend to be high, the borrowing of money expensive—business activity may slow, unemployment go up, and there is danger of recession.

If there is too much money, interest rates decline and borrowing can lead to excessive demand—pushing up prices, fueling inflation.

Just what are the right money-supply rates, the right interest rates—the ones most conducive to stability and orderly growth in an ever changing economy?

In an ornate hall in Washington, D. C., under the American eagle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above the fireplace, meet the seven members of the Board of Governors of the Federal Reserve System. At the head of the great board table sits Chairman Alan Greenspan. Having studied reports of economic conditions across the country, they'll now discuss and vote on what actions the Fed should take.

And what has the Fed done lately? It lowered the discount rate—step by step, from 7 to 3 percent, in order to encourage recovery from the severe recession that began in 1990. At the same time, the increase in the money supply has been kept modest: between 2.5 and 6.5 percent annually, in the hope that inflation can be brought down below 2 percent a year.

AS ARAB OIL WEALTH was the money phenomenon of the 1970s, so in the '80s was the Japanese money machine. I learned about it in Tokyo.

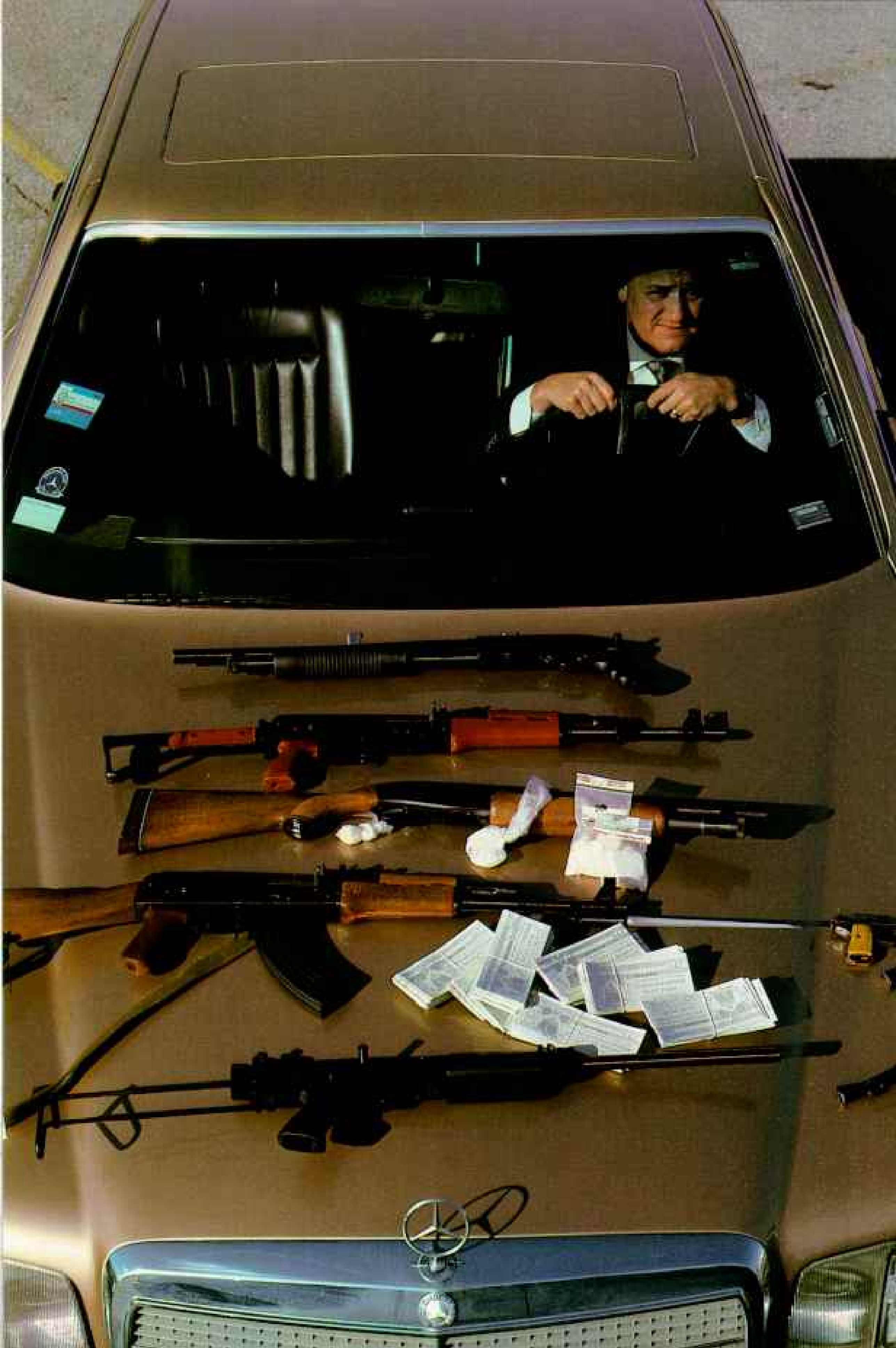
True, the Japanese had been selling lots of cars and electronic stuff around the world and saved lots of yen and put them into the banks—but that wasn't the half of it. As is the Japanese way, manufacturing companies and financial institutions paid only minuscule dividends and kept the bulk of their profits as reserves.

With those profits as collateral they borrowed cheaply to buy real estate, which rose to ever higher paper values. With real estate as collateral, they borrowed to buy shares on the Tokyo Stock Exchange, which rose impressively as well, providing

A kind of money called food stamps helps some 25 million Americans stock their pantries. In Kansas City, Missouri, Angela Freeman works on her food budget as her daughter Martha looks on. Freeman had received $318 in stamps on the first of the month. Two weeks later she was down to $63. "By the middle of the month, most people have spent them all," says Linda Kincaid of the Don Bosco Centers, a social services agency where Freeman attended workshops on budgeting.

Illegal trading is not uncommon. Typically, a recipient sells stamps for, say, 50 cents on the dollar to a grocery-store employee who then redeems them for full value.

Investigator Robert Hillman of the U. S. Department of Agriculture sits in a confiscated car laden with guns and illicit drugs, all bought by food-stamp scams.



More in resignation than expectation, a patron of a Laughlin, Nevada, casino stabs another coin into a slot machine. For some the dream of hitting it big becomes a compulsion that jeopardizes their health, bank accounts, jobs, and marriages. In a circle of prayer, members of a Gamblers Anonymous chapter seek mutual support in a Springfield, Virginia, church.

A staggering windfall of 55 million dollars, a world record, went to Sheelah Ryan, at right, in a 1988 Florida lottery drawing. In Winter Springs, Ryan visits friends who guarded her home after she moved out to elude reporters. So far, she has received more than 750,000 letters asking for assistance. Ryan bought a new house and car and set up a foundation that benefits battered women and the elderly in Seminole County.

collateral for still more borrowing. And then came *zaiteku*.

"Zai"—the Japanese word for the Chinese character for wealth—was combined with "teku," a word borrowed from English that represents technology. Zaiteku means financial engineering—"new ways of making money with money," I was told by Haruhiko Kuroda, a senior official in the Ministry of Finance. And who was the biggest practitioner of zaiteku? Toyota. They were earning 2.9 billion dollars from cars and 1.2 billion from financial operations in 1989.

How? "Rapid currency trading," said Mr. Kuroda, "and issuing securities, say 5 percent bonds, that will be bought by Belgian dentists. . . ." I must have looked puzzled. Mr. Kuroda smiled—he'd meant to say affluent people who are financially unsophisticated, looking for investments that seem safe and yield good returns. "You paid out 5 percent on those bonds, and the money you got for them you put into American corporate bonds that then paid 12 percent." Risky, perhaps, but the Japanese were willing to take that risk for the 7 percent profit involved.

Something else also helped a lot. Back in September 1985 the finance ministers of Britain, France, West Germany, and Japan agreed with James A. Baker III, then the U. S. secretary of the treasury, to push down the value of the U. S. dollar, then worth 241 yen. Baker's

On a Paris boulevard Roland Moreno (left) pays for a phone call with his innovation, the Smart Card, adopted by the French banking industry in 1983. With its built-in microprocessor and a secret code, the card can store data, act as a physical access key, and function as a universal credit card—a step on the road toward a cashless society.

"Mr. Plastic Fantastic," Walter Cavanagh flaunts some of his 1,376 credit cards, the world's largest collection. The California financial planner started collecting in 1971 to win a wager.

purpose was to increase the export of American goods by making them cheaper abroad. Eventually, with the dollar dropping to as low as 120 yen, the Japanese could buy twice as much in the U. S. as before. And they did. Columbia Pictures. Eighty percent of Rockefeller Center. A lot of downtown Los Angeles. Tokyo banks, awash in money based on inflated real estate and stocks, became the world's biggest—and the world's major supplier of capital.

In Tokyo I heard some remarkable figures. A housewife said the cost of an apartment had more than doubled in a year. I passed a downtown office building with rents six times what they were in Manhattan. The grounds of the Imperial Palace in the middle of town were said to be worth all the land in California. A typist said she'd been

flying to Hawaii on weekends to play golf—that was cheaper than playing here. Could this go on much longer?

When I visited the Tokyo Stock Exchange on December 5, 1989, its Nikkei index was at 37,494.17 yen. I didn't know then, nor did anyone else, that at the end of the month it would reach a historic high—38,915.87 yen. As of this writing, the Nikkei has dropped more than 50 percent. Land prices are falling too. Zaiteku has faded; the *bubaru keizai*, the bubble economy, has burst. The big Tokyo banks are pulling back on overseas loans.

TOWARD THE END of my money travels, I found myself in the Republic of Nauru, an island on the Equator in the western Pacific. Only four miles long and three miles wide, it has 1,000 to 2,000 foreign corporations and banks. "They come and they go," said Leo D. Keke, then Nauru's acting secretary for justice; but that's only in a manner of speaking—they have no offices here, no personnel. Mr. Keke had to approve the foreign applications. What Nauru gets out of this, he said, is fees. What do the foreigners get? Secrecy and reduced taxes. "It's arranged through lawyers and accountants in Hong Kong. . . ."

In Hong Kong a partner in the international accounting firm of Ernst & Young told me that these Nauru banks and corporations exist as computer entries elsewhere, maybe in a bank in New York City. Money can go via electronic transfer directly to New York—say to Citibank for account of Bank XYZ, Nauru. It can then be invested in anything, anywhere.

Nauru, he said, is an extreme example of the worldwide phenomenon of tax havens; others like it are the Cook Islands and Vanuatu in the Pacific and the Turks and Caicos in the Caribbean. Considered more solid are Bermuda, the Bahamas, and the Cayman Islands, and especially Luxembourg, Switzerland, and Liechtenstein. They may all be used not only for commercial transactions but also to keep one's money safe. A trust fund for the children. Or to protect your money against wild inflation or political upheaval.

Much tax-haven activity is completely aboveboard—but some is not. Dirty money cries out to be laundered, and I caught a glimpse of

"It's like having Wall Street in your hand," says New York money broker Walter Kaczor, who keeps an eye on a portable quote receiver and an ear on a cellular phone during the U. S. Open. Speculating on the foreign-currency market is, like tennis, a game of split-second decisions.

Outside the Istanbul stock exchange bootlegging brokers with transistor radios pick up price information from cordless phones used inside.

how that's done from the Centre for International Documentation of Organised and Economic Crime in Cambridge, England. This is a real-life example:

A U. S. organized crime group with a lot of hot cash forms a cozy relationship with the central bank of a British Commonwealth country. Diplomats of that country carry the cash out of the U. S. If it's $10,000 or more, they are supposed to report that to U. S. Customs, but they don't; they "externalize" the cash. It goes into the central bank and then into various dummy companies in different countries in return for shares in those companies. The money is thus "agitated," so it'll be just about impossible for investigators to follow. Then, to "repatriate" the money, dummy companies in the U. S. sell their worthless shares to investors in Britain—who are in fact in on the scam—and behold, the money is back in the U. S., clean! Now it buys legitimate businesses, banks, political power.

An operation like this, involving highly placed officials and businessmen, will cost quite a bit, maybe 35 percent, but once the system is in place, people will want to use it—not only drug profiteers but also arms dealers, terrorist organizations, intelligence agencies. . . .

A prime haven for such shady customers was BCCI, the Bank of Credit and Commerce International, headquartered in Luxembourg and the Cayman Islands with branches in 72 countries. It is said to have secretly controlled the First American Bank of Washington, D. C. After BCCI collapsed in 1991, having defrauded depositors of several billion dollars, it became known as the Bank of Crooks and Criminals International.

BACK HOME I RUN ACROSS a little formula that bankers and financial analysts know, that everybody should know—the rule of 72. No one is certain who first developed the rule, but the principle is quite simple: Divide any number into 72 and the answer tells how long it will take for a sum to double in financial terms.

Are you charged 18 percent interest on the unpaid balance of your credit-card account? Eighteen goes into 72 four times—so the debt would double in four years. Say your annual raise is 6 percent; that number goes into 72 twelve times, so in twelve years your salary will double. The same will be true of any investment. And what if inflation runs at 6 percent a year? Then after a dozen years your money will be worth half as much—so in a sense you'll be back where you started.

But look what can happen when inflation runs wild, when governments simply issue more and more currency to cover increasing obligations as prices rise.

In 1986 Peru's currency—the sol, which is Spanish for sun—fell to 14,000 to the U. S. dollar, so the government lopped off three zeroes and called it the inti, which means sun in Quechua, a language spoken by more than half the Peruvians. By mid-1991 a cup of coffee cost 500,000 intis. The government lopped off six zeroes and called it the sol again. Over five years the inflation rate was 2,200,000 percent!

The most drastic inflation ever? Hungary 1946, after World War II, when Germany had taken away the national bank's gold reserves. By June the Hungarian pengō appeared in notes of a million million billion, which would look like this: 1,000,000,000,000,000,000,000. Then the gold came back, confidence returned, and in August Hungary had a stable new currency, the forint.

FROM THE EARLY 1950s ON, a new means for payment in place of currency began to spread from the U. S. to much of the world—the use of what's been called plastic money, meaning charge cards and credit cards. Currently some 250 million MasterCard and Visa cards have been issued in the U. S. alone. Occasionally these cards go to unlikely recipients, such as Tommy Mullaney of Crownsville, Maryland. He was 11 years old when he got a gold MasterCard from a bank in Wilmington, Delaware, with a $5,000 credit limit, even though on his application he had stated his income—his allowance, that is—as five dollars a week. The bank called it an error.

ATM cards, for use in automated teller machines, are also proliferating. More than 150 million are now used in the U. S., not only to draw cash from banks but also to make payments. At gas stations, for instance. And increasingly in supermarkets—with your ATM card and a "point of sale terminal" at the checkout lane, your grocery bill will be deducted from your bank balance.

Are we, as all this might suggest, headed for a cashless society? The answer is yes, but slowly. ATM gadgetry is expensive. Nevertheless,

A glittering fraud fooled Boise, Idaho, townspeople who accepted vintage ten-dollar gold pieces as collateral for loans totaling 5.7 million dollars. The coins turned out to be pre-Civil War pennies that had been gold plated and mounted to obscure the sides reading "one cent."

Whimsical artist Barton Beneš of New York City also transforms money, but only in making art, a legal act if not meant to defraud. Faked and fought over, hoarded, invested, and squandered, money is the fuel that keeps society moving.

new uses for it are being tried, such as letting ATM cards pay for fast food. And one day you may need neither cash nor a card for highway tolls; your car may get electronic tags, and as it passes a tollgate, it will be automatically identified without your having to slow down. The toll will later appear on your bank statement. But for the foreseeable future you'll still have to have currency to pay for a newspaper or a candy bar.

As for me, I'm still amazed that I can go to Paris, stick a plastic card into a machine, and 16 seconds later pull out enough money for a pleasant evening. Not that this electronic marvel has reached perfection, mind you. A newspaper in England reported that when a man punched in his request for £30, the ATM did its beeping and blinking, and then disgorged £2,670.

To an average fallible human, that's comforting. □

Money From the Sea

By PHIL NUYTTEN

Photographs by
DAVID DOUBILET

In the depths off Canada's Vancouver Island, encased in the high-tech NEWTSUIT I developed, I hold a tiny treasure—a live dentalium, a mollusk whose shell was used as money by North American Indians for 2,500 years. As a subsea engineer of native ancestry, I had always yearned to study this little-known medium of exchange and to find out how these deepwater shells were harvested.

Indians prized many substances—copper, obsidian, jade, for example—as trade goods. On the northern Atlantic coast they fashioned bits of quahog shells into wampum belts, which recorded important events and were later used as money. But dentalia were the only shells that became true currency, because they came from a limited area and thus held their value. The best were harvested by the Ehattesaht and Quatsino people, on the west coast of Vancouver Island.

After bringing the mollusks to the surface, harvesters pried the animals from their slender, two-inch-long shells with hardwood splinters. They snapped the tips off the hollow shells and strung them in standard lengths, measuring from the fingers of a man's outstretched arm to his shoulder. Strings of *hy-kwa*, as the shells were called in Chinook Jargon, a coastal trade language, spread over much of western North America.

Dentalia served as decorative wealth as well as currency. The shell dress of the daughter of the Oglala Sioux Chief American Horse (right) marked her as a woman of substance in 1908. Members of the Nez Perce tribe

EDWARD S. CURTIS

wore shells through their noses, earning the name "pierced nose" from early French traders. A six-inch-long purse (left), made of elkhorn and leather, held dentalium strings for an 18th-century Yurok from the lower Klamath River Valley of California. Obsessed with money, Yurok men tattooed their arms with dentalium-measuring marks and recounted myths of Pelintsiek—the Great Dentalium.

RMS PHOTOGRAPHER VICTOR R. BOSWELL, JR., AT PHOEBE APPERSON HEARST MUSEUM OF ANTHROPOLOGY, UNIVERSITY OF CALIFORNIA, BERKELEY (ABOVE); PAINTING BY GREG HARLIN

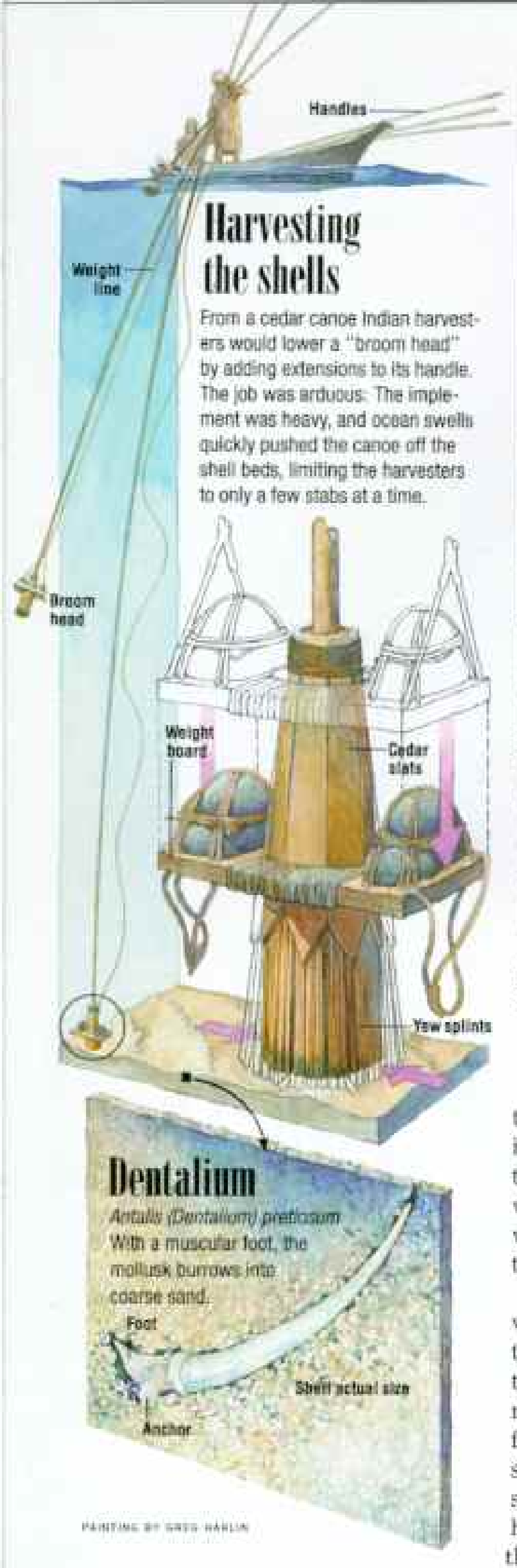
Trading for shells

Currency valued over half a continent

Shell money drove the Pacific fur trade. In the early 1800s Indian middlemen bought sea otter pelts from isolated tribes with dentalia, then exchanged the pelts with white traders for muskets and metal goods. Later, whites bought dentalia directly from the harvesters. Boston traders even tried to counterfeit the currency with London-made porcelain copies, but they earned only disdain from the Indians. In this scene of an Ehattesaht village around 1800, neighboring Indians, at left, bring muskets, iron chisels, and sea otter pelts to exchange for dentalia. Two chiefs and their designated speakers, all with onion-shaped knobs on their cedar-bark hats, take part in a bargaining session.

A century had passed since the last native dentalium harvest when I organized a two-week research expedition among Vancouver Island's rugged offshore reefs in 1991. In the *Sea Urchin*, my eight-foot mini-sub, I spotlight a sea pen as I scan Kyuquot Sound for dentalia. They are easy to spot: Though they burrow into the sandy bottom, their tips often protrude. Expedition biologist Elaine Humphrey of the University of British Columbia noted that many of the tips were covered with red algae, suggesting that they had been exposed for long periods.

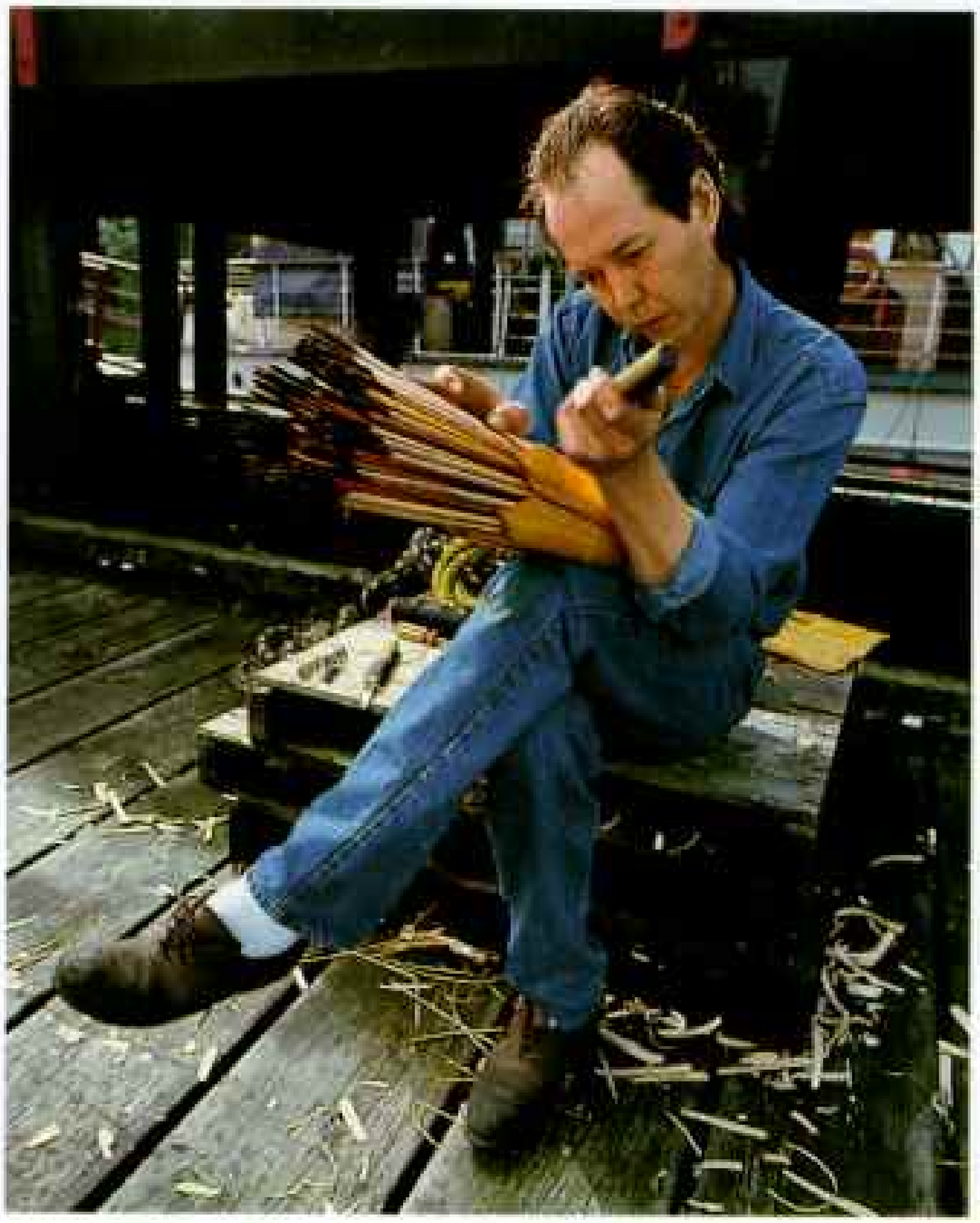
When I fan away the sand from this specimen (below), it digs down (middle) with piston-like strokes of its muscular foot. Hermit crabs (right) sometimes inhabit empty shells, lending credence to early accounts that some dentalium shells were taken with bait: Crabs could grab it with their claws; the mollusks could not.



PAINTING BY GREG HARLIN

Harvesting the shells

From a cedar canoe Indian harvesters would lower a "broom head" by adding extensions to its handle. The job was arduous: The implement was heavy, and ocean swells quickly pushed the canoe off the shell beds, limiting the harvesters to only a few stabs at a time.



Indians designed specialized gear to harvest the money crop and probably had to visualize what their equipment could do without actually seeing it done. Several of these early implements still exist in museums in Victoria and Seattle.

I resolved to build a harvester and try it myself, turning for help to John Livingston, one of the few contemporary master carvers who apprenticed in the old way—with a Kwakiutl master, Chief Tony Hunt.

On the dock at Kyuquot village (above), John puts the finishing touches on the broomlike head of our model. He made the head from more than a hundred sharpened yew splints, scorched to increase their hardness. He then sheathed the bundle in thin slats of springy yellow cedar.

Attached to a 70-foot-long handle made in sections, the head (above left) would be lowered from the surface and jabbed into the bottom. A board, weighted down by rocks and operated by a separate line, would then be eased over the outer slats, thus trapping whatever had been pinched between the inner splints.

An ingenious contraption, but would it work? Some scholars doubted that such an implement could harvest live dentalia. If the shell beds lay as deep as old records indicate—100 to 150 feet—the broom would be extremely difficult to handle. And the mollusks were thought to burrow far too deep for the device to reach them.

In Kyuquot Sound we finally found some answers. The dentalium beds lay at only 50 to 60 feet, and the mollusks live in the top few inches of the sediment—easily accessible. The harvesting implement? It worked like a charm. Perhaps shrewd native harvesters had exaggerated the depths and the difficulties of the harvest to boost the value of their shells.

Money end of the tool at the ready, the underwater test is on. We cheat a bit at first, dropping the broom over shells I gathered earlier. John Livingston mans the handle from the boat, 50 feet above. He stabs the broom into the bottom, penetrating about four inches. When he lifts it up (below)—*jackpot!* By next morning we were poking the sea bottom for the first modern dentalium harvest in Kyuquot Sound.

Smallpox ravaged northwest coastal Indians in the mid-1800s, killing tens of thousands. Missionaries preached damnation to those who survived and dared to cling to old customs. Trading posts appeared, and wool blankets replaced dentalia as the primary medium of exchange. Major harvests ended, but hy-kwa had been spread widely around western North America. Bolstered by infusions of similar shells from the Atlantic, it kept its value among inland Indian tribes well into the 20th century.

Dentalia were sewn onto formal clothes, together with glass beads and other shells. A daughter of Oglala Sioux Chief Crazy Horse owned this dress with a rich dentalium yoke (top).

Shells dangle from the braids and form a necklace for a Sioux doll (right) wearing traditional dress. Sioux women made such dolls to demonstrate their skill in the arts of beadwork and sewing.

A wife of Tlingit shaman Berners Bay Jim once wore this ceremonial headdress of dentalia and beads in Klukwan, Alaska (facing page). The cap is made of green wool cloth and highlighted with red flannel and satin ribbons.

The remaining Ehattesaht who live on Vancouver Island now gather the shells from beaches and use them mostly for decoration. But dentalia continue to be an important symbol of power and wealth, and some families still formally inherit the right to harvest the shells from specific areas. I had imagined that we would be the first to dive at those places.

How presumptuous of me. Native scuba divers pinpointed the dentalia for us when we arrived.

One evening several Ehattesaht women came to our ship, *Clavella*, which was berthed at their town dock. They brought ceremonial blankets richly decorated with their family crests, rendered in dentalia. Used at potlatch feasts, the blankets were not for sale. They were just to show us that the traditional spirit beings of the Ehattesaht—Raven, Thunderbird, and Lightning Snake—still sparkle with the old magic. And the women spoke to us of their sea, a sea so rich that "only a fool could starve here."

A sea so rich that money grows on the bottom. □

HILLEL BURGER, PEABODY MUSEUM, HARVARD UNIVERSITY (TOP); RICHARD AND MARION PEARET COLLECTION, DETROIT INSTITUTE OF ARTS (ABOVE); VICTOR R. BOSWELL, JR., © ALASKA STATE MUSEUM, JUNEAU

ROARING THROUGH

Earth's Deepest Canyon

Risking their lives, a team of kayakers and rafters ride an adrenaline high down the seething fury of Peru's Colca River.

By JOE KANE

Photographs by
ZBIGNIEW BZDAK

"Go right!" orders raft captain Robin Moore, at left. In rafts and kayaks 12 adventurers — including

four who made the first recorded run in 1981 — challenge the isolated, heart-stopping river.

HERE IN THE GUT of this impossibly deep canyon—the wall opposite me rises vertically for more than two miles—Peru's Colca River thunders so I cannot sleep. Instead I write these notes, by candlelight, curled amid granite slabs the size of cars, in a cave whose scored ceiling appears ready to drop chunks at any time. Across the river a waterfall cascades a thousand feet in three bridal veils, and when I poke my head out, the full moon reveals three giant condors gyring far above, going nowhere, as if to emphasize that we have no way out of here but the river itself.

I am bone tired. Today was our longest on the water, sunup to sundown, capped by a brutal confrontation with Canoandes Rapids. About 20 feet above the chute our raft nudged a small, hidden rock, and though it pushed us off course by mere inches, that was enough. Our raft captain screamed "Go! Go! Go!" but it was already too late; the current quickly sucked us out of control. We teetered a lifetime of scant seconds on the lip of the chute, then fell straight down into churning water. I felt as if I'd been thrown off the roof of a house. And I saw, with discomfiting clarity, that I might soon die.

I think I agreed to run the Colca simply because I knew my soul was rusting. I don't mean I was chasing thrills. The Colca is a tremendous white-water river—it carves the deepest land gorge on earth—but white water scares me, and, pushing 40, I find adrenaline a nuisance. Before the Colca I'd run only one river, following a restless Pole named Piotr Chmielinski down the Amazon, from source to mouth, by foot, raft, and kayak, for six months. It was the looniest thing I'd ever done.

But as the years passed, as I collected wife, house, child ("the full catastrophe," as Zorba the Greek said), moments from that journey bubbled up to buoy me through dark times: the nostril-singeing cold of an Andean night, the break-bone crush of a white-water rapid, the smoky musk of an Indian hut. Flexing against such memories, my soul renewed itself. I came to believe that at times risk is the price you pay to reach a place that can blast your spirit clean.

Five years after we'd dipped our paddles in the Atlantic, Piotr called to ask if I'd join him on an expedition to the Colca. It was like being invited to the Colorado by John Wesley Powell. Only a handful of people have seen the heart of the Colca, and not all of them have lived to tell about it. Rising in the southern Peruvian Andes and spilling southwest for 236 miles before emptying into the Pacific, the river carves a gorge that, measured from its lower rim, is 10,500 feet deep—more than twice as deep as the Grand Canyon.

In 1981 Piotr and five Polish friends made the river's first recorded navigation. It was a mess. They got sick, they ran out of food, the rapids pummeled them, they were bombarded by rocks hurtling off canyon walls. I knew the story well enough to at first decline Piotr's offer, but I also understood why he wanted to go back. Peru has a problematic reputation—impoverished, suffering from cholera, and bloody from 12 years of war between violent Maoist revolutionaries and the government. But what's also true, and little known, is that Peru is one of the most startlingly beautiful places in the Western Hemisphere.

I had glimpsed the Colca's gates once, from afar. Ocher ramparts soared like giant organ pipes straight up out of a trench so deep and black that it looked like a wound in the skin of the world. For a slippery second I'd been convinced I could follow that blackness into the earth's very guts—into my idea of a sacred place, a place beyond machines.

BY PLANE TO PERU, by bus through Lima, and south along 800 miles of coastal desert. Despite the bleak terrain the mood inside our bus is upbeat: There will be 12 of us on this expedition, organized by Canoandes, Inc., and sponsored by HP Environmental, Inc., of Reston, Virginia. We have two four-man rafts and four kayaks, and it is a reunion of old friends. My seatmate, the bearish photographer Zbigniew Bzdak, was a raftsman on our Amazon descent; he often held my life in his hands (though he claims, falsely, "Never I stick my neck out"). The same is true of the tall, lean man across the aisle, Jerome Truran, once a kayaker for the British national team; he now naps in the arms of his Canadian wife, the diminutive Morna Fraser, also a world-class kayaker.

San Francisco-based writer JOE KANE is author of the best-selling book *Running the Amazon*. This is his first article for the GEOGRAPHIC. Free-lancer ZBIGNIEW BZDAK photographed "Kayaking the Amazon" (April 1987).

In front of me Piotr pores over maps; behind me, draped across the equipment bags, are two veterans of the first Colca descent, Andrzej Pietowski and Jacek Bogucki. Like Piotr and Zbigniew, they were members of a nine-man team of university students that shipped out of Poland in 1979 armed with 20 homemade kayaks, a year's supply of kielbasa, and dreams of conquering New World white water. "First river we run is the Pescados, in Mexico," Zbigniew had told me. "We put seven kayaks in the river. In 15 minutes we lose six of them. River just takes them away. Big Polish joke."

Despite so ill a portent, they ultimately ran 23 major rivers in 11 countries, including 13 first descents. They intended to be away for a year, but didn't see Poland again for almost a decade. They were in Lima in 1981 when the Polish government banned the labor organization Solidarity, and they led a march against the Polish and Soviet Embassies there. Thousands of people followed them, and the students couldn't go home again.

Eventually they became U. S. citizens. They also became fathers and husbands, and none of them have grown any thinner. They won't come right out and say it, but this may well be the last time they run a river together.

Other crew members on the bus are Johnny Moscarillo, a river-running friend of Piotr's from Virginia, the father of three children; young Dariusz Gozdek, representing the Krakow kayaking club Bystrze, under whose auspices the other Poles first came West; Dr. Tod Gulick, a former U. S. Air Force fighter pilot, who works in an emergency room in Santa Rosa, California; and Robin Moore, a burly, bearded outdoorsman who has spent 17 years guiding rafts on some of the most difficult rivers in the U. S. He claims to be both a sensitive, modern man ("I cried once") and a backwoods West Virginia squirrel-eater.

We stop in Arequipa to collect Duilio Vellutino, the college-age son of Antonio and Ani Vellutino, who took the Poles in after their first, near-fatal running of the Colca—when, as Andrzej tells it, "We had one dollar 60 cents to our good names." Duilio is also the nephew of Alvaro "Cholo" Ibáñez, who ran the Colca with the Poles on their second descent in 1983. In 1985 Cholo returned with his own team. The river was in flood, and,

"I did it!" yells Johnny Moscarillo after a thunderous passage through Organ Rapid, one of the roughest on the 12-day trip. "It was like winning the Olympic gold," he says.

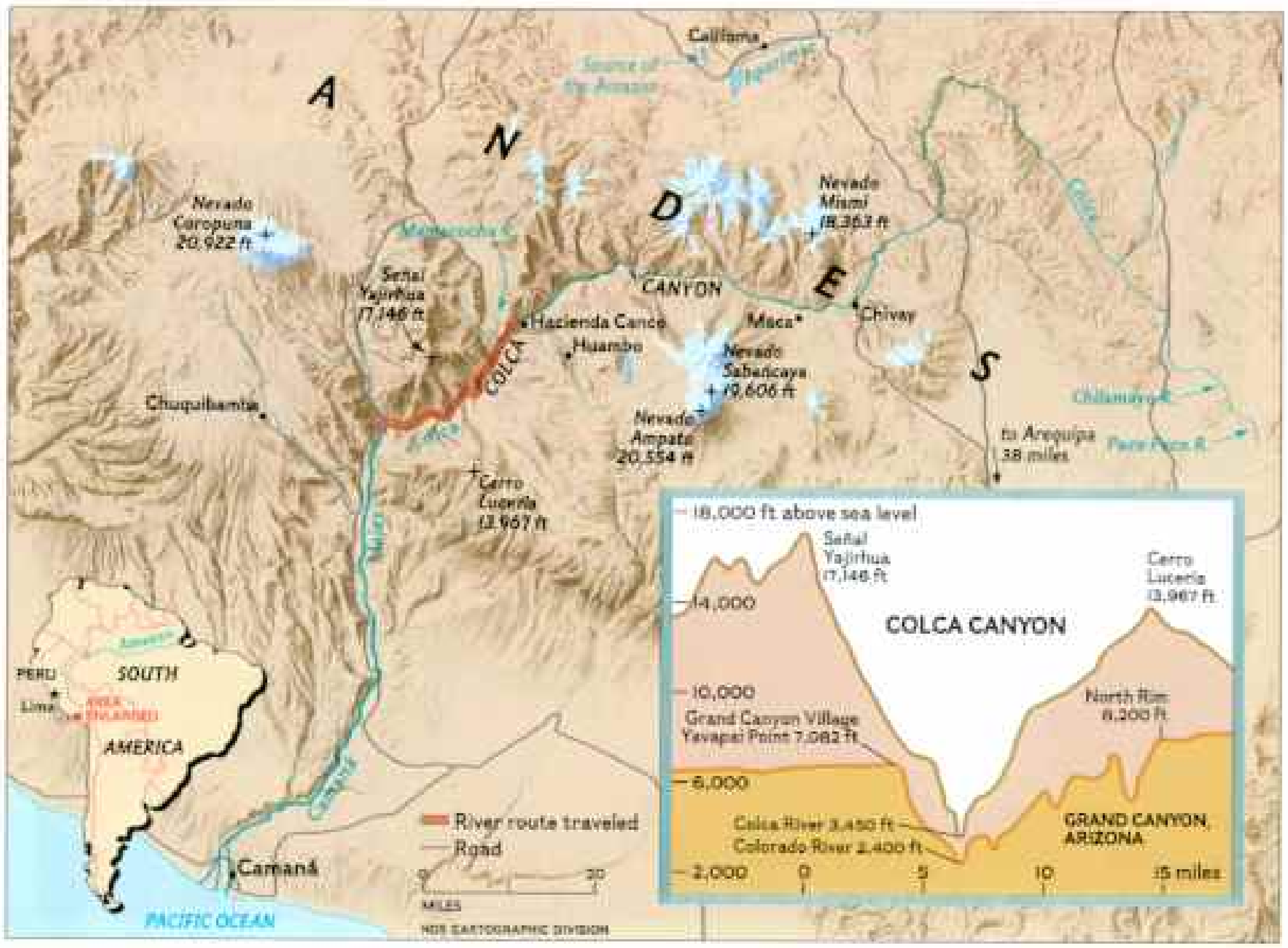
according to the two survivors, their raft flipped in less than a minute. The Poles recovered the raft later that year ("The darkest trip of my life," Zbigniew said), but Cholo's body was never found.

Still, Duilio, high-spirited and tough, has already kayaked the Colca once, an experience he says was marred only by the notorious Reparaz Canyon, a chain of three difficult rapids so blocked by boulders that they're all but unscoutable. Reparaz, he says, ripped him out of his boat and shook him so violently he cannot escape the memory. He must return *para sacarse el clavo*, as the Peruvian expression has it: "to remove the nail."

FROM AREQUIPA we make our final drive into the dry, purple Andes, to about 15,000 feet, cresting the rim of the upper Colca Valley in late afternoon. A black-chested eagle hovers at eye level, then banks and dives, its immense shadow rippling across the quilt work of farm terraces thousands of feet below.

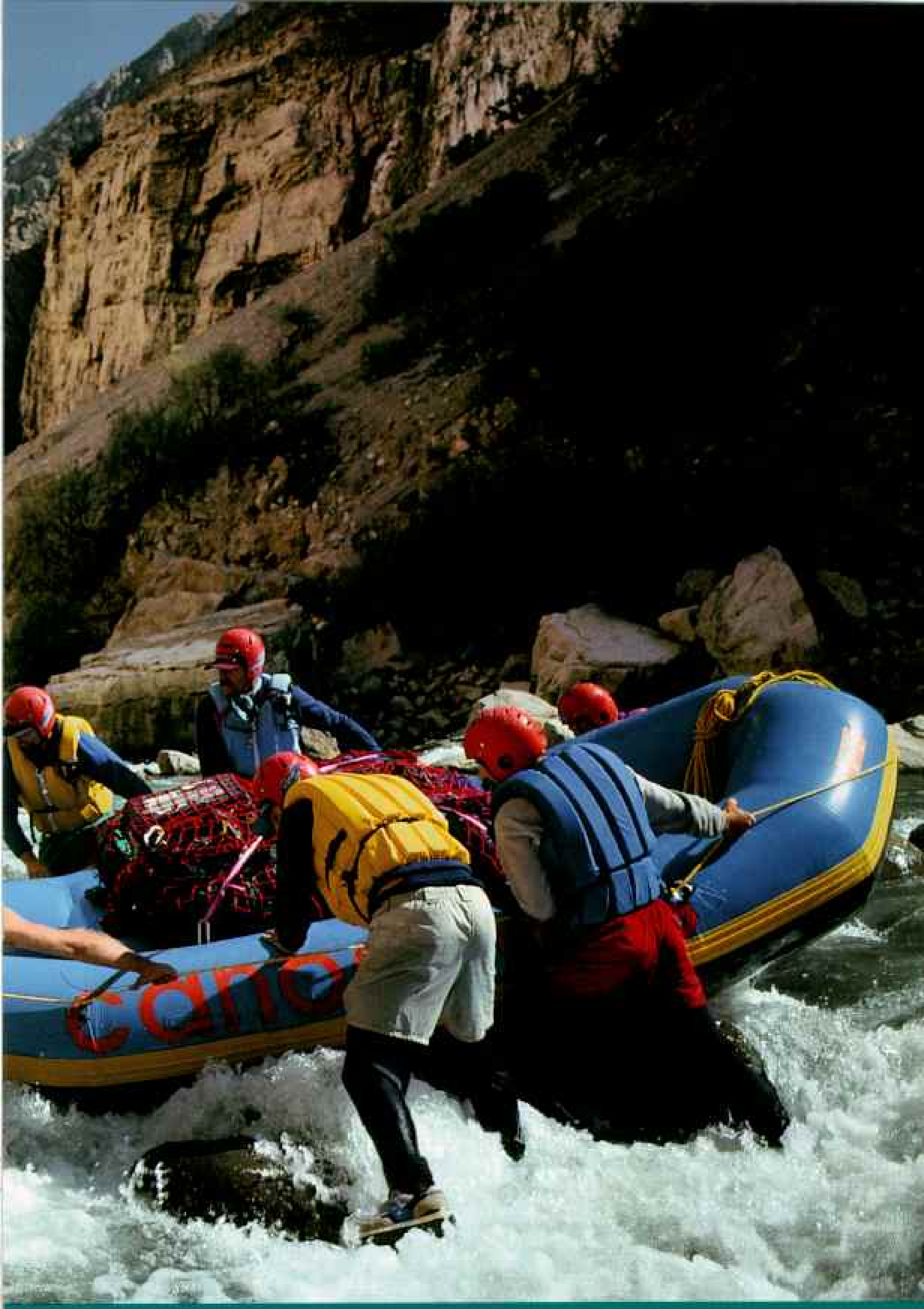
Like many Andean rivers the Colca carves an inhabitable valley in its upper reaches, then dives to sea level. The river changes names five times: It's called Paco Paco at the source; Chilamayo for 7 miles; Colca through the 155 miles of its high valley and breakneck plunge; Majes for 37 miles, in which it broadens and flattens out; and Camaná in its littoral, which begins 30 miles from the Pacific. It is the Colca gorge, the most precipitous drop—some 3,000 feet over 50 miles—that we will attempt to navigate.

If any one mood dominates the Colca, it is one of isolation. The Inca gained control of the valley in the 15th century, but they never really conquered it. Nor did the Spanish, who took over in the 16th century, though they did manage to kill off much of the native population. Life here changed so little down the centuries, in fact, that when American historian Robert Shippee wrote about the area in NATIONAL GEOGRAPHIC in 1934, he described it as "a forgotten valley of Peru."



Colca Canyon (right) cleaves the Andes in southern Peru. Earthquakes, avalanches, and the turbulent river constantly carve new features. The V-shaped river gorge, accessible only by boat, plunges to more than twice the depth of the Grand Canyon (inset).

Boulders block the way along a narrow, shallow stretch of river. "Stepping carefully," says team



leader Piotr Chmielinski, "we heaved the loaded rafts one hundred yards to the other side."

Not until the 1970s did a dirt road reach the valley, making arrivals such as ours possible.

We bed down in numbing cold, and in the morning, goofy from the sparse oxygen, drive west beneath white-hooded peaks. Directly across the canyon rises the Mismi massif, source of the Amazon. About noon a dull explosion 12 miles east of us produces a long black plume from the volcano Sabancaya; it billows into tight clouds, then disperses to a yellow pall that soon fills the horizon.

In midafternoon we reach the baked-earth plaza in the village of Huambo, the end of the road. The sky is cloudless, the air as dry as chalk. Ragged Quechua children play in the dirt. The military made a rare appearance here recently, kicking in doors, and the adults who crowd around us are suspicious, their leathery faces sullen beneath black bowler hats. Quickly we lash kayaks, rafts, and barrels of food and camping gear to 13 broad burro backs. Then I shoulder my pack and fall in behind long-legged Andrzej, his parasol perched jauntily over one shoulder. Burros snorting behind us, we tramp through narrow dirt streets past low, rough houses of mud and stone, then ease ourselves onto the dusty, sun-broiled flanks of the great gorge.

For two days we pursue a treacherous path down barren brown walls, smashing toenails against boot tips. At times a misstep would be fatal; often the trail is loose rock, and even the burros stumble. But late on the second afternoon we land intact at Hacienda Canco, a tiny oasis on the canyon floor, home to five Indian families. Corn, wheat, and cane wave in a soft breeze; bright red chilies dry in the sun. Exhausted, we pitch camp in a pasture by the Colca. A rock wall rises from the far side; twice in the night I bolt awake, startled by the boom . . . boom . . . of falling boulders.

At dawn I plunge into the frigid river, shocking myself lucid. I paint myself with lip wax, sunscreen, bug repellent, and lanolin and wriggle into polypropylene long underwear and socks, running shoes, nylon shorts, helmet, and life jacket. Ready for battle, I help inflate our two rafts; then we hoist them up and conga-line it into the Colca.

DAY ONE

I haven't been on water in a long time, and as we slip into the current and Canco disappears behind rock and shadow, I relearn the magic that happens when you join a river, when gray walls rise up and swallow the land you once knew, and suddenly you're committed. The river has you, and if you shift gears and lose yourself just right, you get fooled into thinking you're sitting still and it's the banks that are moving.

But the Colca doesn't allow much room for indulgence. Though it's not a high-volume river, it is extremely rocky and very steep, dropping as much as a hundred feet a mile through the gorge. Flood, avalanche, and earthquake rewrite it every year, and the combination of violent water and unstable geology has littered it with undercut rocks and banks. A man swept into an undercut

Half alert and half asleep, author Joe Kane, at left, and Andrzej Pietowski listen for the crunch and rumble of falling boulders. "These rocks can kill you," says Pietowski. "We had a few close calls at other camps, but here we were able to rest easier."

can easily find himself pinned beneath a rock ceiling, drowning and cut off from help.

The four kayakers, their boats being lighter and more maneuverable, descend each rapid first, then climb the banks carrying long lengths of light rope. The rafts follow. Heavy with supplies, they are more vulnerable to accident, and we must depend on the kayakers to fish out any rafters who get washed into the river. Injuries will be costly: There is no possibility of rescue from the canyon itself.

I work the right-front corner of a raft captained by Piotr from the right rear. Mainly my job is to paddle furiously at his commands

of "Go! Back! Left! Right!" but I am also a shield for most of the waves that hit us. These are many, and I am soaked and cold all day. But I do not complain. When the raft enters a steep drop, it does so slowly, until the nose approaches the bottom. Then the raft slingshots, whipping the tail viciously. Riding in front, I'm wet but secure.

Not so in back. Piotr controls the raft and can anticipate its acceleration, but Johnny Moscarillo, paddling the left rear, rides what is known as the "ejector seat." Johnny's big and strong, and Piotr and I must paddle hard to balance his efforts. Still, he is soon known as "Flying John."

Paddling athwart me is Jacek, whose rich baritone contradicts his small size. Having settled in Wyoming, he chatters constantly in an ersatz heartland slang ("My goodness, guys! Son of a gun!"), and he paddles weakly, which is good because he seems to be paddling some personal trireme unaligned with the rest of us.

Our second raft has Zbigniew paddling at right front opposite dark, young Dariusz. The back-left man is our doctor, Tod. Presiding over this crew is Robin, a white-water genius with an uncanny ability to dance a raft through truly horrible water.

Mostly it's a day of long floats and small, shallow rapids. The rafts snag often on the rocky bottom, inciting much frantic wrestling to free them, but spirits are high. It's about three o'clock in the afternoon, the Colca in shadows, when the Mamacocha River enters from the right, rushing from its gorge in a furious white froth and roaring ominously; though Piotr shouts at the top of his lungs, I must strain to hear him. But we ride the rapid smartly around a bend, whooping as we go, until the water settles into the most crystalline green I believe I have ever seen. "That was a lovely sucker!" Jacek crows. "Gosh!"

We make our first camp at the foot of the rapid, on a sandy white beach blown bug free by a warm wind. Bats wheel in the twilight; a snow-white egret wings urgently upstream. Tod and Robin catch two thick trout and boil them with rice and red chilies while Piotr and Johnny hang three flags on the rock wall behind our camp—Polish, Peruvian, and American. Later, as I drift off to sleep, a fat toad thumps onto my chest in what I choose to consider a spirit of welcome.

At this confluence it's still possible to climb out of the canyon, but from here down we are committed.

DAY TWO

We knew that below the Mamacocha the Colca would start playing hardball, and this morning, an hour after sunrise, we set off in nervous anticipation of our first Class IV rapid —"Gutter," the Poles have named it. Class IV denotes a "technical" rapid, one that demands skillful paddling. Class V is considered the upper limit of runnable water, where technical failures have mortal consequences. As a whole, the Colca, chockablock with fours and fives and without possibility of rescue, is considered a Class VI run.

"Some rivers just scare you," Johnny said. "There's one in West Virginia, the Cheat. I've run more difficult water, but there's something about the Cheat that I'm really afraid of. I can't explain it. But this river doesn't feel that way." He looked around. "At least not yet."

Is he blind? The gorge is undeniably beautiful, but it's a shattered beauty, chaotic and volatile: Its tone is one of imminent destruction, of a place in constant collapse. Here a fallen knife-edged boulder sits embedded in a patch of sand like a dud missile; there six tons of sandstone perch improbably atop a thin spire.

"When we came here in '81," Piotr said, "we were *scared*. Two times we tried to climb out, but we could not. We see all these landslides around us and we think" (he put a finger to his temple) "we think we are *crazy* to be here."

Soon I heard a low rumble. More accurately, I felt it. It vibrated up from the river, through the raft's rubber skin and into my bones, inspiring a sudden urgency in my bladder. We beached the boats and scrambled downstream along the bank, slipping and slicing shins on the rocks, to find the entire river squeezed through one massive chute. It careered between house-size boulders, then dumped into a "hole," a savage vortex of churning water.

"Have a nice day!" Jacek shouted to me above the roar.

The only thing I remember clearly about running Gutter Rapid is that at some point I had a part of somebody's head in my mouth. Oh, we had picked out a line of attack, of

course. "First we pass this big rock on the right," Piotr had explained from the bank, pointing to the chute. "Then we are left, left, *left hard*, then *straight*, then—no problem!"

That all flew out the door when our raft floor exploded. No one had seen the razor-tipped rock just below the surface. I felt a tickling under my feet as the raft hit the chute and shot over something hard; then there was a sound like a rocket firing, and we went ballistic. I do remember the sensation of being suspended right over the hole, inches from this howling white being that wanted to eat me alive, and somewhere I could hear Piotr screaming "Go-Go-Go-Go!" and Johnny screaming back "We are dead meat!"

And then somehow I was on top of Johnny and the river was on top of us. The raft stood on its side, Piotr yelling "Up-Up-Up!" and we climbed the high side to force it down; then we walloped something head-on, and I was on my way out the front end. But then suddenly the world decelerated and there we were, floating in smooth calm water laughing like hyenas.

Hours later, as I make these notes, my head still rumbles, but only a swallow's squeal pierces the predawn peace of our second camp. At the foot of my sleeping bag, candlelight dances off otter scat laced with shrimp shell. Nearby a shadow stirs: Tod awakens to find a sharp, fist-size rock about five feet from his bag, planted in a spot that last night was only sand. The boulder next to him displays a fresh white gouge two feet above his head.

DAY FOUR

Piotr believes the river has changed greatly since 1985. There are many new rapids, he says, and most of the old runs are reconfigured. We're never quite sure where we are. Yesterday he identified a broad bend as an old campsite, Silent Lake, but late today we

Losing his grip in a 12-foot plunge, team physician Tod Gulick is flipped into a thrashing rapid. "I was waiting for some excitement," jokes the former fighter pilot. "I finally found it."

Fighting to save the raft from a giant hole, Chmielinski, at right, reaches for help. "We got stuck and

lost our sense of direction," he says. "The raft was tipping over. I had to grab that rescue line."

passed what he recognized as the actual place.

Our situation is further complicated by an intestinal virus that has infected half the team and by a limited food supply. Cold and wet the day through, working hard, we are burning calories vigorously, and though our dinners are substantial, our lunches are not: today, two slices of salami, two pieces of stale bread, a handful of raisins, a granola bar.

As we push farther into the gorge, the rock grows harder: less sandstone, more limestone, some granite. The walls, more erosion resistant, are steeper, the canyon narrower, the rapids bigger. Today we ran a four, a four-plus, and our first five, Landslide, the river bouncing along beneath a five-story carpet of dun scree that may have tumbled down centuries ago, or yesterday.

Readying to run it, I looked downstream to see Jerome high on a boulder, rescue ropes in hand. Jerome inspires confidence. Our lead man, his face is a mask of calm in even the worst circumstances, and he has yet to make a mistake. Morna too is an inspiration. She's tiny, but she's powerful and skilled and unafraid to plunge into the heart of a rapid, to challenge the big water. Half the team has a crush on her; the rest are fully in love.

Duilio usually runs third through the rapids. Raised in Peru, which has few kayakers, he taught himself on boats that the Poles left with his family six years ago. His technique is raw: He fights the river as often as he makes it work for him, needing ten hard strokes where Jerome uses two. Still, he shouts with exultation after each difficult run. His joy is infectious.

Andrzej generally goes fourth. His history on the Colca commands respect, but he's 37 and has paddled only once in the last year. He's already nervous about Reparaz, which we won't reach for a few days, and today he alone portaged Landslide. "He once had a very bad experience here," Jacek said. "He got trapped and had to make a wet exit from his boat. For a long time all we could see were his legs sticking up in the air. He really got beat up, God knows."

At first we didn't handle Landslide all that well ourselves. We brushed a boulder on the approach, spun halfway around, and hit the chute broadside. A head wind pushed us slightly left, and suddenly we were boring in on a Class V hole: mortal consequences.

To rein in my panic, I concentrated on paddling steadily rather than frantically ("If you do take a swim and go into a hole," Jerome had advised, "you don't want to be out of breath"), and under Piotr's direction we got our nose pointing downstream in time to punch through the hole. We roller-coastered along head-high waves and cruised into the pool below as wet and happy as ducks.

"Great, guys!" Piotr yelled, and we slapped high fives. But what I found myself reveling in was not so much the fine run as a kind of peace: The discipline of running rapids forces my attention to the moment. The Colca's gurgle and gush, never absent, have become like an inner voice.

We advanced only one mile today; forty-some remain.

DAY SIX

For two days now we have run hard, battling eight major rapids, and this afternoon we quit early. We are tired, and to continue would be foolhardy. We have scouted ahead to find three Brobdingnagian rapids back-to-back-to-back; they are easily our biggest yet.

We are camped a hundred yards above the first, Canoandes. It was named by the Poles for their first expedition. The rapid drops at least 20 feet and is really two waterfalls. It boils with a thunder that even here is overwhelming. It's hard to relax.

Before dinner Piotr visited each of us, quietly checking health and attitude. "I would like to have run these rapids before I went to bed," he told me. "I don't want to dream about them."

We have reached the belly of the gorge. The walls are so high that at times they seem to close overhead, and today a bend in the river revealed the entire north face rising to a peak, 14,300 feet of vertical rock. The air is dry, the landscape parched (I have not seen a tree since Canco), and as we ate dinner, a boulder cascaded down the far wall, setting off dusty explosions each time it hit. A powdered cloud settled over our camp, coating my chicken à la king with a gritty film.

The last rays of sun hit the upper ramparts about five o'clock; by seven the canyon is absolutely black. Last night I was asleep at half past, only to be jerked awake, as if by a spotlight shining on my face, when the full moon rose over the southern rim. Bathed in silver, the canyon was as bright as dawn. I wrote by moonlight. Now I do the same, until I hear a voice a few yards to my left.

"I am just so happy when I am here," Andrzej murmurs. He's propped up in his bag, leaning against a rock. "No matter how crazy life gets—and I tell you, I live in Manhattan, I know crazy—always in my mind I am coming back to the Colca."

"Does the river scare you?" I ask.

"Of course. The water is deceptive. It's so much more powerful than it looks. It would be foolish not to be afraid."

DAY SEVEN

I must report that we did not run Canoandes quite as we had planned. The kayakers handled the rapid safely, Morna executing a nifty Eskimo roll to extract herself from the bad hole, but taking rafts over waterfalls is a very different exercise altogether.

Basically we went over the falls completely out of control and the raft hit the hole and stuck, pounded into place by the full force of the river. It bucked wildly and for a brief second stood me straight up. Then something sucked the legs out from under me. I struggled to keep my balance but lost and went right over the side.

For two months before this trip I'd gone swimming every day, anticipating just such a moment. I'd forced myself to swim underwater till I knew I'd pass out, then swam two strokes more, trying to tame the constricted panic of drowning. I never succeeded, and as I went underwater at Canoandes, I relived that terror. It was like one of those stomach-churning carnival rides, but with no guarantee it would stop. I whirled and spun. I went limp; no use fighting it. I waited. And

Cuts, torn toenails, blisters, and biting flies plagued Robin Moore's feet (left). "The flies were tiny, but they packed a mean sting," he says. Sharp rocks ripped a three-foot gash in Chmielinski's raft (above), which took him half the day to dry out and patch.

I waited. And I waited, helpless, while the river beat me at will.

Then, for no apparent reason: Air!

A rescue line floated on the surface. I grabbed it and found a grinning Andrzej hauling me up to a boulder.

"Welcome, Mr. Trout!"

Duilio had taken Jacek's place for this run, and he and Piotr were still in the raft, clutching grimly to rescue lines thrown by Jerome and Morna. The raft itself was still leaping insanely in the hole, threatening to flip. It took 15 minutes of yanking and bouncing to break it free.

Flying John, meanwhile, had washed downstream. He too had come up to a rescue line, but, unlike mine, his had nobody on the other end. Scant yards above the next rapid he managed to swim to a safe eddy, and we retrieved him as we passed. "In actuality," he reported, "I was once again dead meat."

I admire Johnny's stamina. Most of the muscle work has fallen to him, particularly the dangerous job of tethering the raft from shore when we send it through a rapid unmanned—"lining," as it's known. And this afternoon he swam again, in another Class V, but when we stopped to collect ourselves, he seemed unfazed. Not me. Soaked all day, running in shadow, low on calories, I was on the verge of hypothermia. By the time we made camp at Condor Falls, an hour later, my teeth were chattering uncontrollably. They didn't stop until I'd wrapped myself in my sleeping bag. I now sit sipping tea, finally warm enough to use a pen, and grateful to be alive.

DAY NINE

We are camped 200 yards above the penultimate piece of the Colca puzzle, Reparaz Canyon. We cannot scout it at ground level—the walls are too steep and too fragile—but we have climbing rope with us, and Piotr hopes to scale the cliffs tomorrow morning to get a view.

For the last two days, thoughts of Reparaz have obsessed us. Piotr, Duilio, Andrzej, Zbigniew, and Jacek have been through it, and they say that missing any of its three highly technical rapids leaves one at the mercy of a truly awful hole at the bottom—as Duilio learned painfully the year before. Tempers have been short and not improved by our rations: Today lunch was just four crackers and a sardine. Most of us are now hungry all the time, though Tod and Robin have been supplementing our meager supplies with trout, which we bake unadorned atop hot rocks from our campfire.

With each day this landscape grows more aggressive: It jumps out at you. Every bend unveils a towering view of one wall or the other and with it the sensation of living rock launching itself skyward. It is impossible not to think of the canyon as a being, impossible also to fathom its intent.

We need no further reminders of the consequences of lapsed attention. Yesterday Piotr, Johnny, and I attempted to run a short falls and got so screwed up we ran it backward. Following us, Raft Two went sideways and shot Captain Moore into the drink. He was cursing loudly as he went, directing his vitriol at Dariusz, who was not paddling as hard as the rest of the crew. Reparaz will tolerate no such mistakes.

Tonight we camp amid small sulfur pools, the air thick with biting bugs and the stink of rotten eggs.

DAY TEN

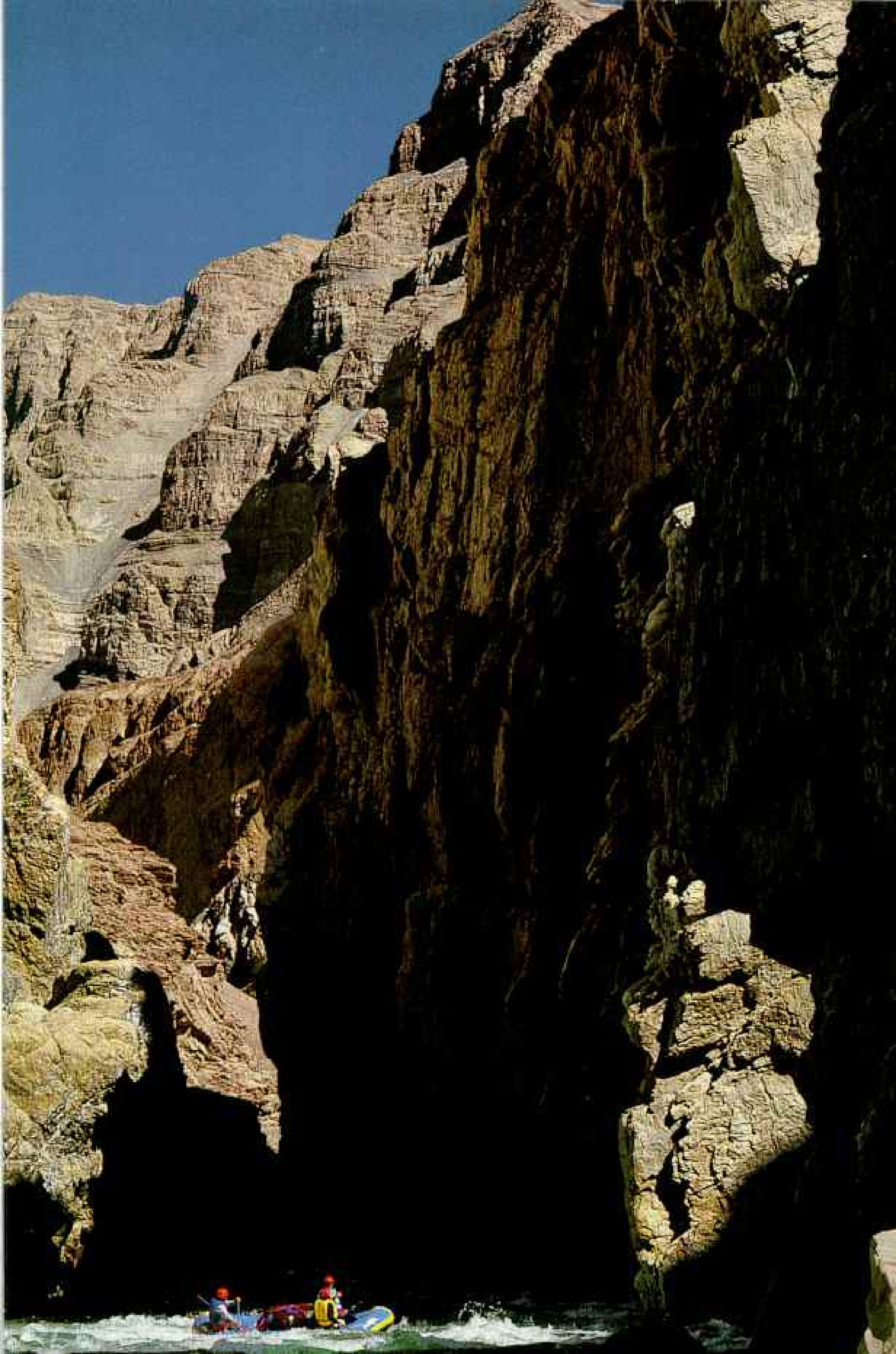
"Running the big rapids is like sex," the late Ed Abbey once wrote. "Half the fun lies in the anticipation. Two-thirds of the thrill comes with the approach. The remainder is only ecstasy—or darkness." Right now I'd take either of those.

Anticipation is half the fun only if your idea of fun is being wound up tighter than a two-dollar watch. For most of the last seven hours I have been sitting on the beached raft, waiting to run Reparaz, and I am now ready to chew granite, if that would get my mind off the rapids.

Piotr, Andrzej, and Duilio spent the morning setting up ropes, which the rest of us used to see what we could of Reparaz. (Not much: five turns, lots of white, lots of rock.) Then we trooped back upstream and waited. For Piotr, still climbing somewhere. For Jacek and Zbigniew to arrange their camera gear.

Beautiful and barren, Colca Canyon's walls support little life. "All I could think of when we started was getting out," says Chmielinski. "At the end all I could think of was going back."

JACEK BIEGUCKI



For the kayakers to make their run.

Still we wait. In one hour it will be too dark to go.

Now I see Piotr: His red helmet bobs and weaves among the boulders as he picks his way upstream. He arrives, smiles, says, "Robin's raft will go first."

Dariusz, so castigated yesterday, bravely extends a hand to Robin: "I am ready, Captain." They climb aboard, check helmets and life jackets. And as they move out to Robin's low, rolling "Allll fooorrrrr-waaarrd!" it appears that his anger has borne fruit. Dariusz is stroking mightily, in perfect sync.

We sit in silence, watching Raft Two disappear into the gate as if swallowed by the mammoth boulders. We wait 15 minutes. Then Piotr says, softly, "OK, guys." I pack up my notebook, and we are off.

DAY ELEVEN

In the end we ran those damn Reparaz rapids in less than a minute.

Frankly, it was a blur. I can't remember the drops, can't remember much of anything save the brief explosion of white as we spun sideways into the second chute and I felt myself being launched. Then I got yanked back in, and we burst through a wall of foam and into the promised land.

"Hey!" Robin said when we caught up with them. "It's just water and rock!"

We weren't out of the Colca, but an air of triumph filled the camp last night. For Duilio, certainly; he ran Reparaz intact, pulling the nail ("Now I am free!"). And young Dariusz proved himself: "Robeen!" I heard him exclaim to Captain Moore. "Thank!"

And now, finally, Poles' Canyon, a Class VI rapid that sits like a cork in the mouth of the gorge. It's a narrow, thunderous maze of undercut rock and crisscrossing currents—in short, a death trap—and we have spent most of the day portaging our gear along the north wall, forming a line to haul bags, winching the rafts along the ramparts with Robin's clever system of ropes and pulleys before lowering them into the river.

But two-thirds of the way down we ran out of portaging room and now have no choice but to run the rest of the rapid. I'm squatting on a thin rock ledge above the raft. We've maneuvered the raft to face downstream; the river rages inches from its bow. Piotr, Johnny, Jacek, and I have already sent our teammates on their way, and now they are out of sight, 600 yards below us. Should we launch more than two feet off course, we will be thrashed to a watery grave.

It comes down to this: six strokes. Execute them correctly, we're home free; make a mistake, we're dead. I'm terrified. Even the portage, shimmying along sheer faces directly above the torrents, was unnerving. But . . . but. In truth there's nowhere else I'd rather be. If we make it, yes, there will be sweet memories. The bonds of friendship will draw even tighter, and as old men we will meet and drink beer and say, "Remember the Colca?" But it's more than that, much more. I can no longer tell the sound of my own breath from the roar of the river. This rogue canyon has pushed and prodded and pounded me until I understand eternal secrets: Rock lives. Water lives. Earth lives.

If soon I die—so? In this moment I am fully alive, alive forever.

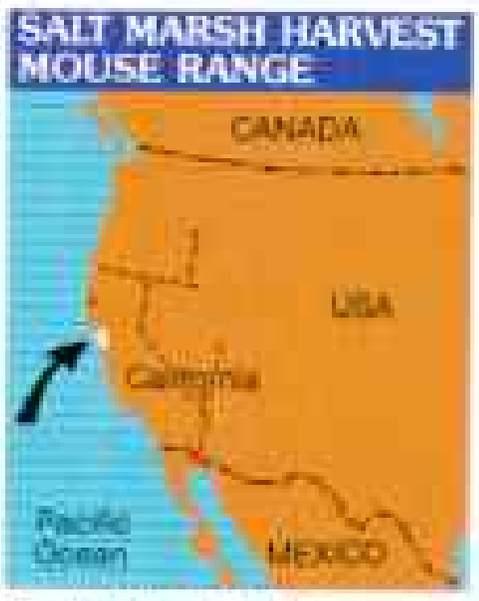
We line up and load our equipment, then take our positions. I go first, jamming myself down onto the tube. As each man joins me, I hand him a paddle. Piotr is last. Standing on a boulder four feet above us, he quickly releases the stern line. He holds the raft against the current but scant seconds, then leaps aboard, shouting "Go forward! Hard, guys!"

All is white. We glance off a boulder, twist, straighten out. We race through white toward a long green tongue. I look up: Far downriver I see walls pulling back and sunlight touching water; I see safe passage home from this glorious, wrecked place.

IT HAS BEEN A WHILE now since I last saw the Colca. The news reports from Peru, such as they are, continue to suggest a torn and violent nation, and I'm sure that that raw canyon remains an isolated and all-but-unknown jewel. The villagers of Canco still spread their chilies in the sun to dry, and boulders still thunder unheard down those great walls.

Meanwhile, awakened at a ridiculous hour by the squeals of someone newly born, I see that the moon has once again come full. Here in San Francisco it shines not on condors and eagles but on jays and pigeons, and these days I ride not a careening raft but a rusting sedan. But I sometimes find that if I sit quietly, I can conjure an oddly comforting gush and roar: the voice of the Colca, timeless and utterly wild. □

WILDLIFE AS CANON SEES IT



Salt Marsh Harvest Mouse
Genus: *Reithrodontomys*
Species: *raviventris*
Adult size: Length, 7 cm
Adult weight: 9 g
Habitat: Salt marshes in the San Francisco Bay area of California, USA
Surviving number: Less than 2,000
Photographed by B. "Moose" Peterson

To escape the winter high tide, this salt marsh harvest mouse has moved to a higher location in its home amidst the pickleweed. Usually hidden below, the tiny mouse is clearly visible and now vulnerable to predatory birds as it nibbles on the succulent pickleweed. But the main threat to the mouse is the loss of wetland habitat, over 80% of which is already gone. To save endangered species, it is essential to protect their habitats and understand the vital role of each species within the earth's ecosystems. Photography, both as a scientific research tool and as a means of communication, can help promote a greater awareness and understanding of the salt marsh harvest mouse and our entire wildlife heritage.

Report from the President

LAUREN GREENFIELD

Water for Our Future: A New Society Initiative

Planet Earth faces a water crisis. Our freshwater supply is being used faster than nature can replenish it.

I am reminded of the great energy crisis of the early 1970s. Had we been prepared, that crunch might never have happened.

But the threat to fresh water is an even bigger issue. Unlike oil, there is no water alternative. This time, we simply cannot wait for a crisis. So beginning this month, the Society launches a multiyear program examining the state of our fresh water.

We call our effort the "Geography of Fresh Water: A National Geographic Initiative."

Just one percent of the world's water is available and fresh, yet we guzzle it shamelessly: Despite California's drought woes, some areas of the semiarid state are deliberately flooded to grow rice.

At the same time, rapid growth in the Southeast pushes water supplies to the limit, and farm-belt groundwater levels are dropping. Over the past decade from the High Plains Ogallala aquifer we have reduced reserves by an amount equal to the volume of Florida's 730-square-mile Lake Okeechobee.

The 30-foot limestone columns of northern California's Mono Lake are monuments to our unquenchable thirst, as teachers learned during a recent water workshop organized by the Society's Geography Education Program (above). The columns were uncovered as Los Angeles, 300 miles to the south, siphoned off Mono's water sources.

Water use is also a global issue. When one nation dams a river for irrigation, for example, nations downstream can suffer devastating consequences.

We feel that an informed public is the best start for using fresh water wisely. That belief is shared by the Conservation Fund and the United States Geological Survey, our invaluable partners in this effort.

In an unprecedented coordination of all our resources, over the coming months every arm of the Society will explore this one vital topic:

- A special 13th GEOGRAPHIC issue in November will focus on water use, quality, and conservation.
- A November Television Special on PBS will include sequences about the Colorado River, Great Lakes, Columbia River, and Everglades.
- EXPLORER TV program segments will address water issues.
- A new classroom film will teach students how to conserve water.
- WORLD and TRAVELER magazines will both feature freshwater themes.
- With support from the Seaver Institute we have granted $360,000 for freshwater studies, which will be highlighted in a special issue of RESEARCH & EXPLORATION, our scholarly journal.

In addition, nearly a hundred teachers attended our "Workshop on Water" in California and Nevada last summer—thanks to grants from the W. K. Kellogg Foundation, Kraft General Foods, and Chevron.

In the coming years we will be doing all we can to educate and inform our members on the status of this most precious resource.

Gilbert M. Grosvenor

National Geographic, January 1993

Forum

Dolphins in Crisis

Last June I visited the Amazonian port city of Manaus and often saw *botos*, river dolphins described in your September 1992 issue. Some area people believe these animals represent sexual potency, that the male dolphin can transform itself into human form and seduce unsuspecting women. This superstition is used to explain unexpected pregnancies. I was told that dried parts, especially eyes, are considered aphrodisiacs; I inquired at a stall selling medicines at the city market and the proprietor produced a bagful of dolphin eyes for sale.

PETER PRINEAS
New York, New York

You report on Randy Wells, a 20-year student of dolphins in the wild. He is now spearheading the effort to build a facility at Sarasota, Florida, for the rescue, rehabilitation, and release of stranded dolphins, whales, and manatees. Medical pools and a lagoon will be constructed on 3.5 acres donated by the city at Mote Marine Laboratory. Focused on research and education, the 3.3-million-dollar facility will be built over a five-year period.

KERRY KIRSCHNER
Mote Marine Laboratory
Sarasota, Florida

Living in the Chicago area, I am lucky to have several places to visit where I can observe dolphins and other marine mammals to learn more about them. But where can I find out about the groups that Denise Herzing takes to observe the spotted dolphins in the Bahamas?

DAVID J. HAWKSWORTH
Mundelein, Illinois

You can write to Dr. Herzing in care of the Wild Dolphin Project, 21 Hepburn Avenue, Suite 20, Jupiter, Florida 33458.

I can attest to the problem author Kenneth Norris observes—the proliferation of plastic in oceans. I crossed the Pacific between the West Coast and Hawaii 13 times between 1966 and 1987, often in small vessels. Being close to the water affords an intimacy with the ocean that is missing with larger vessels. The situation has deteriorated from occasional clumps of flotsam and jetsam to virtual blankets of barnacle clusters, each with a piece of plastic at its core.

TOM CARR
Watsonville, California

We represent sportfishermen who set nets around Banks Peninsula in New Zealand's South Island. We are disturbed by the caption (page 17) about an entangled Hector's dolphin, which states that these dolphins are caught in sport gill nets. Nearly all such entanglements were in commercial nets.

BERNARD R. WALKER
Set Net Action Group
Christchurch, New Zealand

Pushkin

The article credits the poet with being liberal, yet one line shows him "empire proud, defending Russia's harsh suppression of a Polish uprising in 1830-31." If Pushkin was truly a liberal, I do not think he would have defended the suppression of any ethnic group inside or outside the Russian Empire.

LISA A. MIERZEJEWSKI
Middletown, Connecticut

Leafing through the September issue before settling down to serious reading, I came to page 60 and the first four lines of the poem dated 1821. Having just lost a very special person, I finally understood. I shall read more Pushkin.

JILL POOLEY
Waterloo, Ontario

Dostoyevsky, the psychological master, held Pushkin in the highest esteem. His four major works are dotted with Pushkin quotes and allusions. The speech that he delivered upon the dedication of the Pushkin memorial was the most famous public tribute Dostoyevsky ever offered. In your delightful and informative sketch, a photograph of that Pushkin monument was conspicuously absent.

STEPHEN E. SWOYER, JR.
Hatboro, Pennsylvania

African Slave Trade

Colin Palmer has managed to write about the painful subject of the European slave trade in Africa with passion, compassion, and objectivity. As one urban black professional in the story put it, "As a people, we cannot be prisoners of the past." Maybe we could all—black, white, and brown—take our cue from Palmer the next time we talk about modern race relations. A little more objectivity and compassion might just enable us to throw off our shackles together.

JESSICA GRIESS-WRIGHT
Stanford, California

The excellent article on the slave trade confirms the fact that without the cooperation of the African natives themselves, slavery could never have expanded into a widespread industry and institution. The logistics of slavery depended on animosities among various African groups. When they

battled one another, the winners either killed the losers or sold them to slave traders.

TOM MUSSER
Mexico City, Mexico

On page 88 the little girl is sitting in front of a portrait not of Toussaint Louverture, but of Gen. Jean-Jacques Dessalines, one of Toussaint's lieutenants. After the capture of Toussaint by the French, Dessalines led the Haitians to final victory and proclaimed the nation independent on January 1, 1804. He was Haiti's first head of state.

EDNER PIERRE-LOUIS
New York, New York

A substantial traffic in kidnapped Africans continued into the United States right up to the Civil War. Estimates of the number of illegal laborers so transported between 1808 [when the U. S. slave trade was outlawed] and 1861 range from 54,000 to as high as a million.

JOHN KNOPE
Lake Oswego, Oregon

Minnesota Lake Country

In 1988 I had the privilege of working for three months in the Chippewa National Forest as part of my forestry study at the agricultural university in Wageningen. Reading this good article brought back beautiful memories. It gave me a chance to prove to friends and family that I didn't exaggerate in describing this lovely country. On the other hand it confirmed my fear of the bad influence of too many people visiting the area—especially as I come from a densely populated country.

HUGO VERNHOUT
Kampen, Netherlands

The article sparked memories of my own childhood. I remember that Lake Rebecca's fish population died out one winter because of a hard freeze. The lake was considered "dead" and became unfit even for swimming. Through years of work it was brought back to life and with others outside the Twin Cities has been set aside as a state park reserve. It harbors one of the few sanctuaries of the endangered trumpeter swan.

JOE KOECHER
Burbank, California

In 1989, at age 70, I returned to visit the region near Detroit Lakes. As children at the lakes we were taught to pick up after ourselves and after everyone else. Not true any more. I also found that trees had been cut to make room for more cabins. It was one of the saddest days of my life to realize what man has done to these wonderful places. People may have made progress but have sacrificed much.

BETH ABEL
Oklahoma City, Oklahoma

My father grew up in Brainerd. Every summer we headed up north. My earliest vacation memories are of my cousins' cabin on Perch Lake. Later our family of seven progressed to a tent of our own and finally to a camper trailer. Years later I made a pilgrimage with my own children. For a week they tried their hands at fishing for sunnies, swimming with loons, and sleeping on the ground in a tent. We all shed tears when it was time to go. The magic of the lakes lives on.

BRENDA FITZGERALD
Alabaster, Alabama

Cacaxtla Murals

I was very much interested in the developments at Cacaxtla since I last saw the murals, some years ago. An additional note on the history of the discovery: Information of the clandestine dig was brought one night by a local schoolteacher to Peter J. Schmidt, resident archaeologist of the German Proyecto Puebla-Tlaxcala in Puebla. Schmidt rushed that same night to the site and arranged for the guarding of the trench. He later did the first excavations there before the site was put directly under the management of Mexico's National Institute of Anthropology and History.

WOLFGANG HABERLAND
Ahrensburg, Germany

The photograph of the captain's sacrificial death scene shows a small round object on each of ten leg bands (page 132). These closely resemble the metal bells from the Platanito archaeological site, about 500 miles north of Cacaxtla, as reported in *Science*, August 28, 1992.

KAY COOPER
Trenton, New Jersey

On Television

The September "On Television" page mentions a chimp called Koko, chained to the basement floor of a private residence before being rescued by Primarily Primates. Please assure readers that this is not the gorilla Koko, whose use of sign language has been featured in the GEOGRAPHIC.

FRANCINE PATTERSON
President, Gorilla Foundation
Woodside, California

Forum

In the August issue a letter mentions the odor of Gilman's paper mill intruding on the pleasure of a Cumberland Island tour. Gilman has recently installed a 30-million-dollar system to remove this odor, so there will no longer be cause for concern.

WILLIAM H. DAVIS
President, Gilman Paper Company
St. Marys, Georgia

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

Geographica

WILLIAM D. BOUTWELL (ABOVE LEFT); MARK THIESSEN

Rediscovering the Wagon in a GEOGRAPHIC Photo

An eight-year-old Virginian, Franklin Zirkle, peers from under the cover of his family's Conestoga wagon, his five-year-old sister beside him and his nine-year-old brother pointing out the wagon's toolbox. The image (above) appeared in the April 1929 issue of NATIONAL GEOGRAPHIC.

A decade later their mother sold the 1810-vintage freight hauler; it was then taken to an exhibit at the 1939 World's Fair in New York City. Franklin Zirkle never saw it again until last year—in Colonial Williamsburg, where it has been displayed since 1959.

Zirkle learned of its whereabouts by chance. When Ron Vineyard, master of Colonial Williamsburg's wheelwright shop, came across a report in a Roanoke, Virginia, library that Zirkle had written about the vehicle's history, he called its author, now 72 (above right). They met and exchanged photographs of the wagon, and Zirkle soon visited Williamsburg. "It was his wagon," Vineyard says. "There was no doubt about it." If there were, Zirkle provided proof when Vineyard told him he couldn't unlatch the toolbox. Zirkle pointed out a metal heart on the front. "Move it to the right half an inch," he urged. Vineyard did; the latch opened.

Peary's Greenland Map Signed by a Few Friends

Robert E. Peary sketched this early map of northern Greenland (below) after his 1900 expedition. He had reached the northernmost point of Greenland and proved that it was an island. He tucked this chart of Peary Land into his report to the Peary Arctic Club, a group formed to support his explorations.

Peary had named more than a dozen geographic features after club members and friends, and they were happy to autograph the map. Club president Morris K. Jesup, a businessman and philanthropist, signed next to his namesake, Greenland's northernmost cape. E. W. Bliss, a manufacturer, signed near Bliss Bay. And the President of the United States penned "Theodore Roosevelt" across the Roosevelt Range.

"This map hung in the living room of our home on Eagle Island, Maine, for as long as I can remember," says Peary's son, Robert E., Jr. The family donated the 17-acre island as a state historic site in 1967 but retained the map in its private collection of Peary memorabilia.

ROBERT E. PEARY COLLECTION

National Geographic, January 1993

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Geographica

Is This the Tomb of a Biblical High Priest?

Did this limestone box (below)—from a cave discovered by workers building a water park in Jerusalem—contain the bones of Caiaphas, the high priest who presided over the trial of Jesus?

Zvi Greenhut, a city archaeologist of Jerusalem who excavated the cave and found 12 ossuaries—boxes containing human bones—isn't sure. "It could hold the priest's grandfather, an uncle, or the man himself," declares Greenhut. "But there is no doubt that the ossuary belongs to the family."

Ossuaries like this were used by wealthy Jewish families from the first century B.C. to A.D. 70, the late Second Temple period. Graffiti-like inscriptions in Hebrew on this box and a less ornate one include the name "Qafa," the Aramaic form of Caiaphas. The elaborate ossuary held the bones of six people, one a male 60 years old, which is about the right age for the high priest.

The Gospels mentioned Caiaphas, and the first-century Jewish historian Josephus wrote of "Joseph who was called Caiaphas." One inscription on this ossuary reads: "Joseph, son of Caiaphas."

BRUCE COLEMAN, BRUCE COLEMAN, INC.

GARO NALBANDIAN

A Flower-power Attack on Malarial Mosquitoes

Gardeners have long valued marigolds to ward off plant-nibbling insects. Now a team of Canadian scientists has enlisted the humble flower in the war on malaria, which each year kills more than a million people worldwide.

Using alpha terthienyl, a substance produced by the marigold that is harmful to insects, plant biologists devised an insecticide to spray on ponds and swamps where the malaria-carrying mosquitoes breed. When activated by light, it destroys mosquito larvae.

"Basically, it barbecues them," says team leader John Arnason of the University of Ottawa.

Many insects have become resistant to synthetic chemical insecticides. The Canadian scientists are experimenting with other insect-repelling plants to create new biologically based insecticides.

WORLD WIDE FUND FOR NATURE

Puzzles of Vietnam's "Lost World"

"It's a little lost corner of the world, cut off from development and exploration, filled with the new and unexpected." That's how John MacKinnon of the World Wildlife Fund describes Vu Quang Nature Reserve in central Vietnam.

When he and Vietnamese scientists surveyed the reserve last spring, they counted 62 species of fish, 37 kinds of reptiles, and more than 200 species of birds, including the laughing thrush, previously seen only along the Vietnamese border with China, hundreds of miles away. But some birds common to Southeast Asia, like the spangled drongo and the black-crested bulbul, were strangely absent.

Most curious of all, however, was evidence of a horned mammal, perhaps a completely unknown species, that local people call a forest goat.

"They showed us three partial skulls, just the front of the head with no teeth," says the British biologist (above). "The horns are smooth, not ribbed as in most goats, and their parallel form is unusual too." He has sent hair and skin samples to specialists for DNA analysis. He also hopes to return to film live specimens.

—Boris Weintraub

National Geographic, January 1993

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On Television

BOTH BY JOHN LUCEY

Reenactments Bring Alive Archaeology's Lost Maya

Infused with divine majesty, the Maya king stands on a stone terrace while his people crowd the ceremonial plaza (above), as reenacted in a new National Geographic Special on PBS TV.

With his queen at his side, he performs a most sacred rite. Gripping a stingray-spine lancet—representing the Perforator God—he pierces his foreskin, releasing royal blood onto thick paper strips. The saturated paper is burned, and in the swirling smoke appear visions of gods and ancestors.

Bloodletting and the vision quest were at the heart of Maya civilization, which thrived from A.D. 250 to 900 in fabulous city-states scattered throughout southeastern Mexico and northern Central America.

Two-time Emmy-winner Christine Weber, producer of the Special, "Lost Kingdoms of the Maya," recalls that the powerful rituals stir souls even today. "Our extras, a team of Mexican ballplayers, told me that when the 'Maya king' appeared, they felt awed."

Archaeologists are not immune to awe either, as Ricardo Agurcia Fasquelle, a co-director of the Copán Acropolis Archaeological Project, found when he unearthed before the TV cameras a cache of unique 1,300-year-old chert silhouettes—"eccentric flints" of extraordinary mystical significance and artistic imagination.

Artistic ingenuity inspired art director Yeorgos Lampathakis, who was in charge of the theatrical representations of original Maya clothing. He confides that the queen's headdress (left), based on an eighth-century carving from Yaxchilán, Mexico, is built atop a baseball cap.

Society-wide projects that bring the Maya to life include a video, a book, and articles in WORLD, TRAVELER, and NATIONAL GEOGRAPHIC.

"Lost Kingdoms of the Maya," Special on PBS TV, January 20, 1993. For information on Maya-related Society projects, call 1-800-638-4077.

Geoguide

PTERANODON INGENS (LEFT), A FLYING REPTILE WHOSE WINGSPAN WOULD DWARF THAT OF TODAY'S LARGEST BIRDS, GAZED DOWN ON DINOSAURS DURING THE LATE MESOZOIC ERA. SOME 70 MILLION YEARS LATER, SCOUTS TAKE AN OVERNIGHT SAFARI AT PHILADELPHIA'S ACADEMY OF NATURAL SCIENCES (BELOW). AFTER AN EVENING OF MUSEUM ACTIVITIES, THEY CAMP BENEATH THE SKELETAL CAST OF FEROCIOUS *TYRANNOSAURUS REX*.

AGE OF Dinosaurs

No human being has ever seen a live dinosaur. Yet we know much about these long-extinct animals descended from even more ancient reptiles. How do we know? We have learned about them from fossilized bones, teeth, footprints, and eggshells. Comparing such fossil clues with today's animals gives scientists a good idea of the dinosaurs' size—from 100-ton giants to delicate 20-pound creatures—and of how they ate, moved, protected themselves, and cared for their young.

Children can be encouraged to ask the same kind of questions paleontologists ask. First, bury clean bones from a cooked chicken or turkey in a box of sand or soil—without revealing the animal's identity. Break a larger bone to add a challenge. Then ask the child to use toothpicks, a small paintbrush, and imagination to do the following:

- Unearth and clean the bones. Blow through a straw to remove debris from the bones.
- Assemble the skeleton on a flat surface. Do you have all the bones? What kind of animal was it? How can you tell?
- Try to draw a picture of the whole animal. Can you tell its shape? Did it walk? Fly? Is there any way to tell whether it had fur or feathers? Or what its color was?
- Look at the supplement map. Have dinosaurs been discovered near you? If you were to look for fossils, in which province or state would you begin? Why?

LOUIE PSIHOYOS; PAINTING BY JOHN SIBBICK

USE THIS GEOGUIDE PAGE ALONG WITH THE ARTICLE AND MAP SUPPLEMENT ON DINOSAURS IN THIS ISSUE TO HELP CAPTURE THE INTEREST OF YOUNG READERS AND STIMULATE DISCUSSION WITH THEM. GEOGUIDE IS PUBLISHED FOUR TIMES A YEAR.

Earth Almanac

TOSHIHIDE HIRAMOTO

Animals Heal Themselves With Nature's Pharmacy

Why do dogs and cats eat grass? Probably to purge themselves of tainted food. Likewise, wild animals medicate themselves with certain plants of the world's rain forests. And such behavior is leading scientists to study the same plants, partly because this natural pharmacopoeia may also benefit mankind—if destruction of rain forests can be slowed.

In Tanzania a chimpanzee seeks out a plant of the spiderwort family (above); instead of chewing the leaves, it swallows them whole. Harvard University anthropologist Richard Wrangham suspects the purpose to be medicinal, because chimps eat another plant, *Aspilia*, the same way. *Aspilia* contains a red oil called thiarubrine-A, which is very potent against bacteria, fungi, and parasites, according to Eloy Rodriguez of the University of California at Irvine. He believes that swallowing the leaves without chewing allows most of the medication to be released in the intestines where the parasites are found.

Chimps select such plants, even though they provide few nutrients. But other animals get food along with a taste of their own medicine, researchers are finding. In Ethiopia baboons eat a fruit containing an agent that attacks parasites. In Brazil the fertility of muriqui monkeys may be linked to the plants they eat at certain times of the year. And in Costa Rica howler monkeys even eat different plants that may determine the sex of their offspring.

Mountain of Trash—Fuji, Japan's Sacred Peak

"He who climbs Fuji once is a wise man; he who climbs it twice is a fool," goes a Japanese saying. For centuries pilgrims have ascended 12,389-foot Mount Fuji. Now even as its slopes are scarred by erosion and defiled by tons of garbage, planners seek to accommodate more people.

For years climbers ascended the entire route on foot. But in 1964 a road was paved to the halfway point, where souvenir shops now are rampant. In 1991, 3.5 million people drove there; about 270,481 went on to climb the mountain.

KAREN KASMAUSKI, MATRIX

GEORGE F. MOBLEY, NGS

The price has been steep. More than 40,000 trees have died, many of them from air pollution. The local government has replanted many and proposes to deal with increased congestion by building a new three-story parking garage—a move opposed by conservationists.

National Geographic, January 1993

Earth Almanac

A Plan With Teeth to Curb Shark Overfishing

Sharks worldwide have been decimated by a feeding frenzy of fishermen. But in the U. S. a new management plan will soon set quotas that will halve 1991's staggering catch of 3.2 million sharks in the Atlantic and Gulf of Mexico. Laws will protect 39 species, including coastal sharks such as the tiger and lemon and deepwater varieties like the mako.

Mutilation by slicing off fins, then releasing the sharks, will also be tightly controlled. With the Arabian Sea and Nigerian and Mexican waters all but fished out, suppliers are turning to the U. S. population just for the fins, which can bring more than $20 a pound for shark-fin soup. "What you don't want is a big tiger shark to survive without fins, lie starving on the bottom, move into shallow water, and attack a human," says Mike Justen of the National Marine Fisheries Service.

ALEX WEBB, MAGNUM

Gnawing North America: The Beaver Strikes Back

Trapped nearly to extinction a century ago, beavers have staged a triumphant comeback. So much so that in the United States and Canada farmers and homeowners are gnashing their teeth when beavers mow down trees and their dams flood crops, block waterways, and back up sewers.

"There may be six to ten million beavers in Canada," says Milan Novak of Ontario's Ministry of Natural Resources. Although the primary beaver-control agent is still the trapper, few now make the effort, because pelts bring only about $15, a result of a decrease in consumer demand.

In the U. S., beavered by at least two million of the rodents, 34 states seek federal assistance to control damage. One attempt to implant a birth-control device in a female suffered from a misconception: The beaver turned out to be not a she but a he.

TOM AND PAT LEESON

Mystery Shrouds California Die-off

Vital winter staging area for water birds, the Salton Sea National Wildlife Refuge in southern California hosted a teeming horde of a million eared grebes last year. But something went very wrong. Many birds became lethargic and gulped water—unusual for grebes. Then they hauled themselves out onto the banks of the Salton Sea and died, 150,000 of them, the biggest die-off ever recorded for this species.

The 360-square-mile inland sea collects pesticides and fertilizers from agricultural runoff, plus sewage from Mexico—all suspected candidates for contaminating the birds. Laboratory analysis showed elevated levels of the toxic element selenium in worms that the grebes eat, but not high enough levels in the birds to be fatal. Says U. S. Fish and Wildlife Service biologist Bill Radke, "We still don't know what killed them." —John L. Eliot

WILLIAM R. RADKE, U. S. FISH AND WILDLIFE SERVICE

National Geographic, January 1993

On Assignment

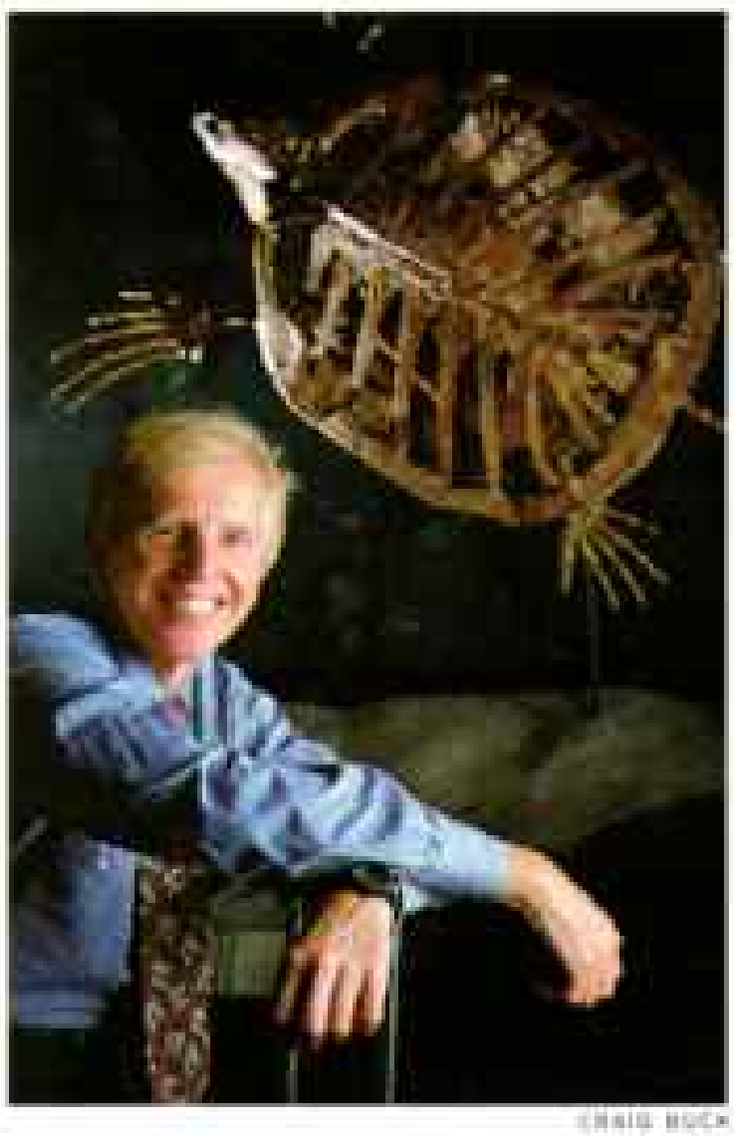
JOHN ESCHERICH

Bringing 165 million years of extinct creatures to life was an assignment free-lance photographer Louie Psihoyos took in stride. From Pittsburgh's Carnegie Museum of Natural History, where he stepped into the frame with skeletons of an *Apatosaurus* and a modern *Homo sapiens*, to the farthest reaches of Mongolia, Louie pursued dinosaurs for a year and a half with single-mindedness, a sense of humor, and enough black velvet backdrops to cover a football field.

"Dinosaurs were the dominant form of life on the planet for 500 times longer than humans have been around," he notes. "I was sprinting around the world just trying to get bits and pieces of the picture."

A great disappointment occurred in Alberta, Canada, where a coal strip mine had exposed a cliff covered with thousands of perfectly preserved dinosaur footprints. Louie decided to wait a day to photograph them in better light. "I thought I had the luxury of time. Those tracks had been there for 110 million years. What was one more day?" But the next morning he found the cliff had collapsed, destroying the tracks. "Fossils are a great testament to time, but I learned they're very fragile."

Senior Assistant Editor Rick Gore—here in the Smithsonian Institution's fossil collection, which includes a turtle that coexisted with dinosaurs—remembers better timing. On a three-day visit to Argentina to check on paleontologist Paul Sereno's excavation, Rick witnessed the discovery of a lifetime—the most primitive dinosaur known, a new species that Sereno calls "Eoraptor."



CRAIG BUCK

"I felt luckier than Sereno, and he considers himself a lucky guy."

Rick appreciates the persistence of scientists. He studied science journalism at Northwestern University and took his master's degree to New York to write for the science department of *Life*. He also worked with the staff that created *People* magazine. Since joining our staff in 1974, he has written 33 articles.

In his spare time Rick writes musicals. Working on lyrics reminds him of doing picture captions: "Since you have very little space, you have to be extremely economical, and it all has to add up to something in the end."

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